Karlsruhe Institute of Technology

Faster Multi-Modal Route Planning with Bike Sharing Using ULTRA

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Jonas Sauer, Dorothea Wagner, and Tobias Zündorf

INSTITUTE OF THEORETICAL INFORMATICS · ALGORITHMICS GROUP

Multi-Modal Route Planning

Goals:

- Journey planning for public transit
- Find **optimal** journeys
- Consider modes of transportation:
  - All timetable-based modes (trains, trams, buses, ...)

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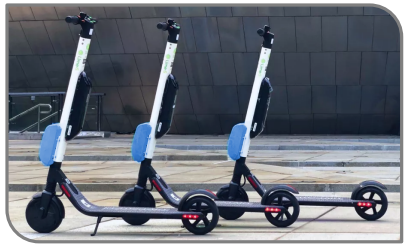

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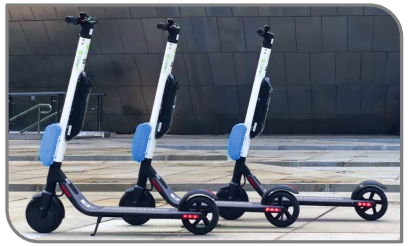
  - Walking (from, to, and between stops)
  - Bike sharing (or other rental based services)
  - No limits on any of the transportation modes



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Problem Statement

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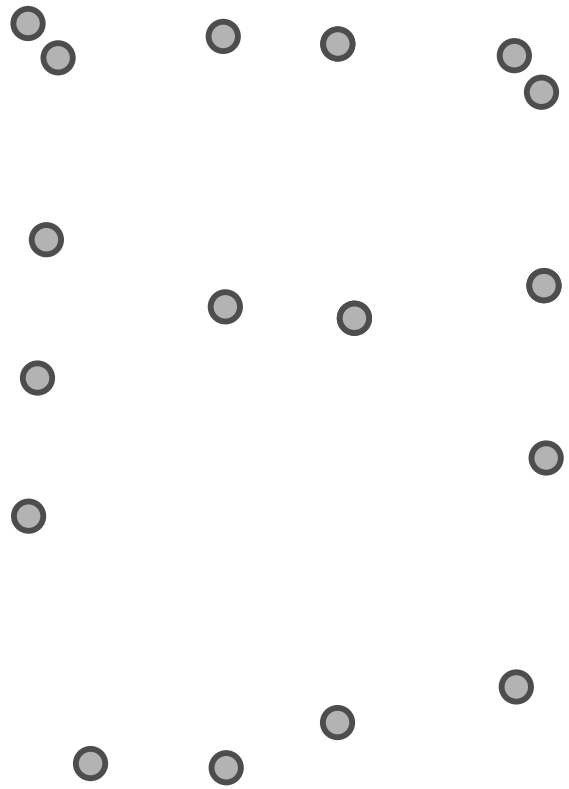
  - Stops (bus stops, stations)



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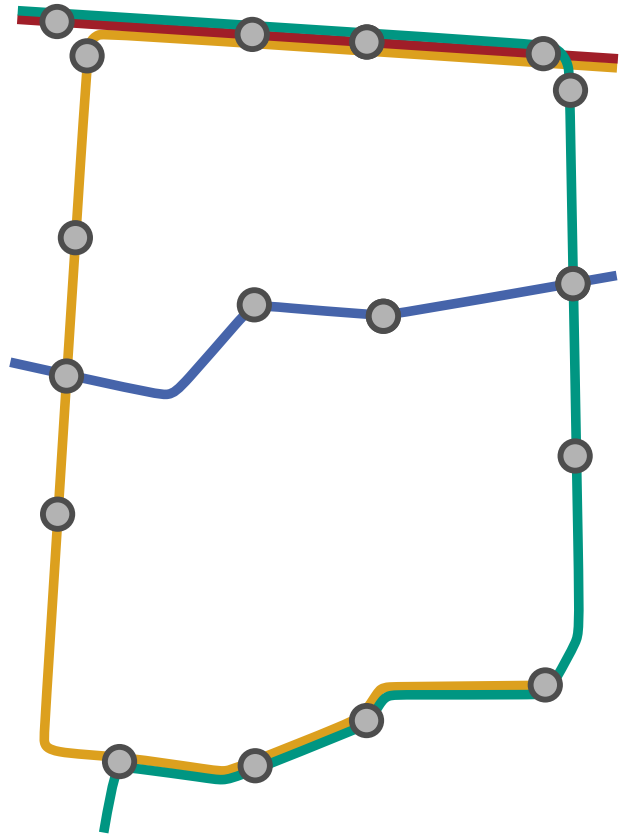

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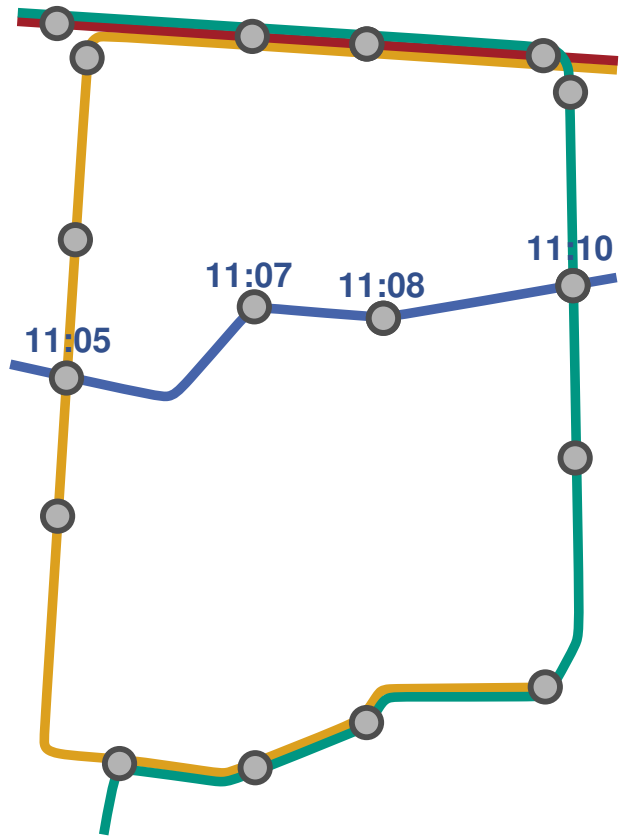

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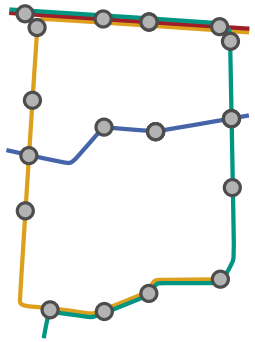

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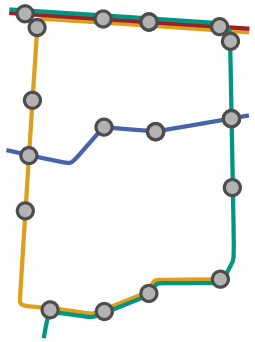

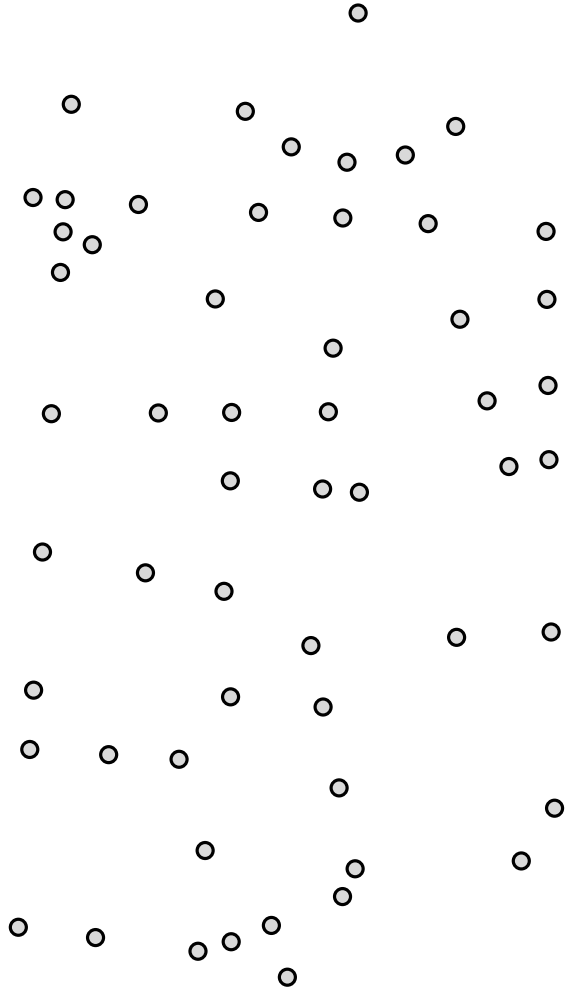

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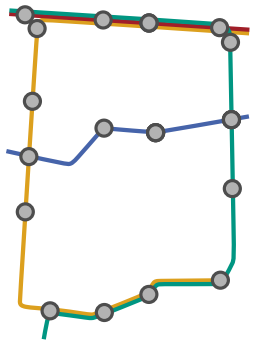

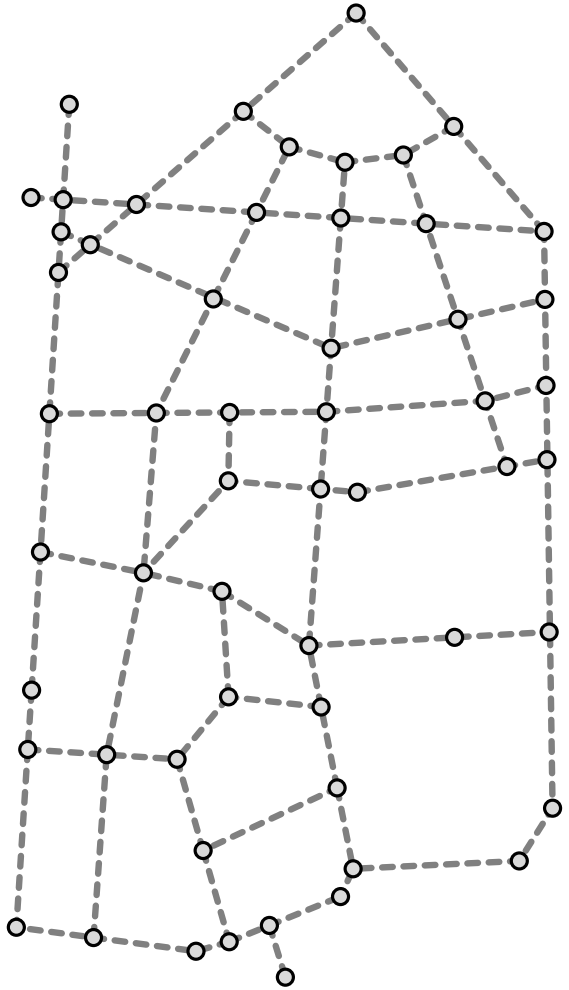

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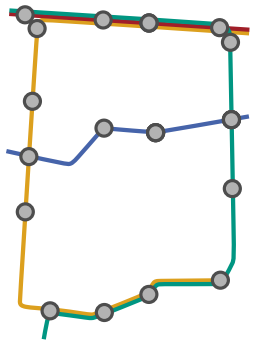

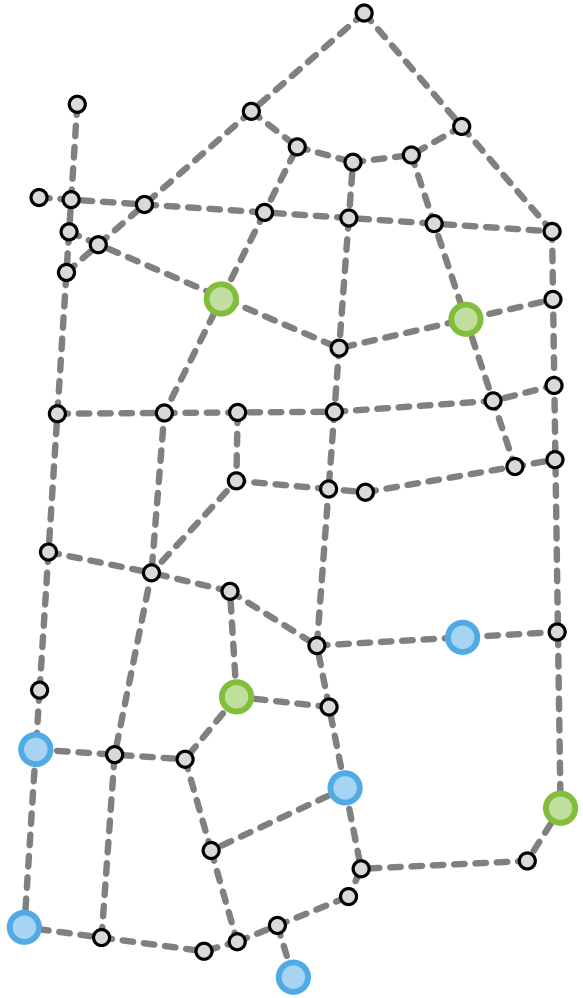

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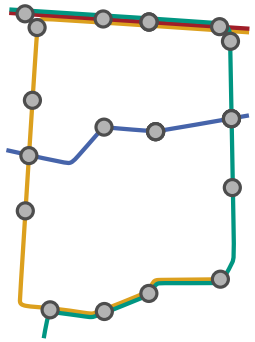

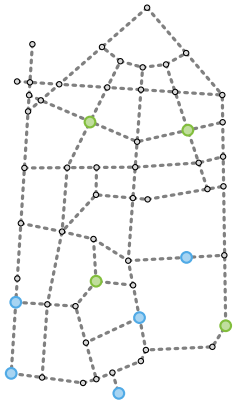

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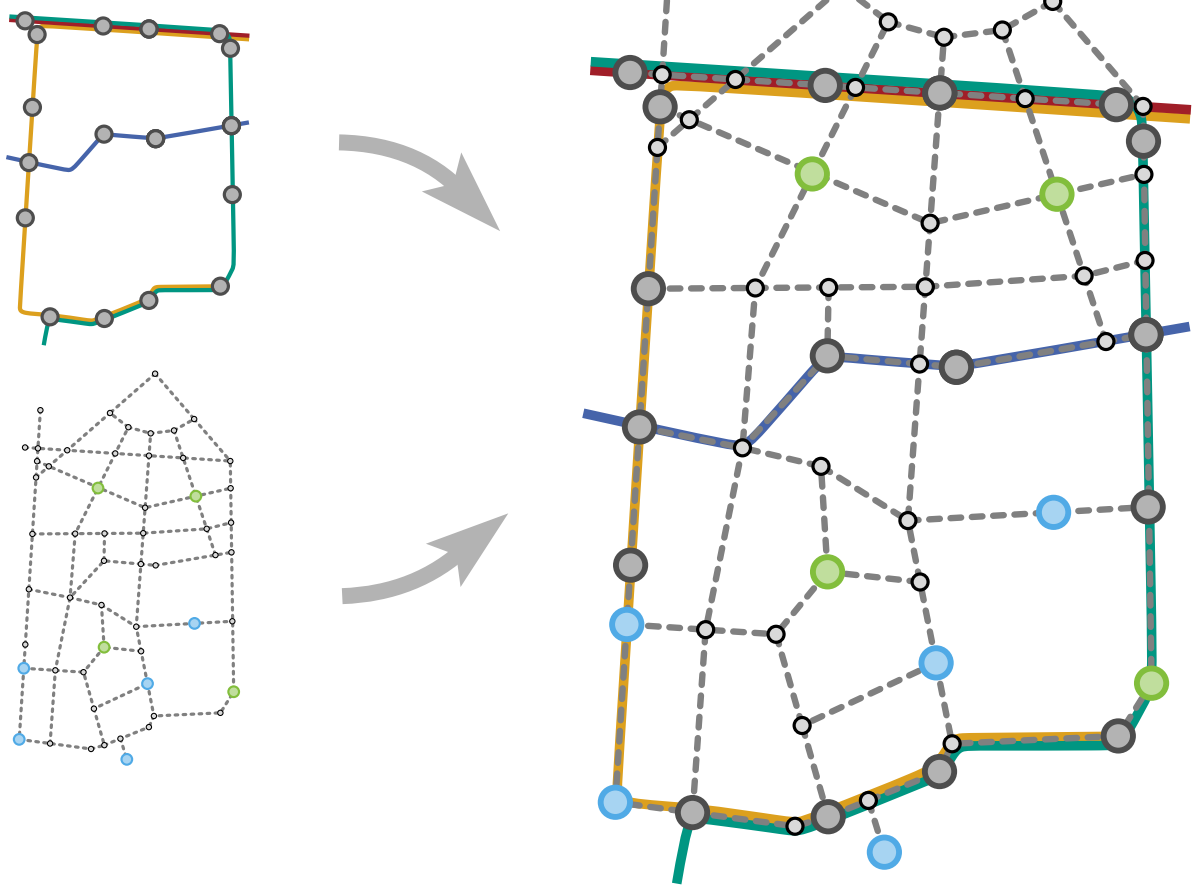

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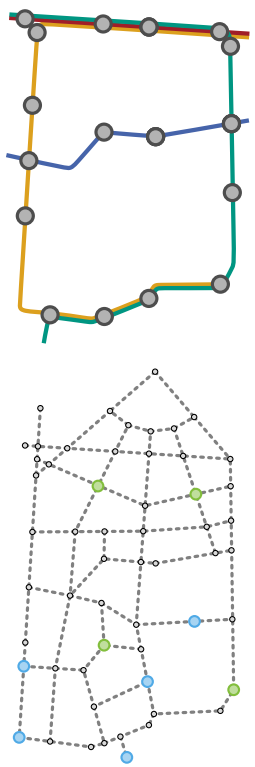

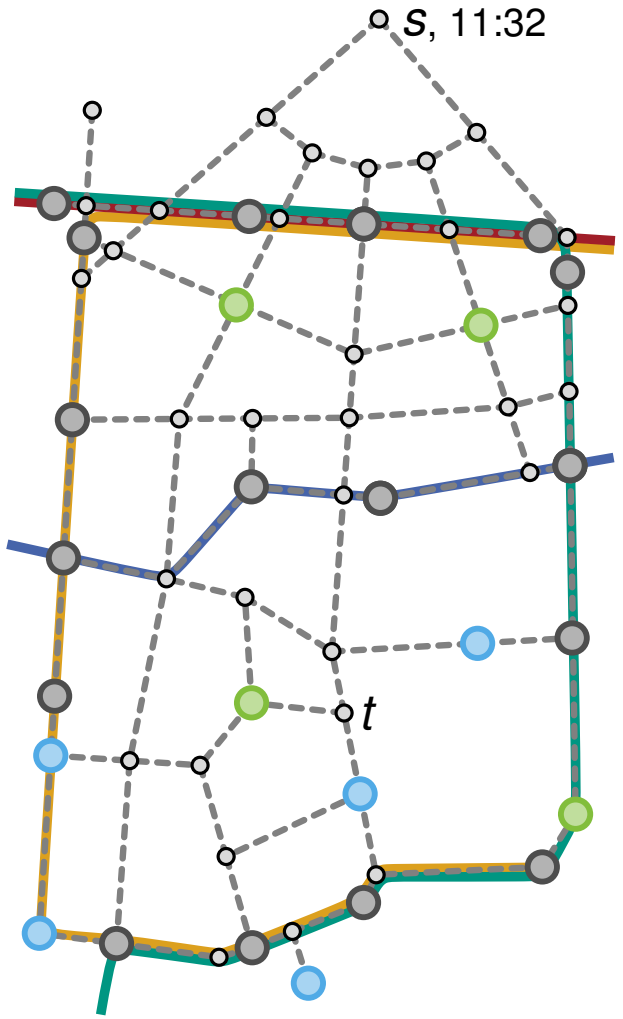

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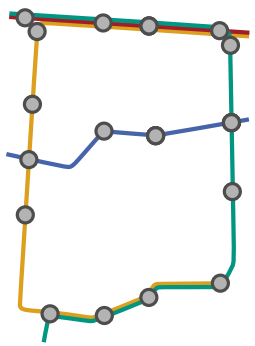

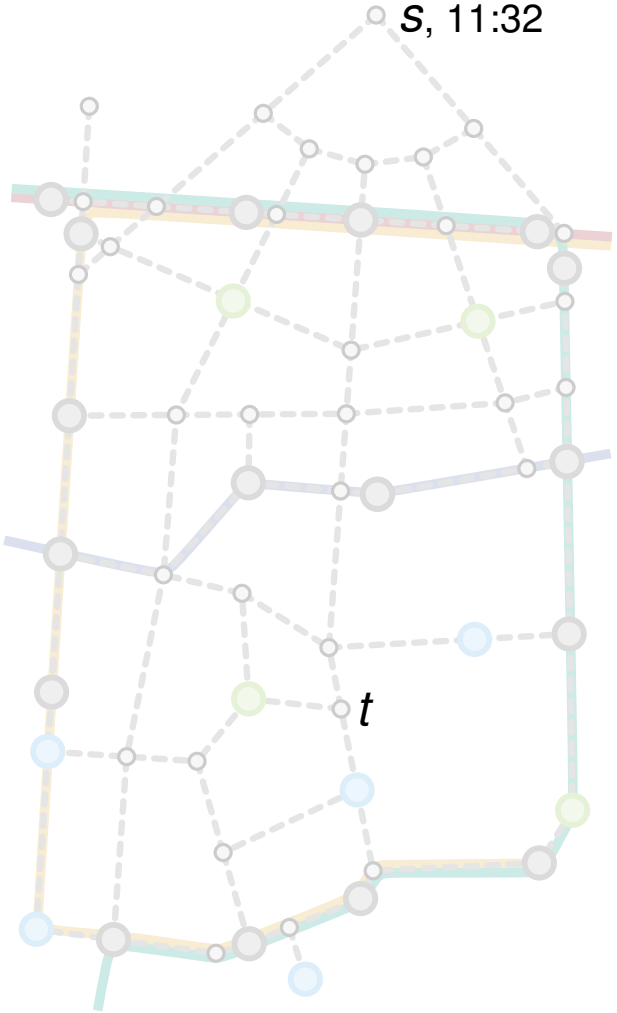

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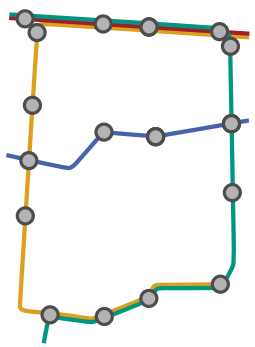

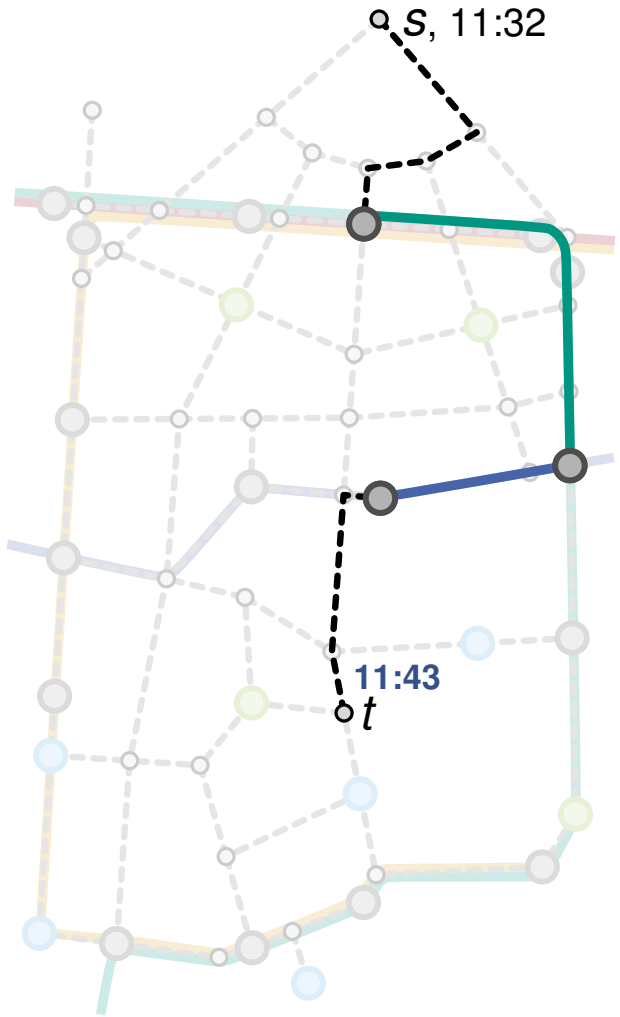

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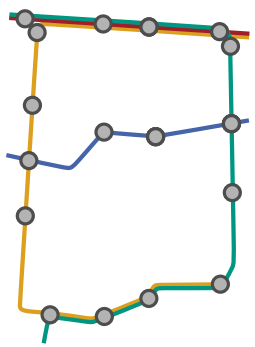

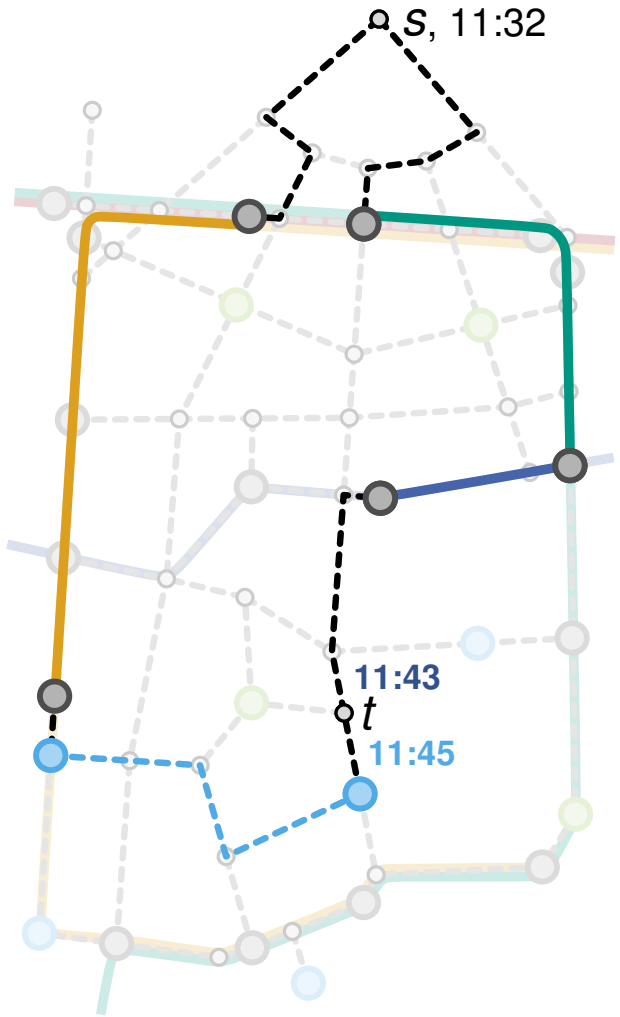

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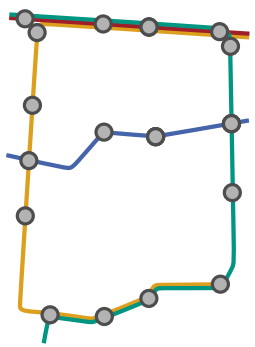

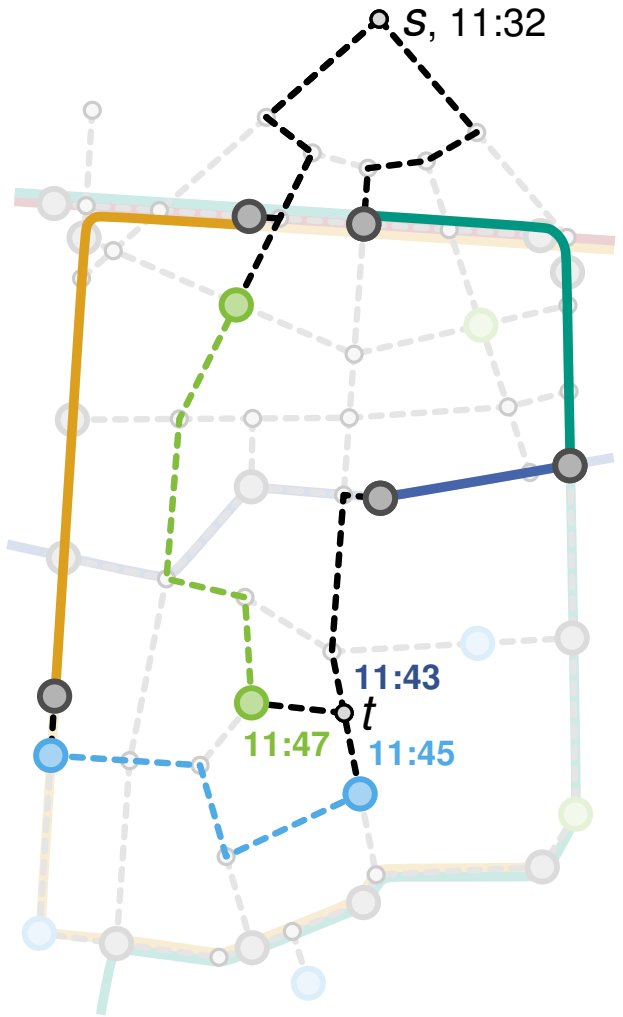

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- Distinguish and handle multiple bike sharing operators
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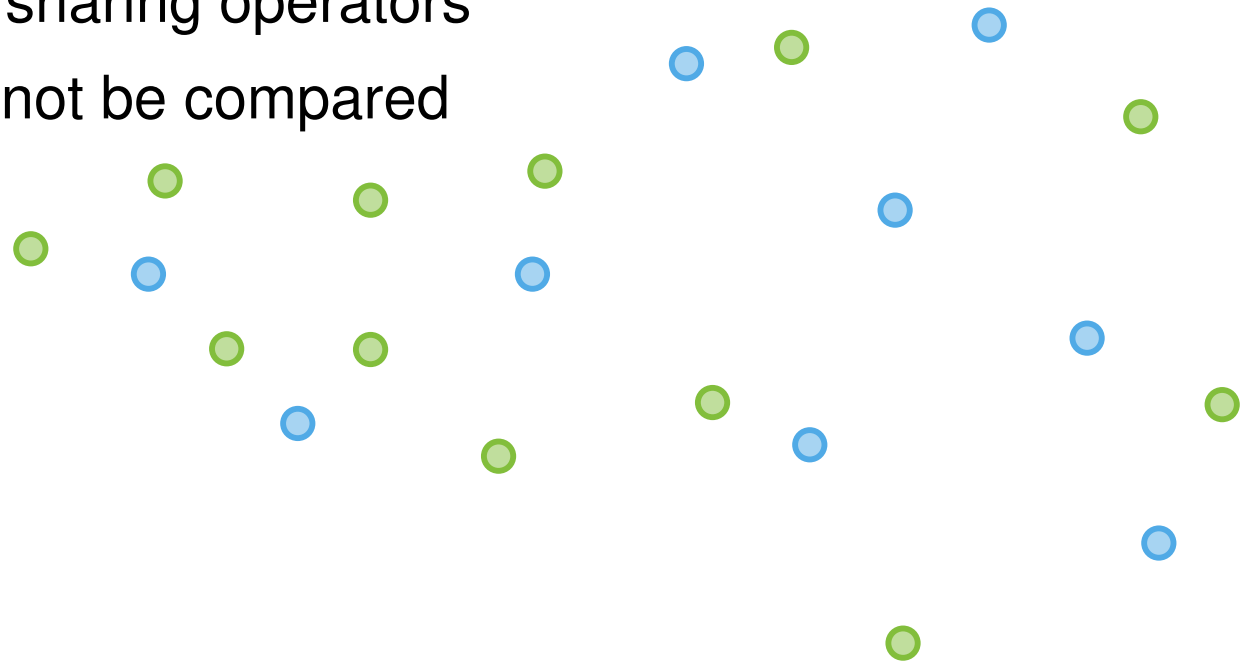

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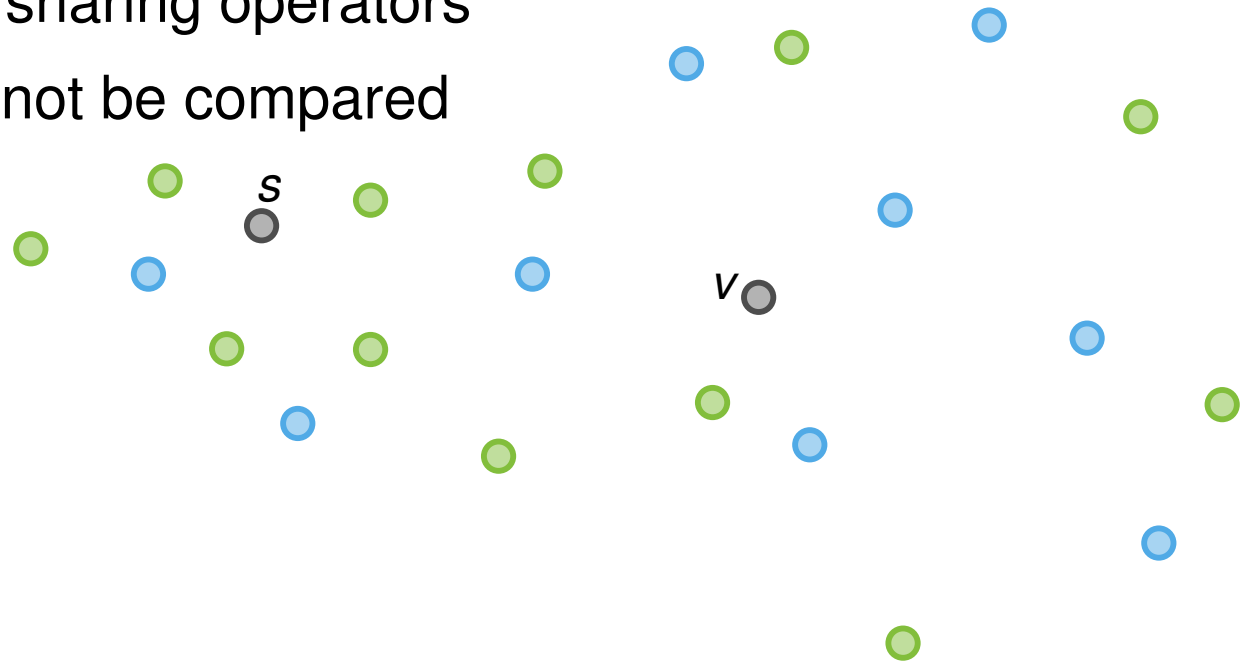

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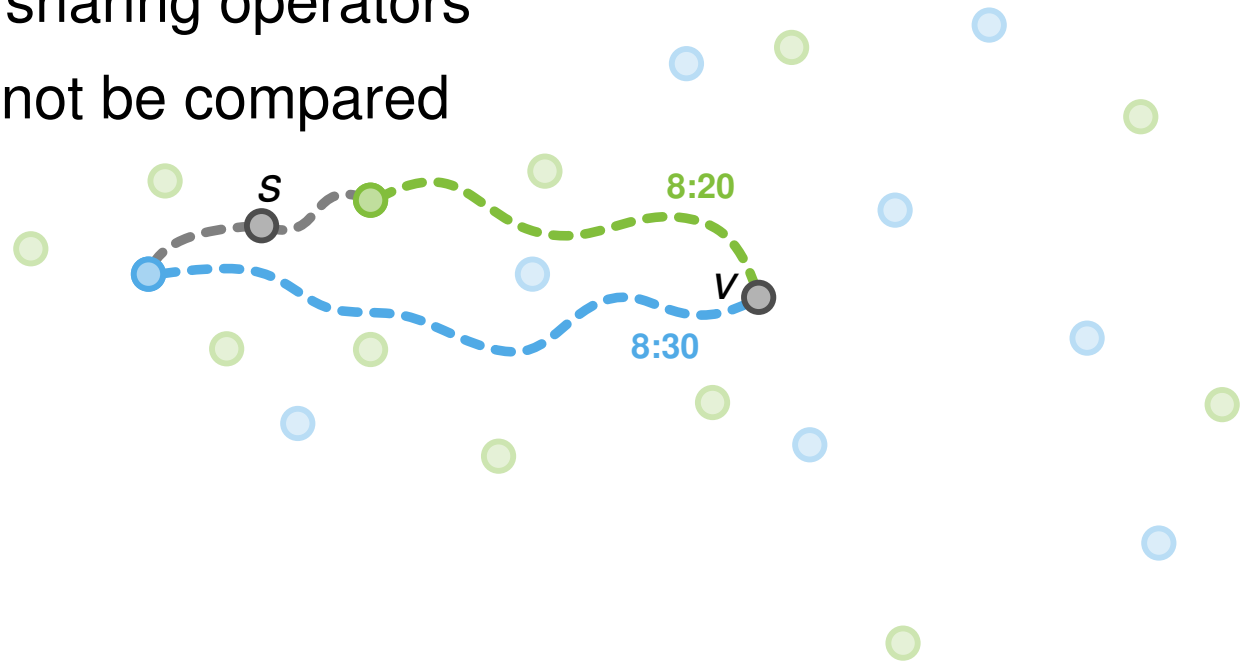

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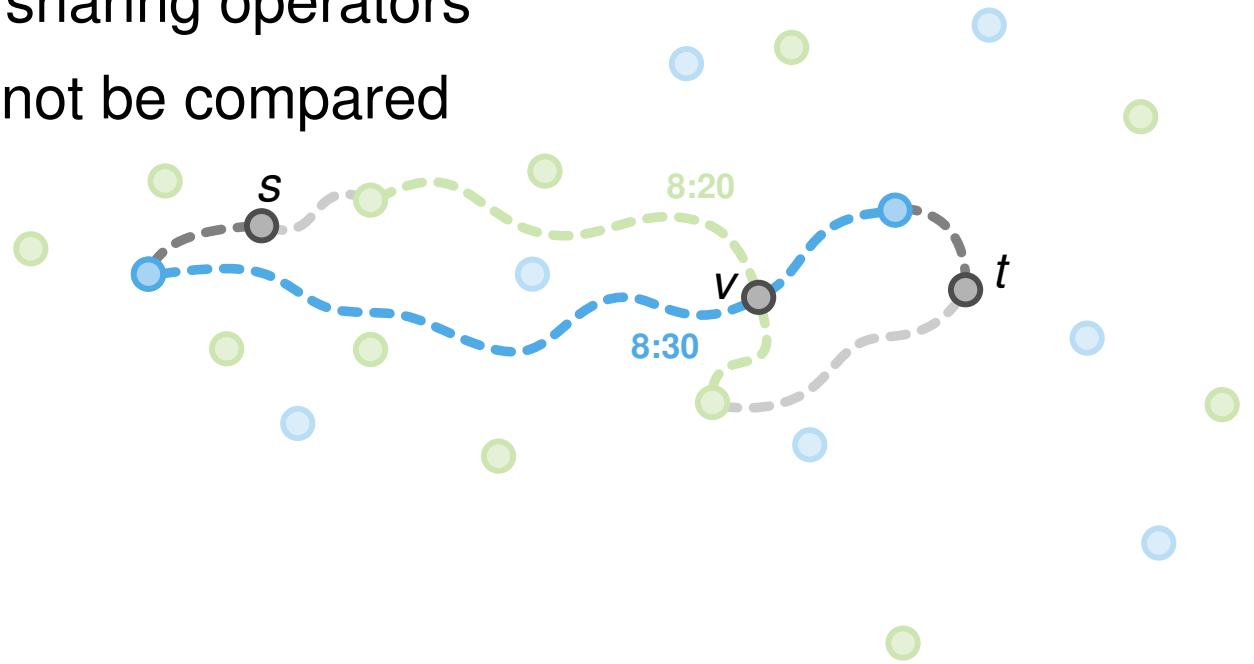

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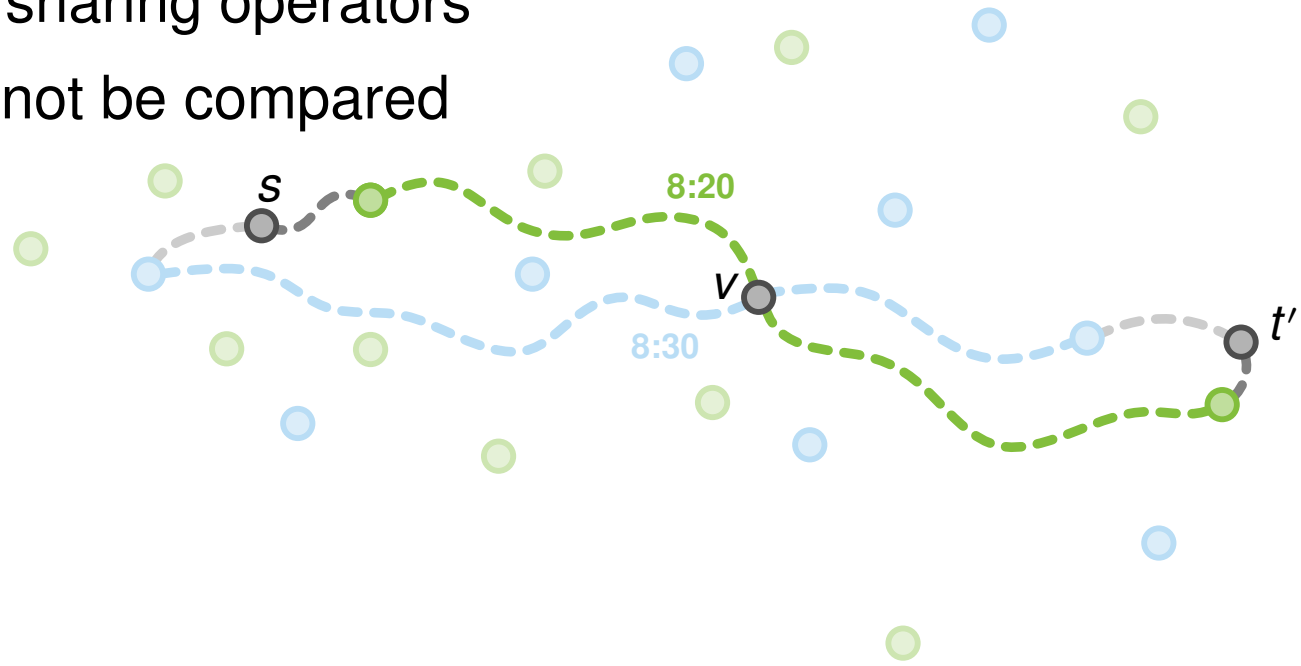

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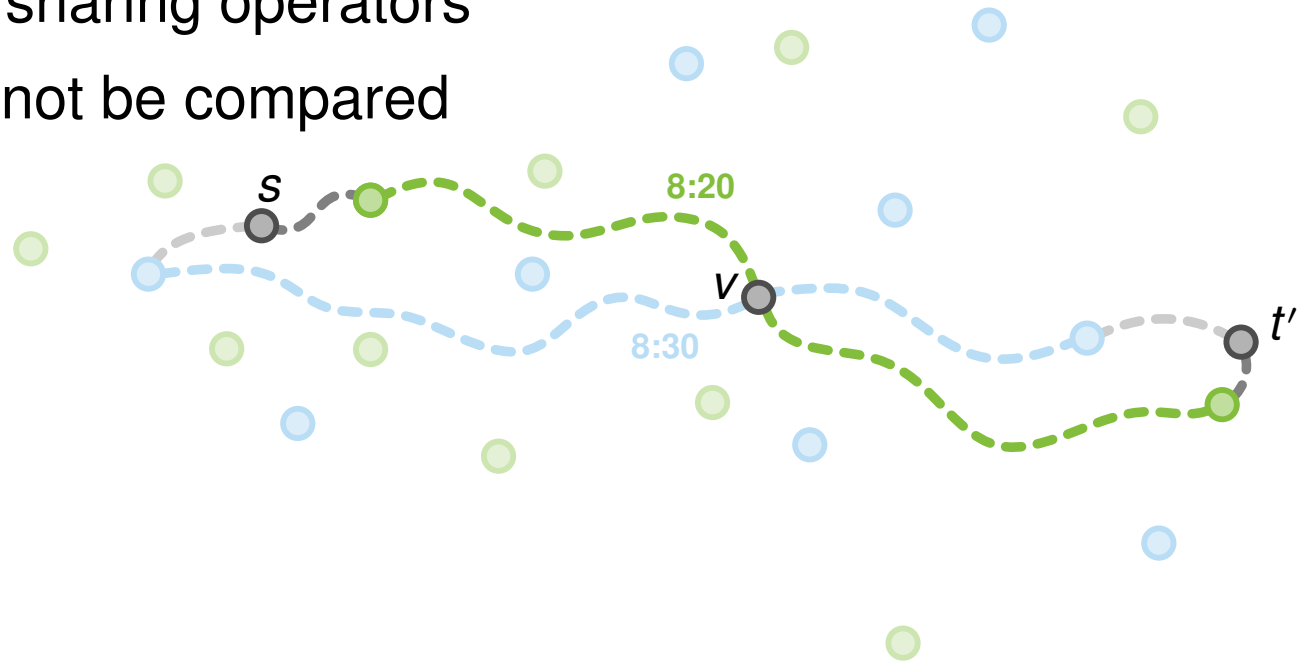

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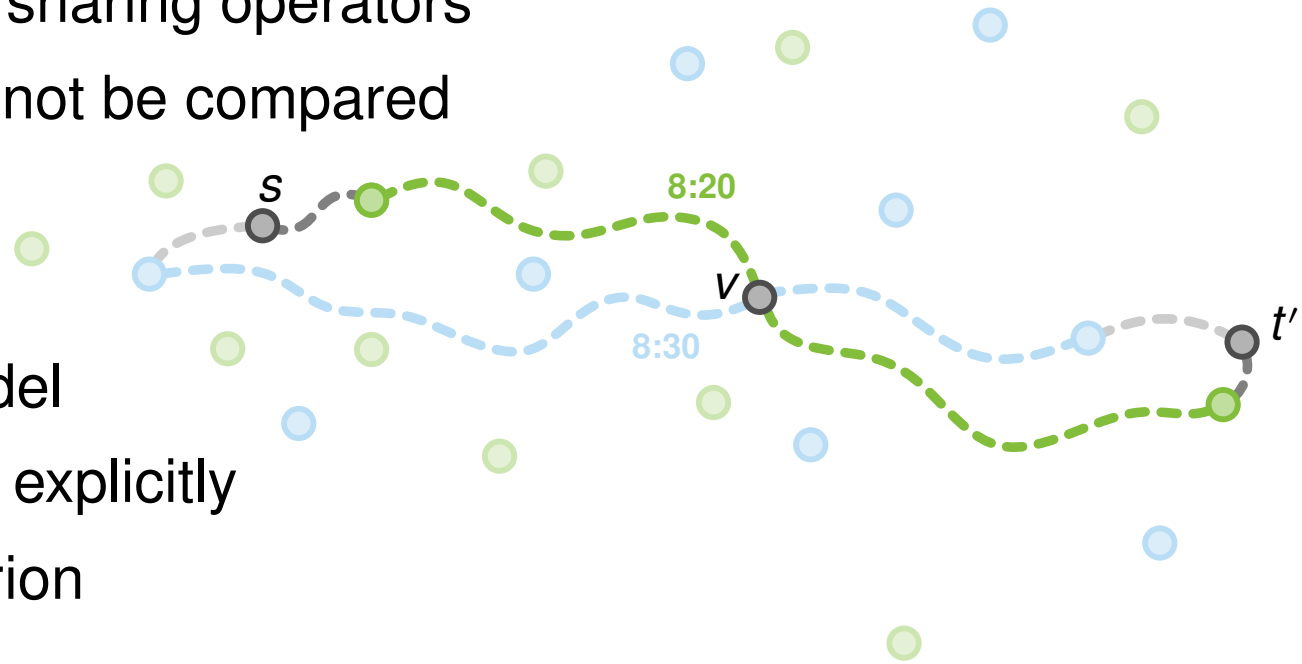

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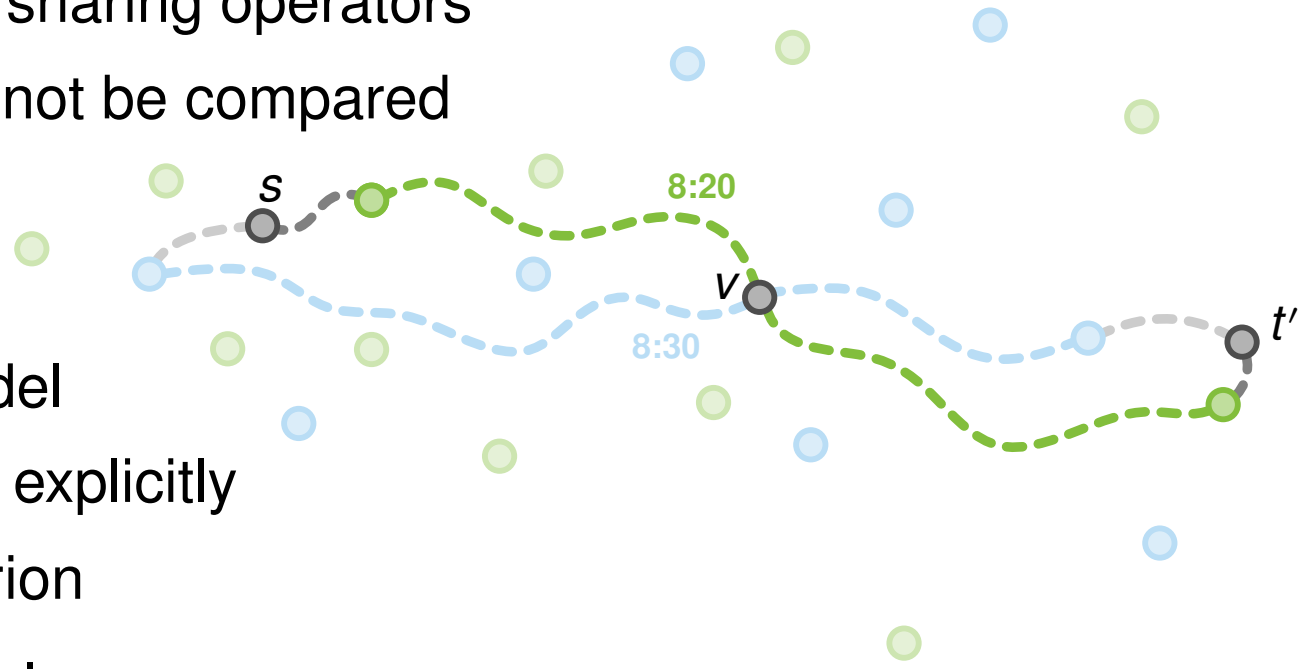

Two Possible Solutions:

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  - Handle operators in the algorithm explicitly
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- The **Operator-Expanded** (OE) model
  - Encode operators within a “normal” network
  - Use an existing algorithm with the modified network

The Operator-Dependent (OD) Model

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Basic Idea:

- Treat bike sharing as an additional optimization criterion
- Handle renting and returning of bicycles with the algorithm

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Integration into multi-Modal multi-Criteria RAPTOR (MCR): [Delling et al. 2013]

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⇓

Entry per **stop**, **#trips**, **operator**

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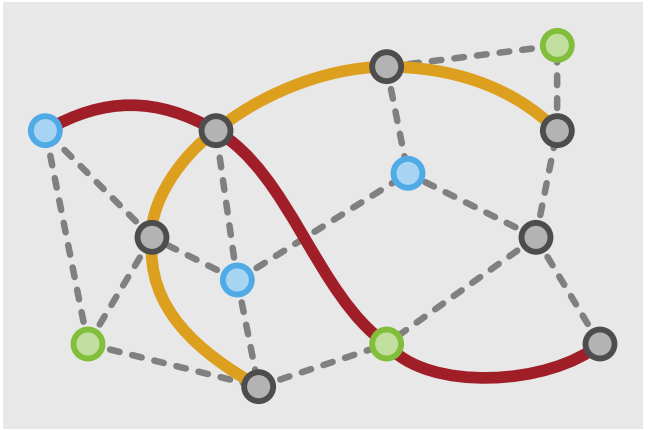

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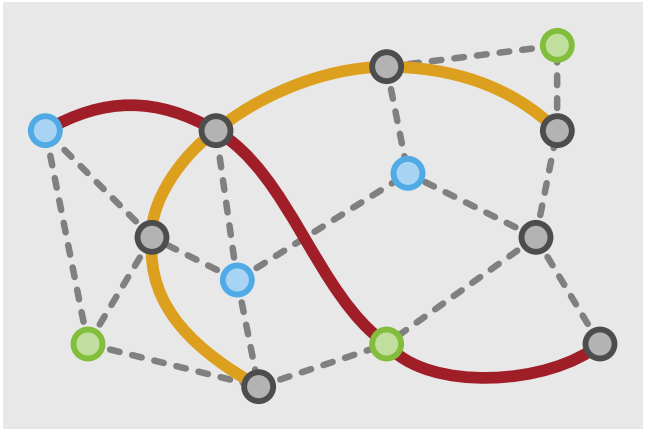

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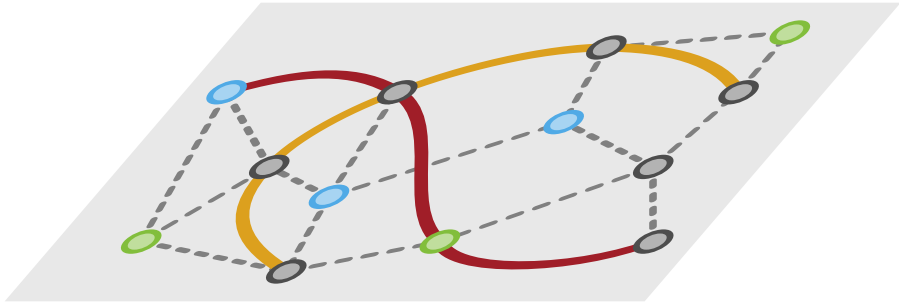

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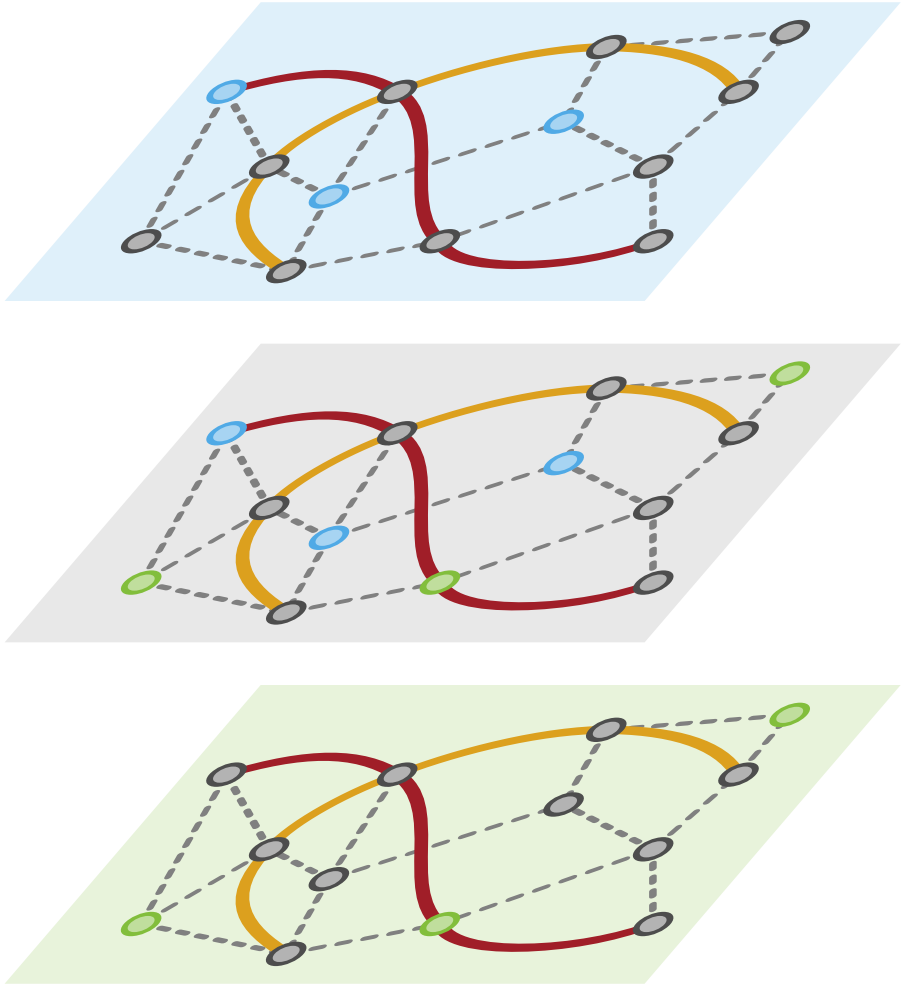

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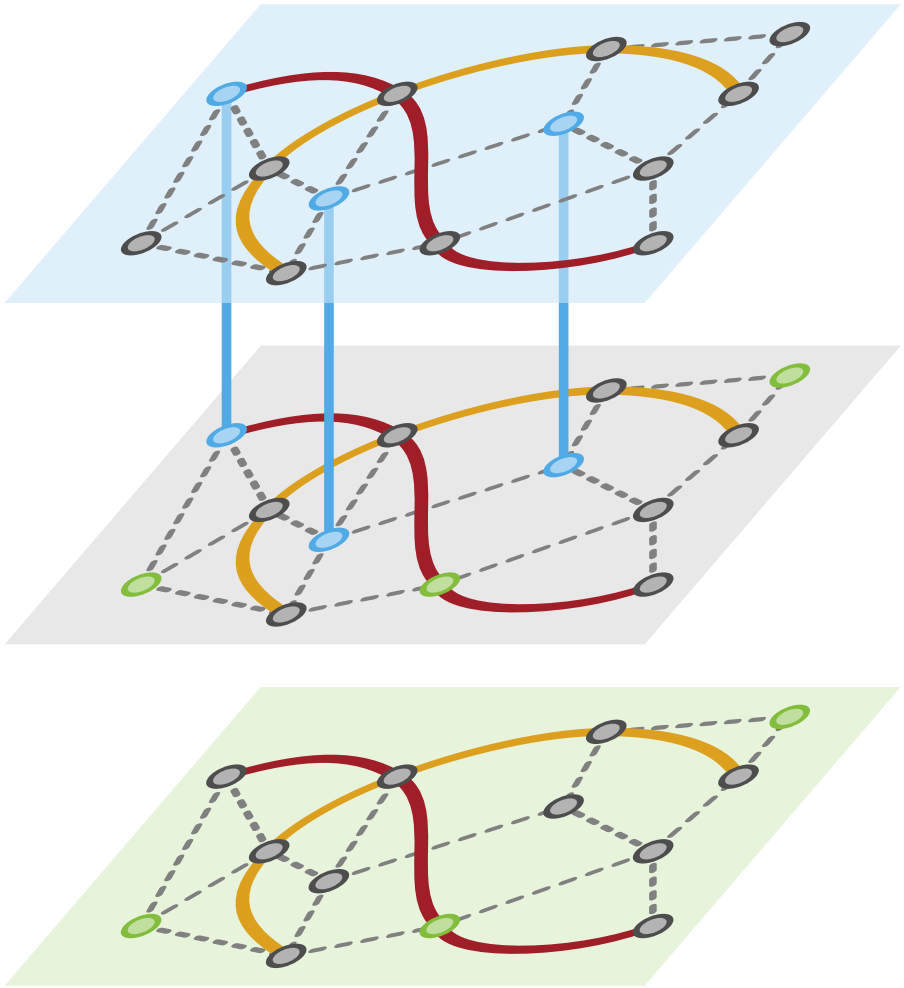

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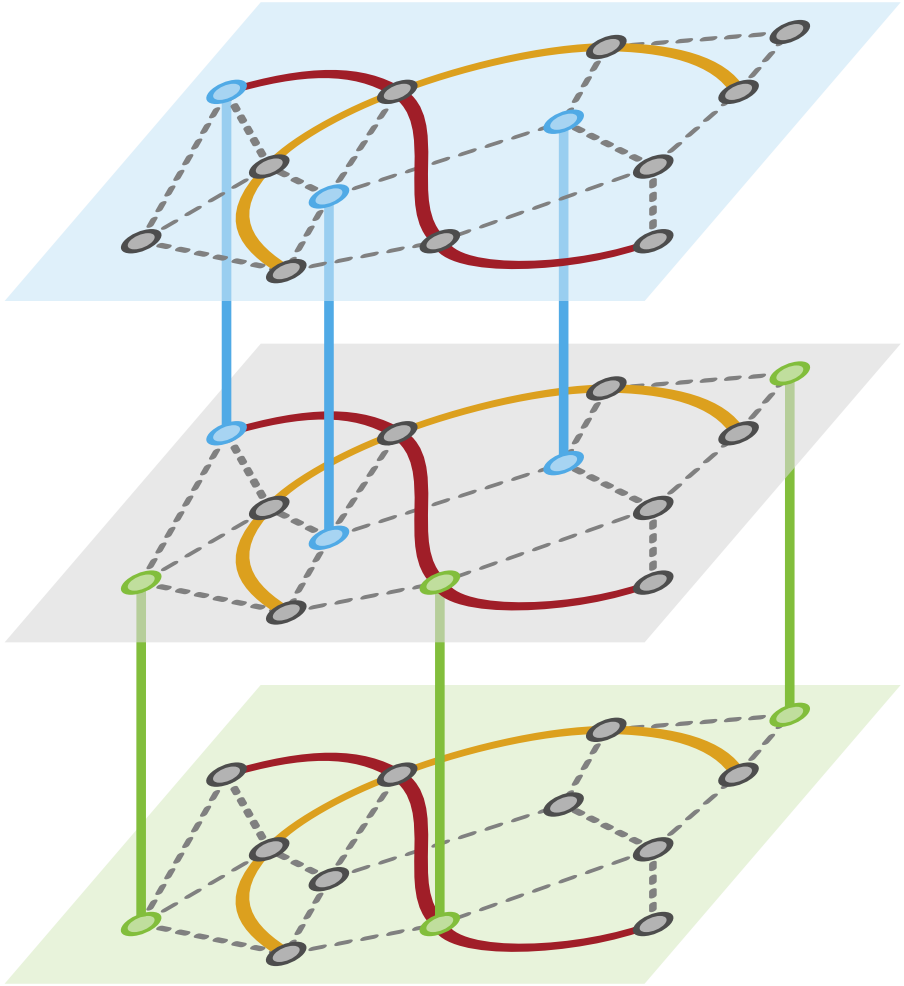

The Operator-Expanded (OE) Model

Basic Idea:

- Encode bike sharing within a “normal” network

Our Approach:

- Copy network once per operator
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Properties:

- Any existing algorithm can run on this network
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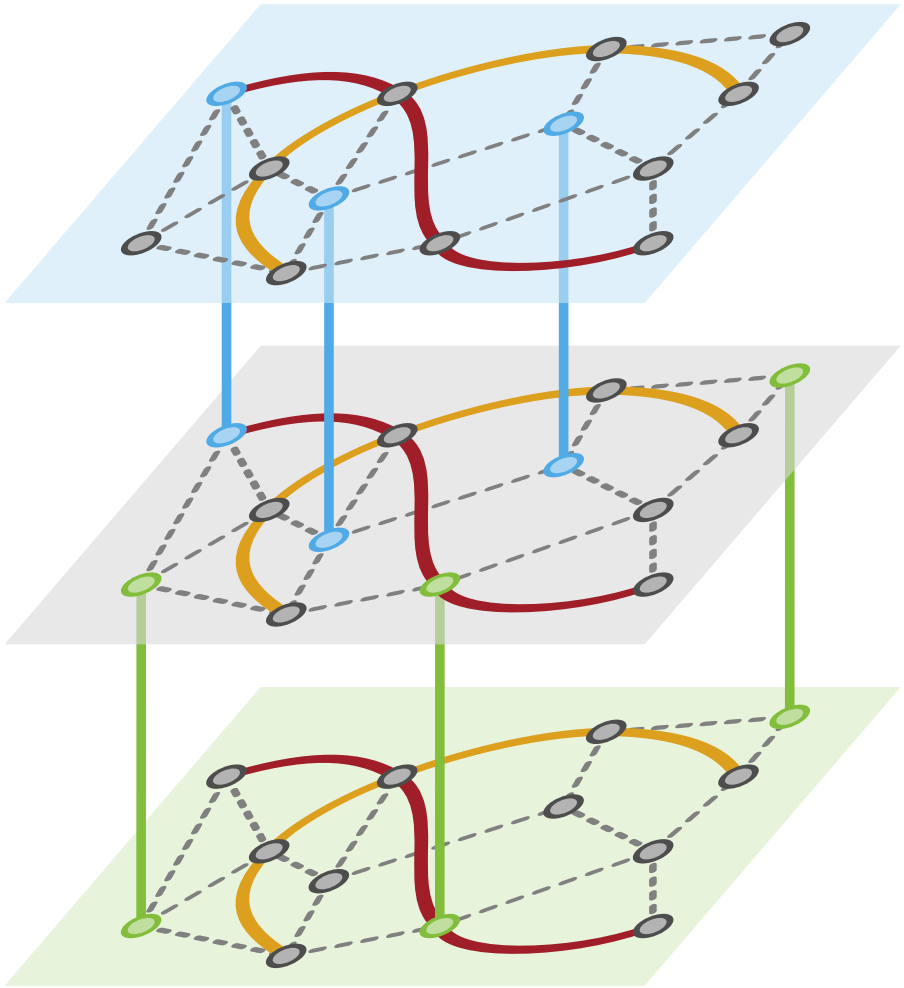

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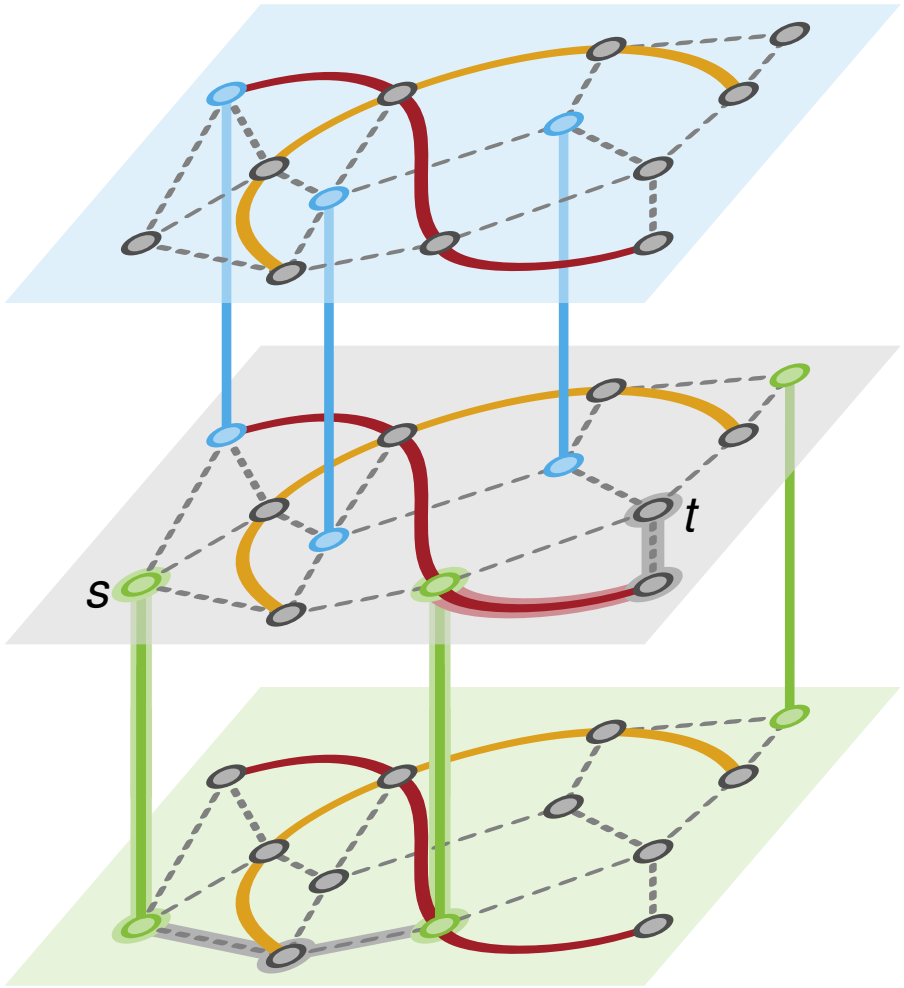

Speed-up Technique: Operator Pruning (OP)

Observation:

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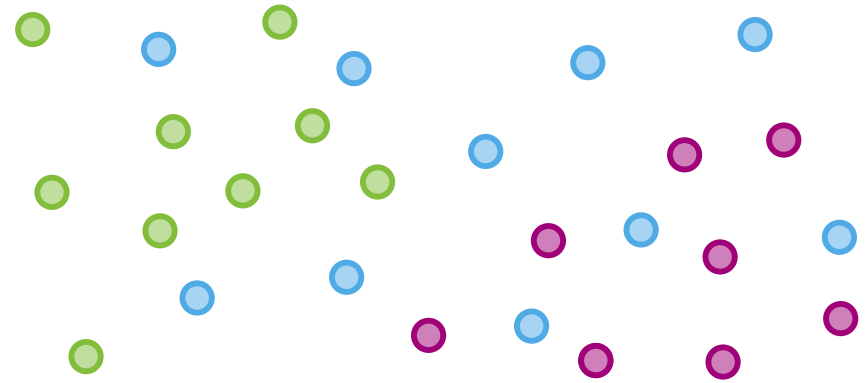

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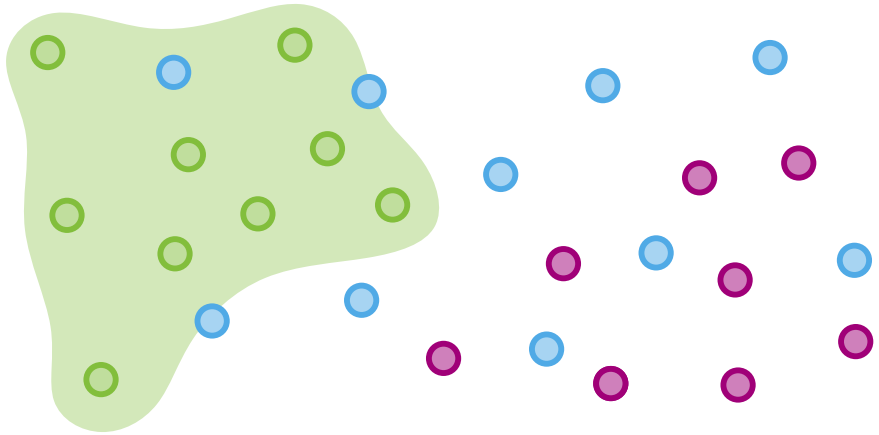

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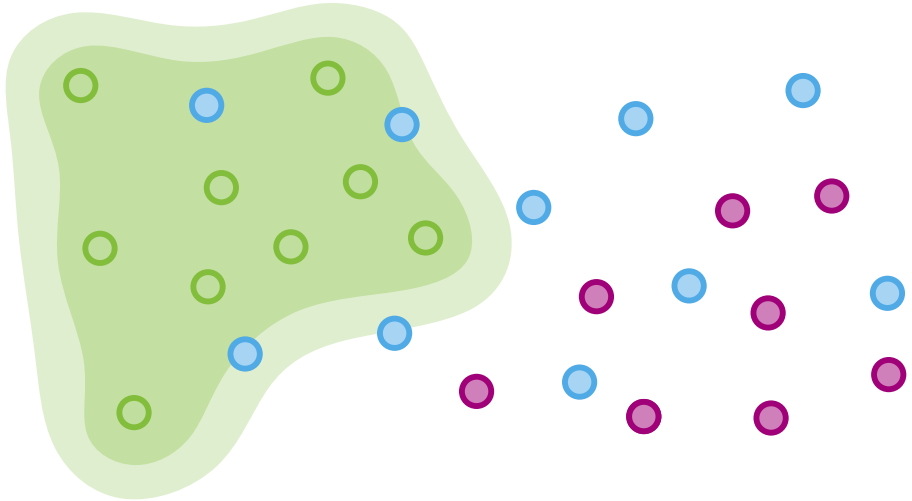

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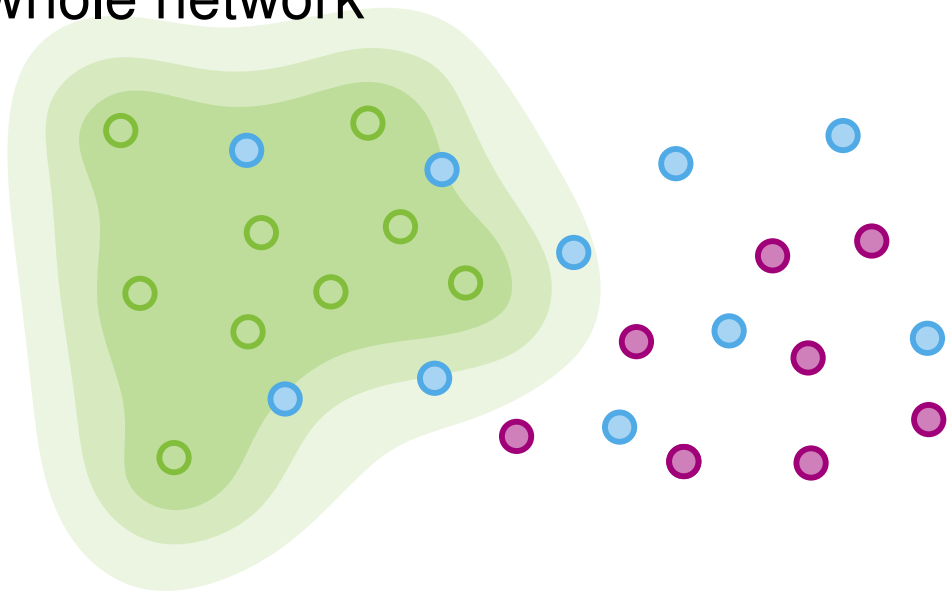

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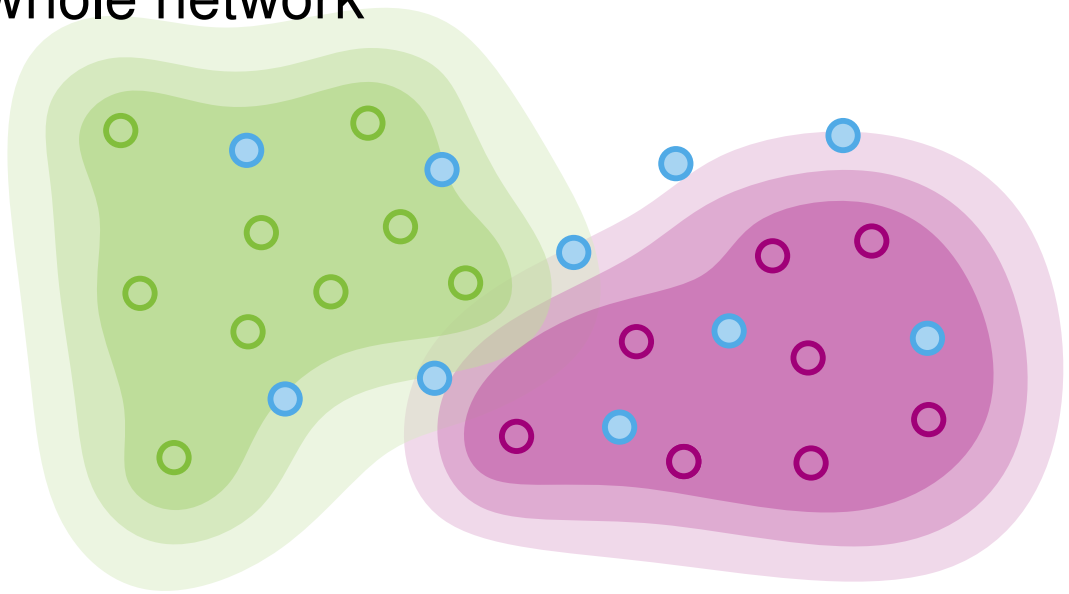

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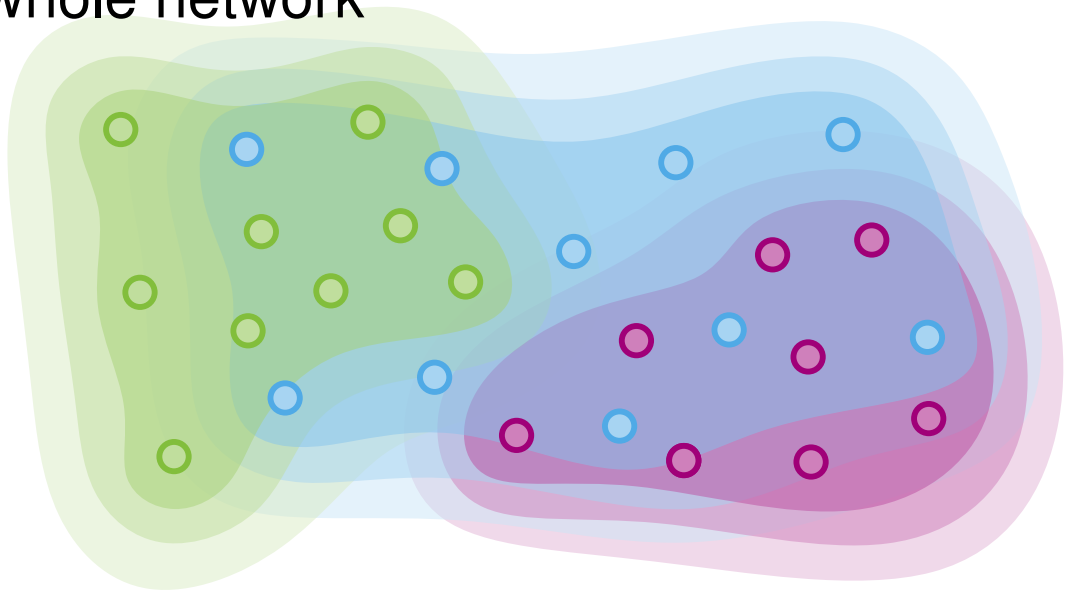

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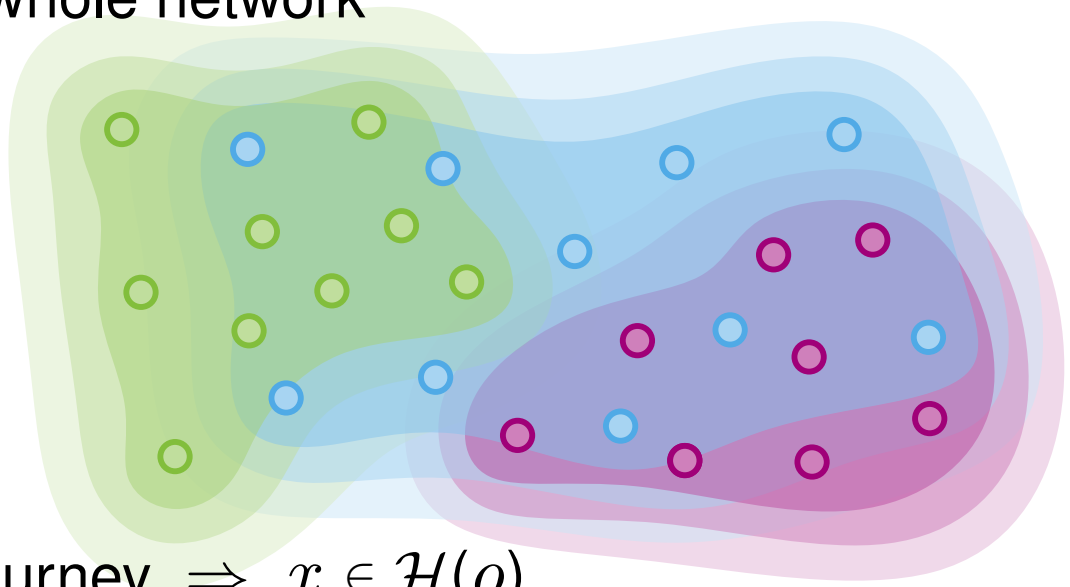

Operator Hull $\mathcal{H}$:

- Subset of the network
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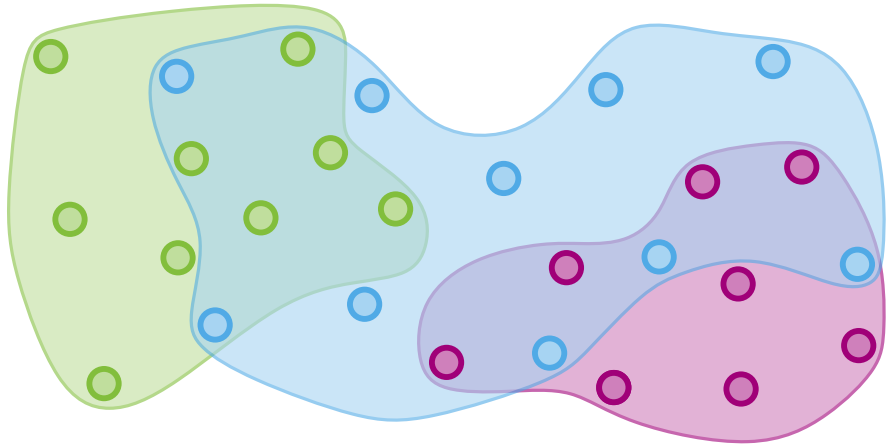

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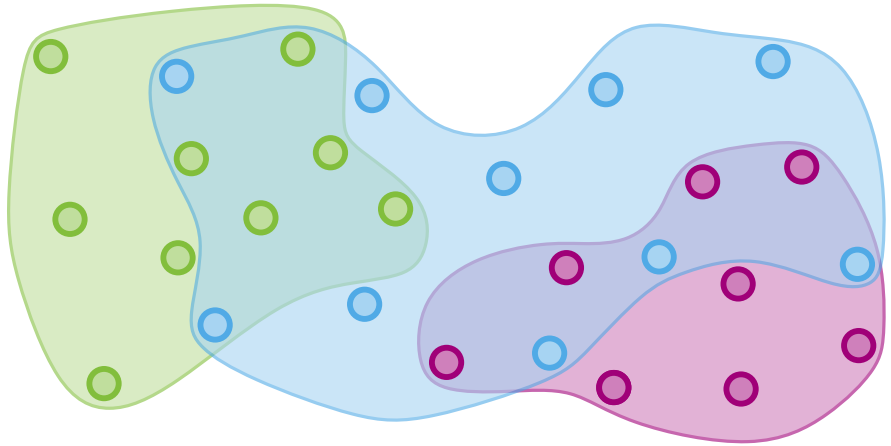

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Preprocessing:

- Computing $\mathcal{H}(o)$ can be done with standard MCR

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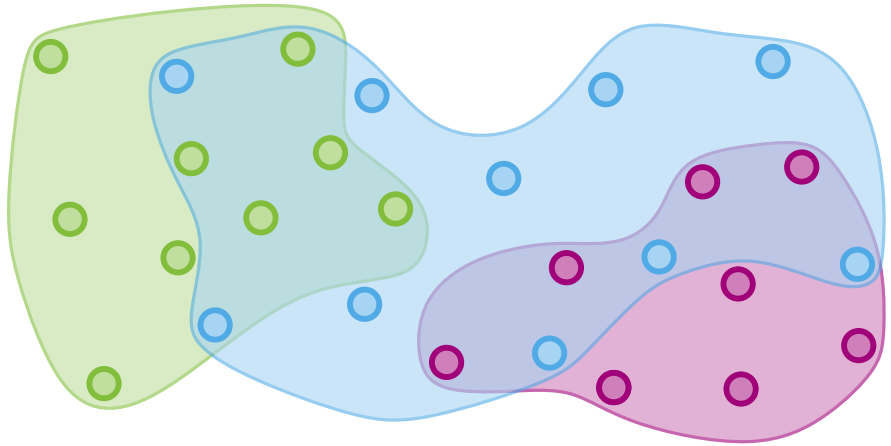

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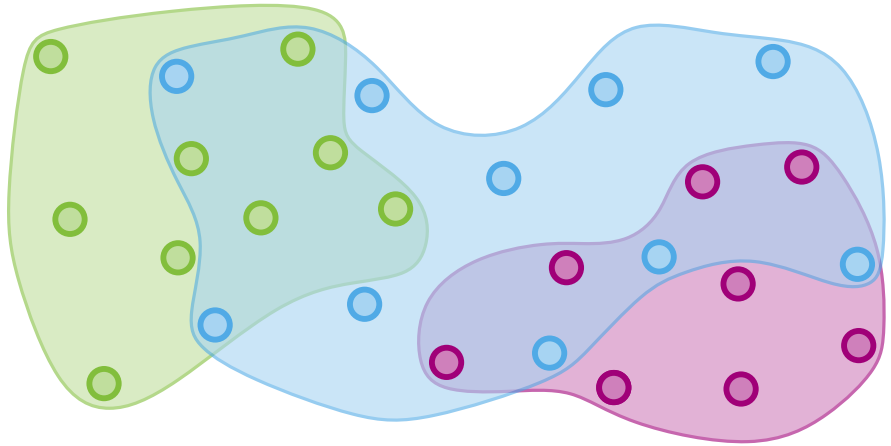
- Use $\mathcal{H}(o)$ to prune the search space



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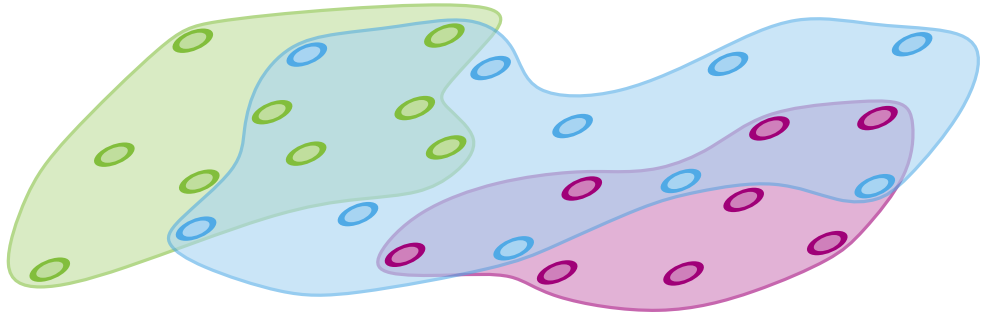

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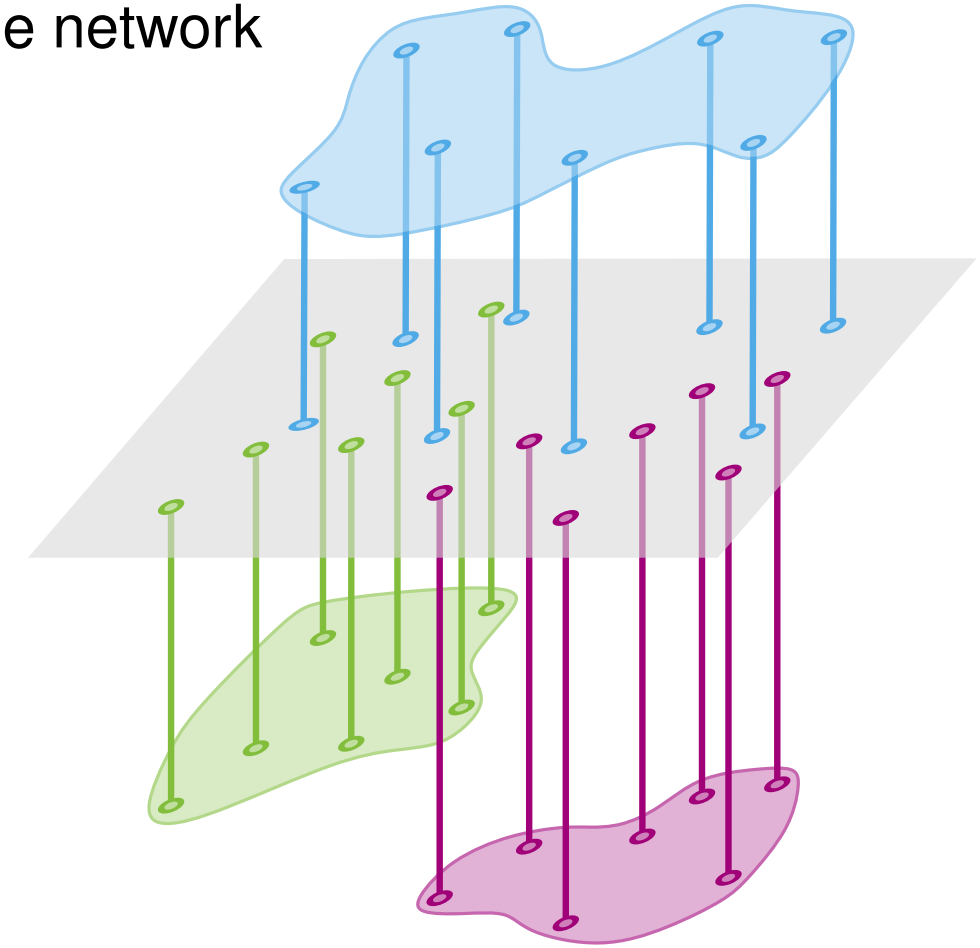

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ULTRA (UnLimited TRAnsfers) overview:

- Speed-up technique for public transit + one additional transfer mode
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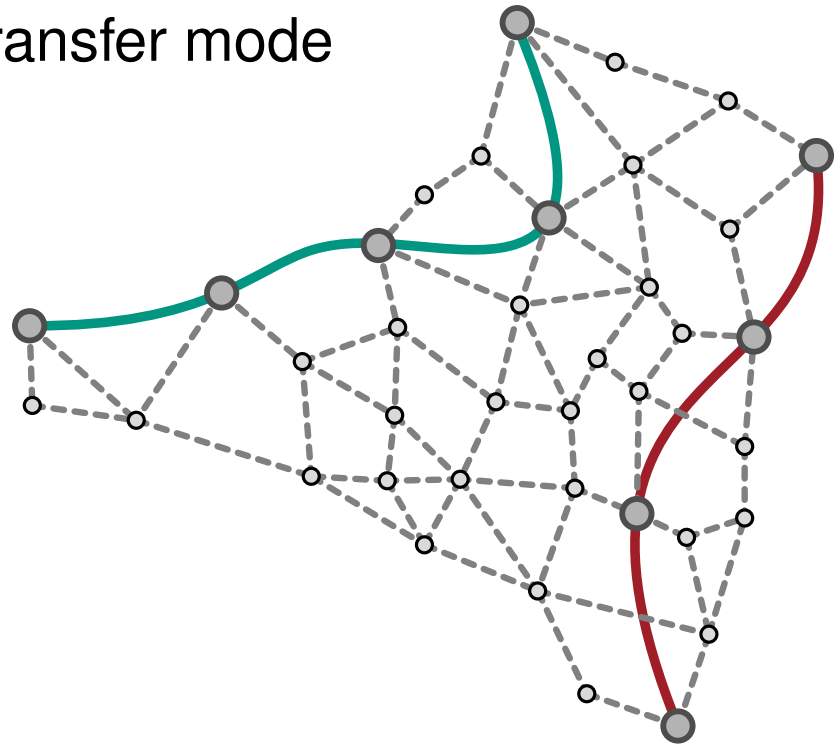

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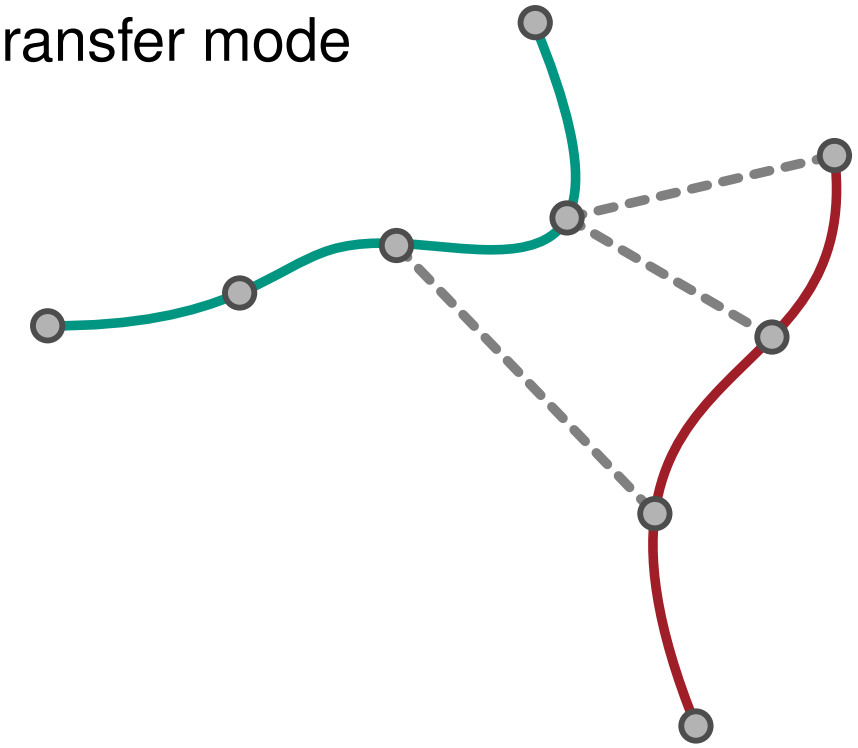

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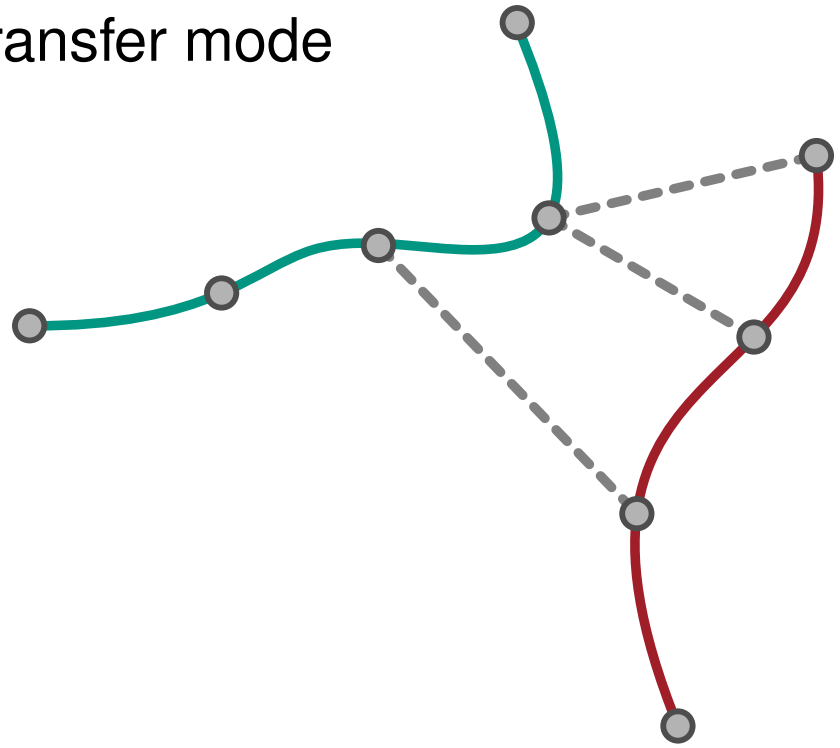

Adaptation for Bike Sharing:

- Check if bike sharing is useful while transferring
- If so, represent the transfer with a single shortcut
- Independent of the number of bikes rented

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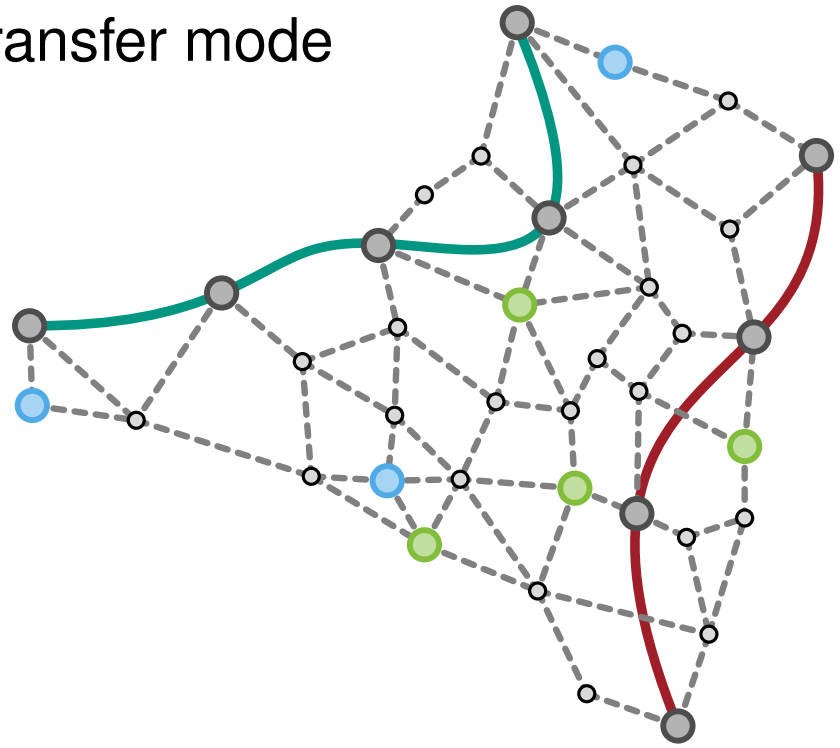

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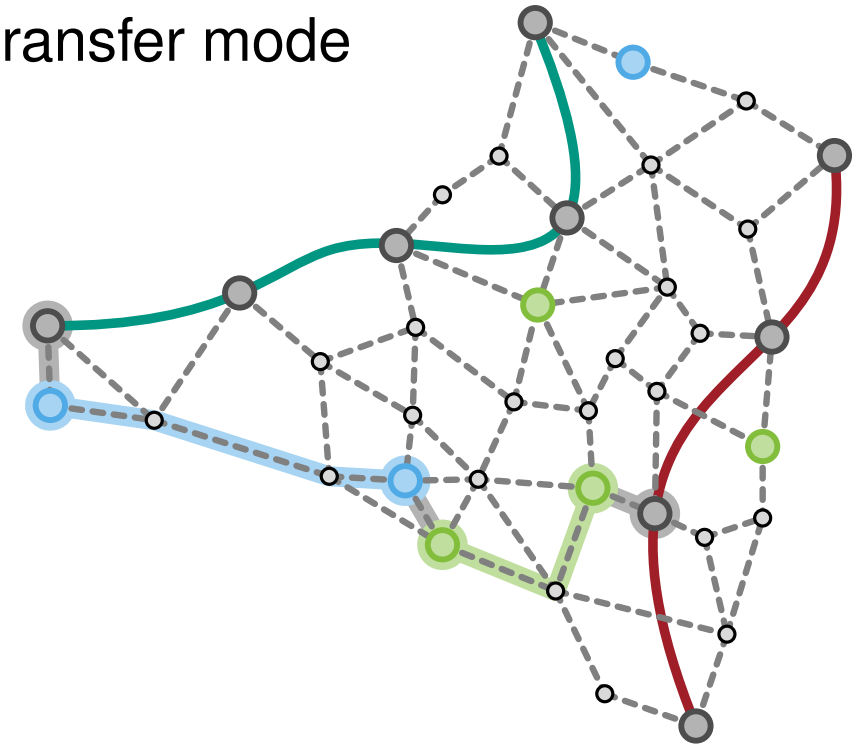

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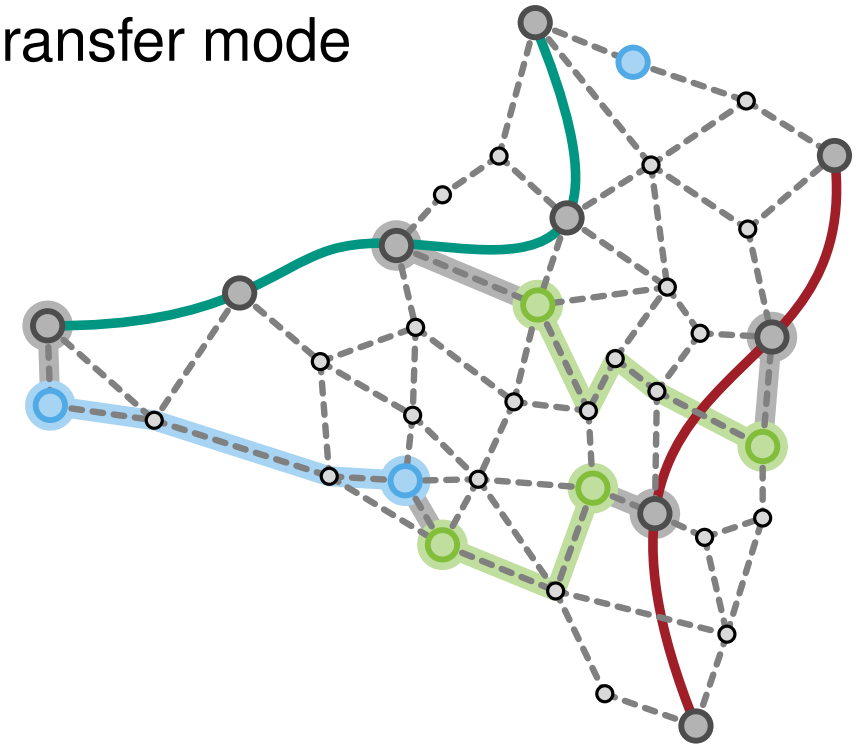

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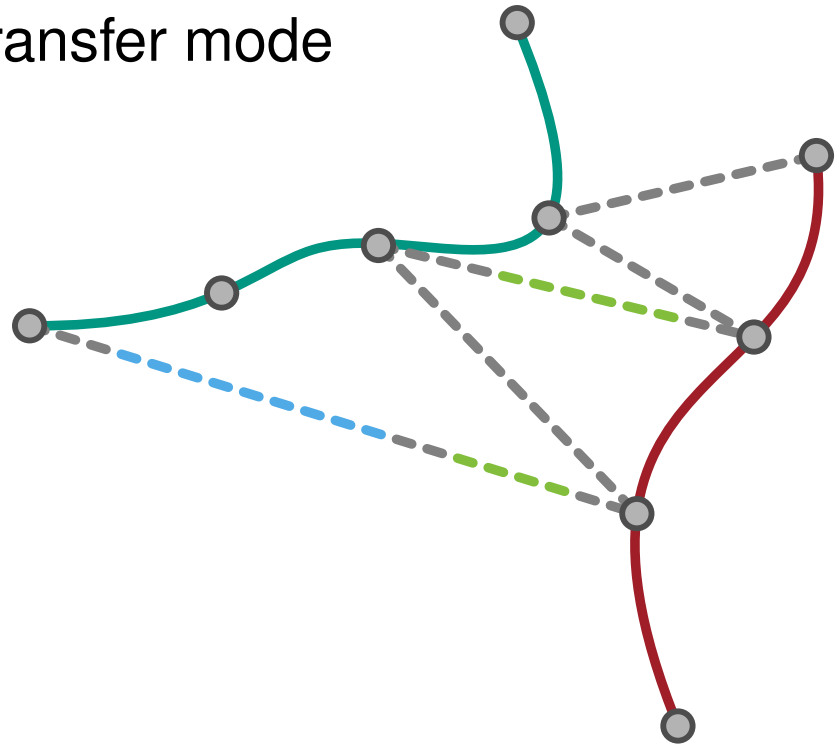

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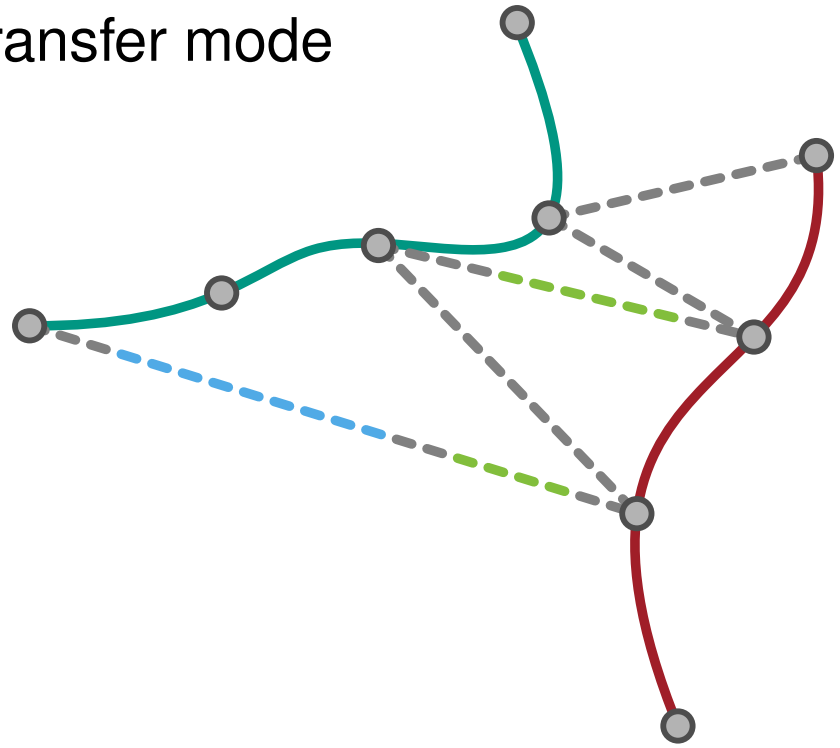

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Solution:

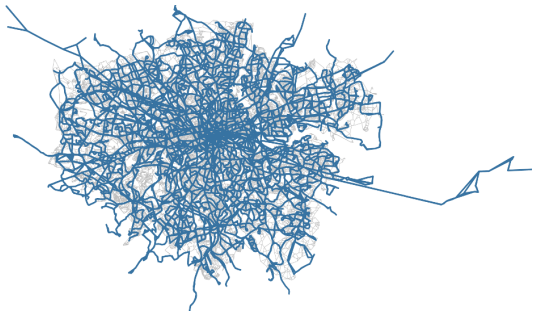
- Perform the ULTRA preprocessing on the operator-expanded network

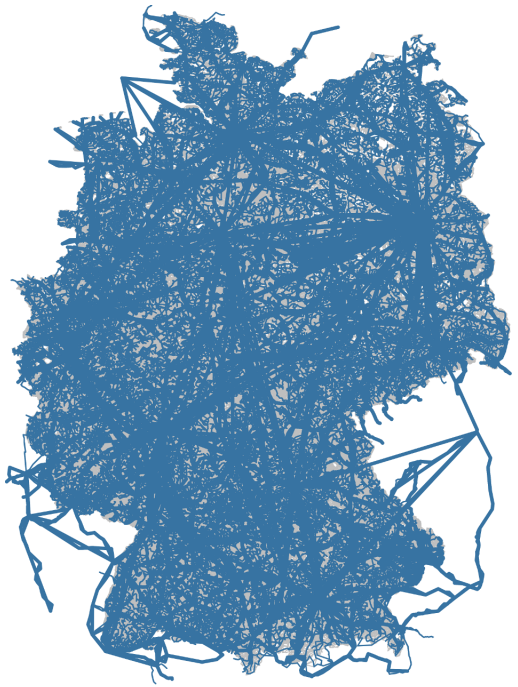
Experimental Evaluation

Instances:

- London, Switzerland, and Germany
- Timetables comprising two days from TfL, GTFS-CH, and DB
- Transfer graphs and bike sharing stations from OpenStreetMap

Network	Stops	Routes	Trips	Vertices	Edges	Stations	Operators
London	20 595	2 107	125 k	183 k	579 k	823	4
Switzerland	25 426	13 934	369 k	604 k	1 847 k	534	11
Germany	244 055	231 089	2 387 k	6 872 k	21 372 k	2 682	22





Experimental Evaluation – Preprocessing

Impact of Operator-Pruning:

- Computation of operator hulls is quite fast
- Leads to significantly smaller operator-expanded networks
- Makes ULTRA on the operator-expanded network feasible

	London		Switzerland		Germany	
	OE	OE-OP	OE	OE-OP	OE	OE-OP
Expanded stops	102 975	31 216	301 500	36 892	5 613 265	411 980
ULTRA shortcuts	1 831 779	521 882	3 389 309	435 514	?	7 873 379
Operator hulls (sequential)	–	3:01:21	–	50:20	–	83:38:15
Operator hulls (parallel 16)	–	15:34	–	4:15	–	8:45:22
Total (CH + OP + ULTRA)	14:15:19	59:33	10:01:54	28:03	≈21 weeks	40:13:48

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Average Running Times:

- Combining ULTRA, OE, and OP yields the fastest algorithm

Network	Algorithm	Preprocessing	Query			
		Time [h:m:s]	Rounds	Vertices	Routes	Time [ms]
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	MCR-OE-OP	5:40	8.35	144 k	43 k	52.8
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Germany	MCR-OD	13:19	11.99	17 421 k	2 888 k	9 830.1
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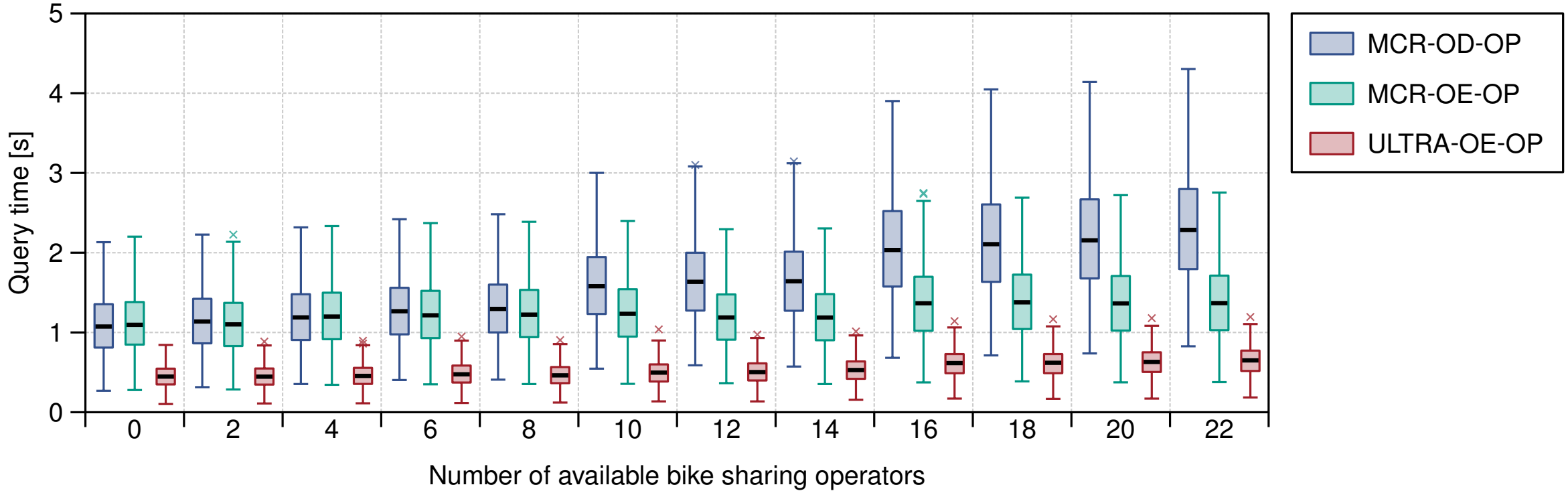
Experimental Evaluation – Query

Running Times Depending on Number of Operators:

- Operator-expanded model benefits more from operator-pruning
- ULTRA reduces query time significantly



Conclusion

Our Contribution:

- We introduced two new approaches for modeling bike sharing:
  - Operator-Dependent
  - Operator-Expanded
- We presented a novel speed-up technique: Operator-Pruning
- Overall, we are more than 10 times faster than the base-line