Multi-Commodity Flow Routing

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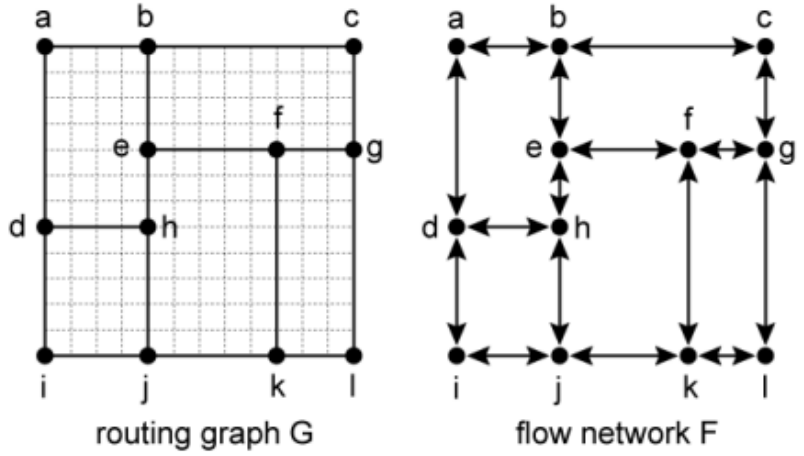
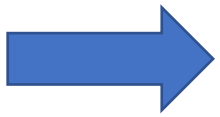
Problem Formulation

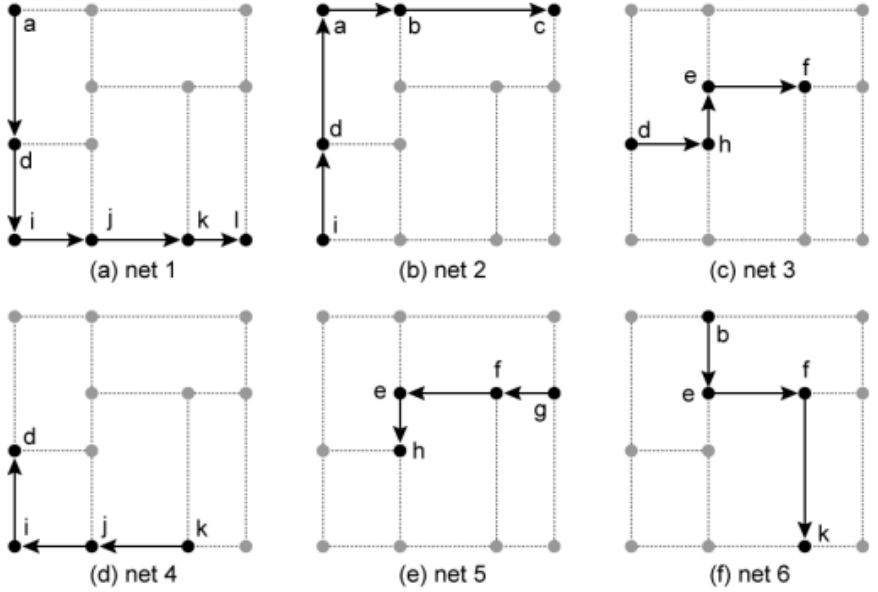
- Given a set of Nets and a Flow Network, need to provide a routing that satisfies an edge capacity constraints while minimizing total wirelength.



routing graph G

flow network F





- Will implement both the ILP algorithm and the MM heuristic for MCF

Algorithm Discussion

- ILP algorithm
  - Given a benchmark, ILP router auto-generates the input file for ILP solver
  - Uses already existing ILP solver
  - Gives the best possible solution
- MM heuristic
  - Starts with shortest path solution, ignoring edge capacity constraint
  - Makes 1 "best" net change every iteration by recomputing shortest paths while ignoring high overflow edges
  - Needs a well-defined exit condition
    - Less strict exit condition -> better solution, more runtime
  - May not give the best solution

Implementation Issues

- Parsing input files given was confusing
  - No node list or flow network initially defined, must extrapolate
- Efficiently writing MM algorithm was difficult
  - Large data structures with many accesses in each iteration
  - Really slow for larger benchmarks
  - Real MM might end sooner than ours, but provide worse solution (greater wirelength)
- Needed to increase edge capacity for solution feasibility
  - Increased edge capacity until ILP solution feasible, then used value for MM

Benchmark Results

- Runtime and Total Wirelength for all benchmarks
- ILP always gives best WL
- MM runtime is very long for larger benchmarks
  - Loose exit condition
  - Possible inefficient data structure implementation

Benchmark	Edge Capacity Required	ILP Runtime (ms)	MM Runtime (ms)	ILP Total Wirelength	MM Total Wirelength
20_15	5	16.678	2.674	281	281
40_30	4	48.498	200.939	976	1040
80_60	7	230.04	1,581.907	3747	3749
225_75	7	640.773	7,419.232	13043	13265
600_350	18	316,994.209	1,301,741.198	138936	138936

Benchmark Results

- **Individual Net Wirelength**

for 20_15 and 40_30

- Highlighted differences
- Note: 20_15 is solvable with just shortest path solution

20_15

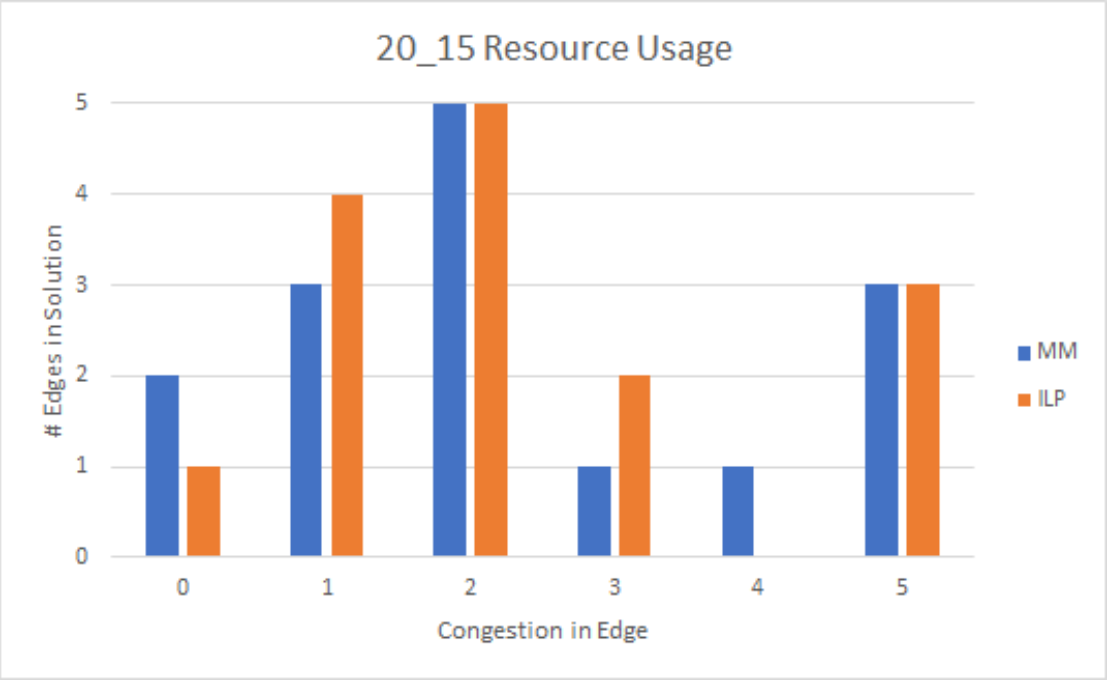
Net	MM	ILP
0	33	33
1	12	12
2	3	3
3	9	9
4	4	4
5	5	5
6	14	14
7	16	16
8	32	32
9	25	25
10	28	28
11	20	20
12	25	25
13	27	27
14	28	28

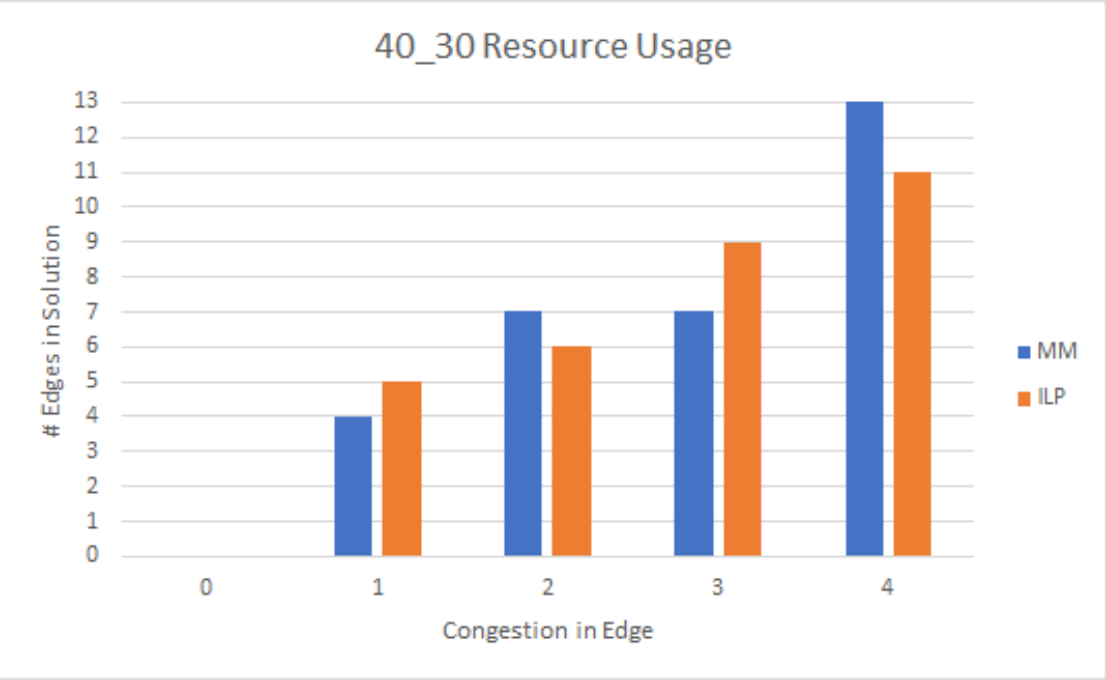
40_30

Net	MM	ILP	Net	MM	ILP
0	34	34	**15**	33	33
1	15	15	**16**	54	54
2	22	22	**17**	34	34
3	54	26	**18**	50	50
4	80	68	**19**	6	6
5	73	75	**20**	8	8
6	35	35	**21**	25	25
7	35	35	**22**	102	76
8	4	4	**23**	45	45
9	19	19	**24**	12	12
10	7	7	**25**	10	10
11	19	19	**26**	74	74
12	37	37	**27**	36	36
13	15	15	**28**	40	40
14	36	36	**29**	26	26

Benchmark Results

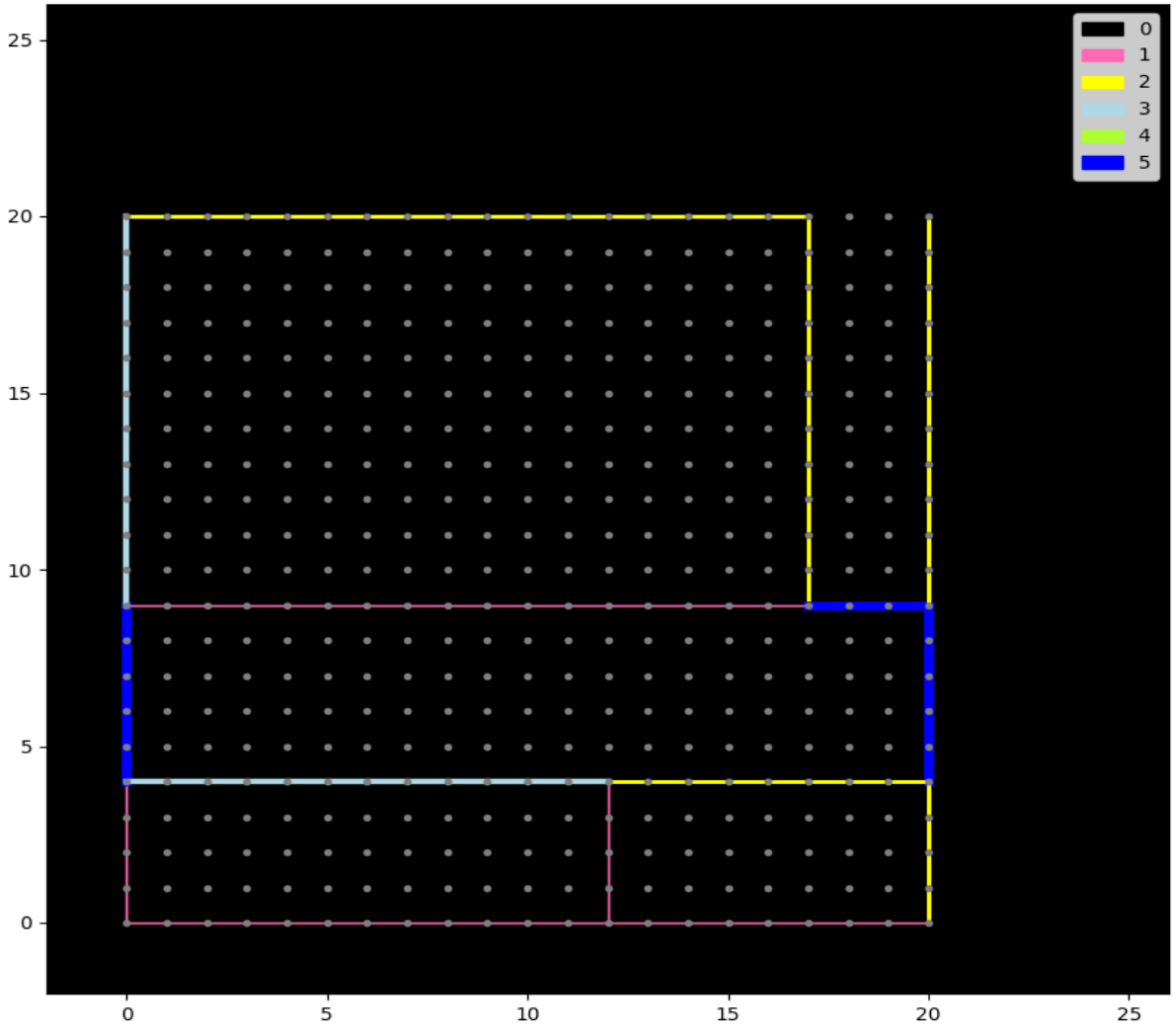
- **Routing Resource Usage** for 20_15 and 40_30





ILP-based Routing GUI

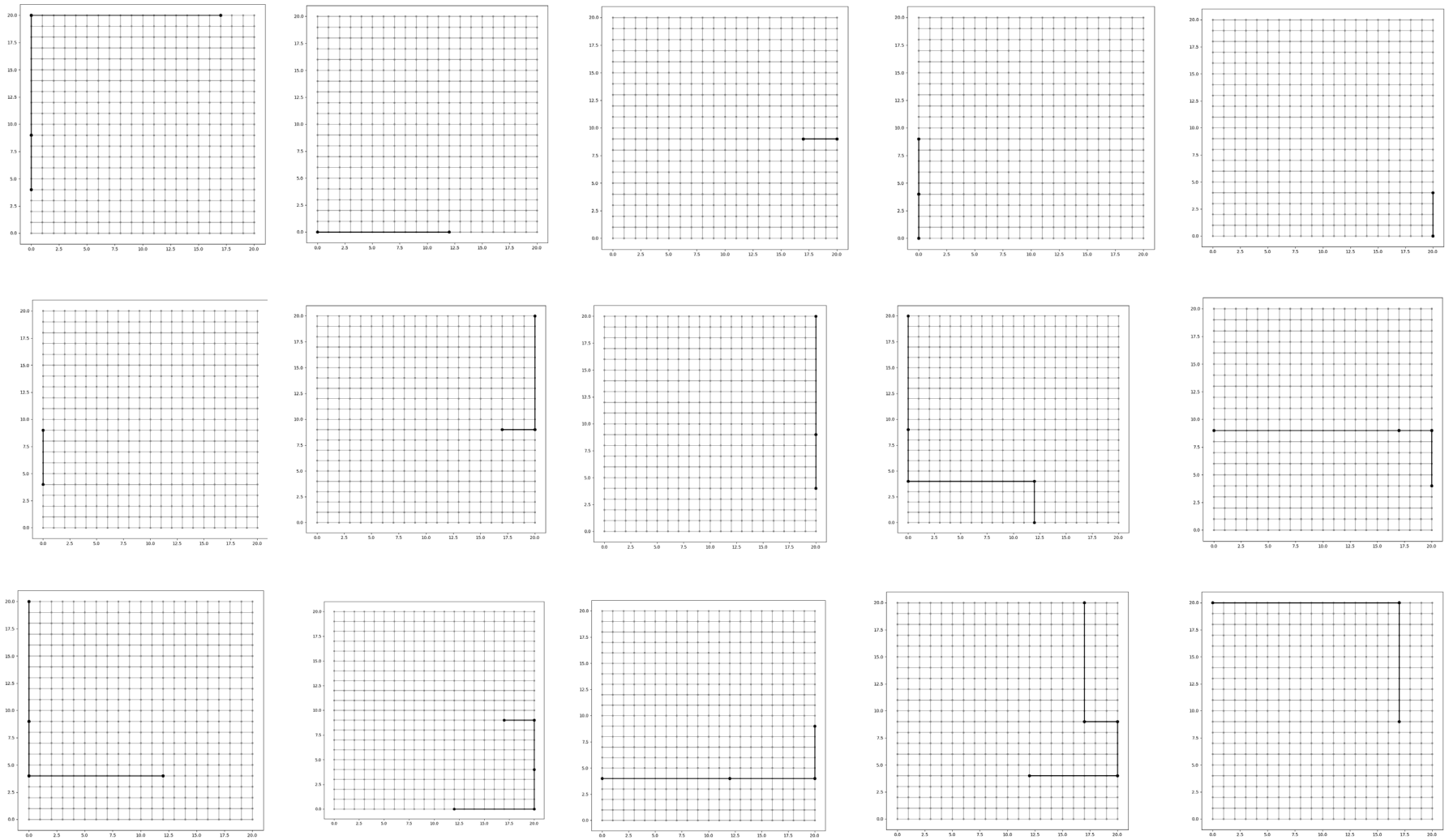
ILP Results 20_15 congestion map



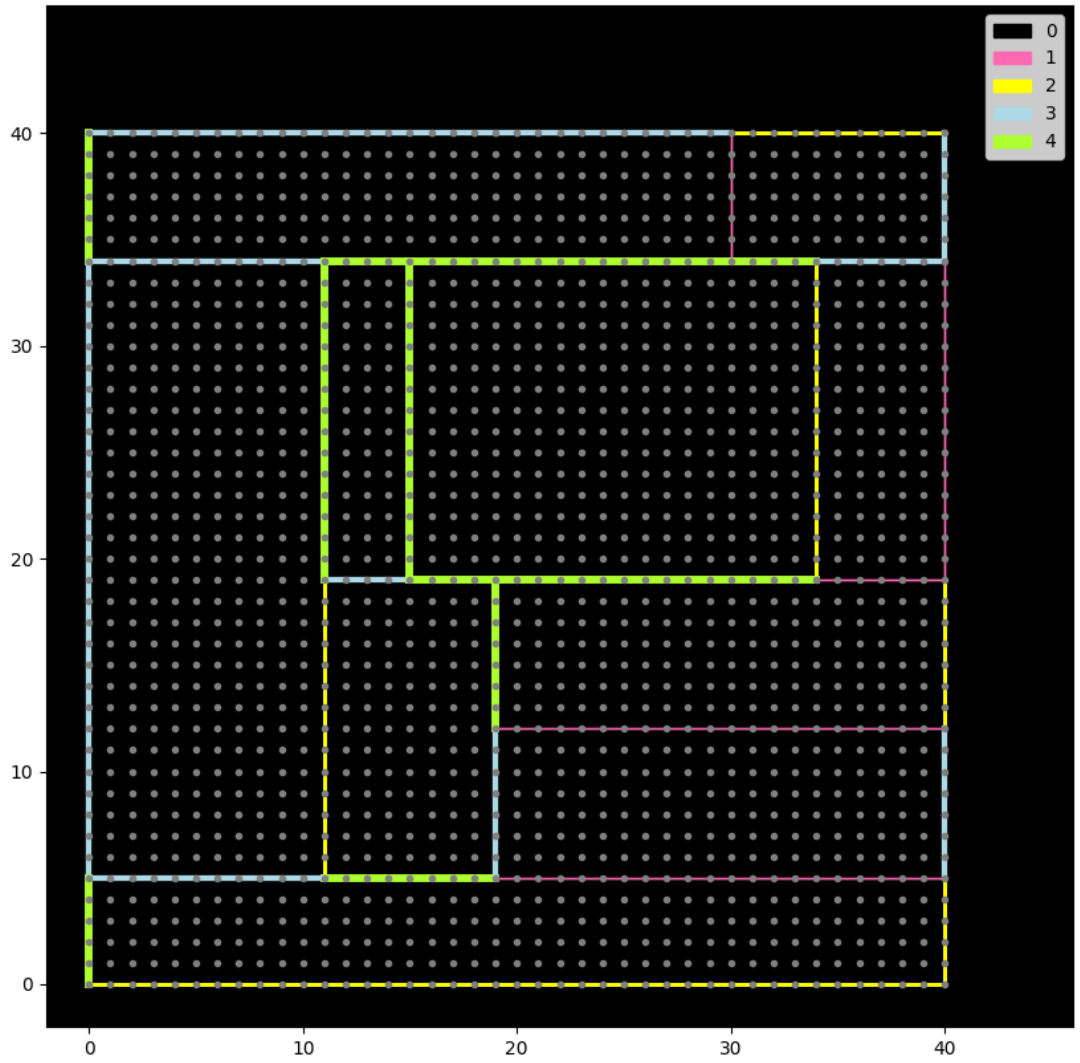
- The color and thickness of each channel represents its capacity, which is highlighted by the color-map shown in the graph. Channels with larger capacities are thicker.
- For eg. The edges marked blue have a capacity of 5 and are shown 5 times thicker than the pink channels, which indicate edges with capacity of 1

ILP Results 20_15 net routing

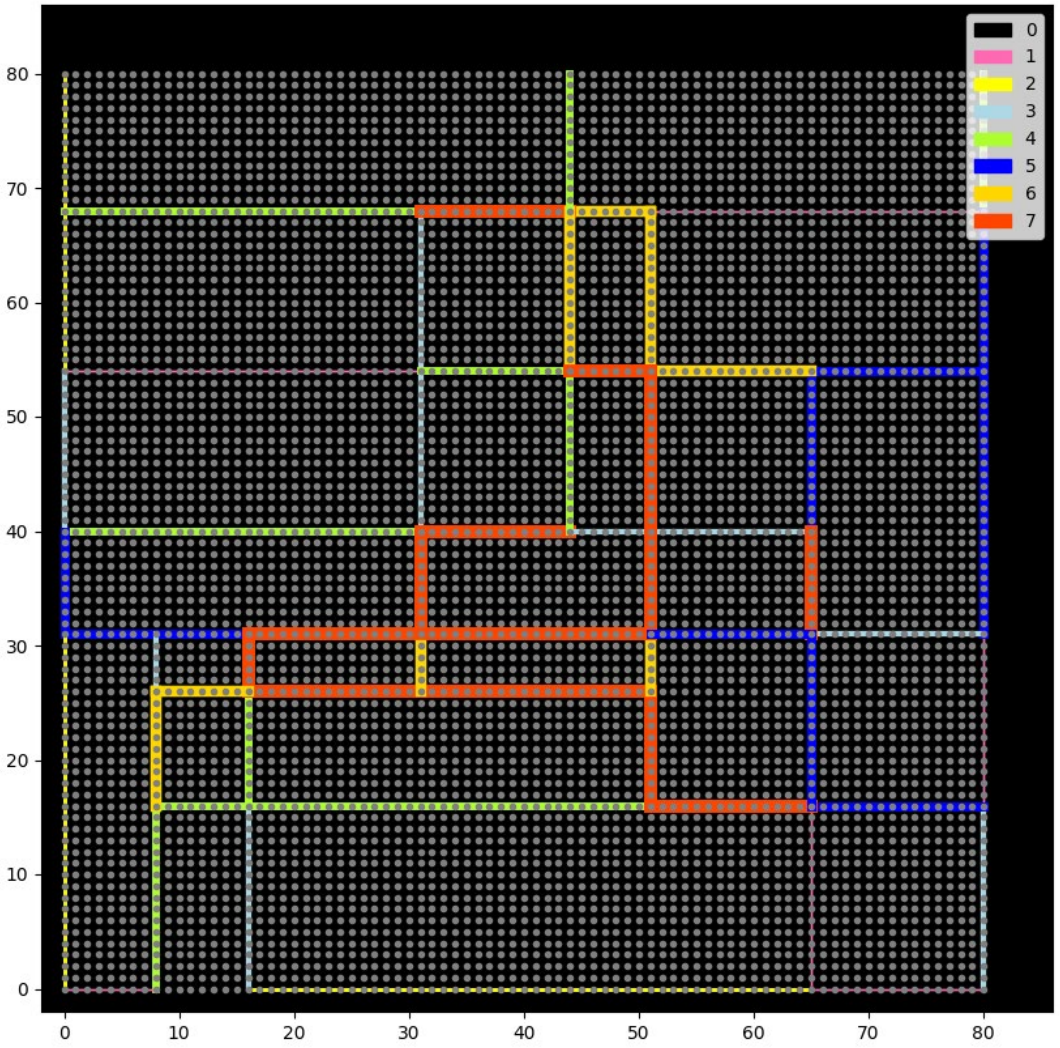
- The final routing results for all the 15 nets of the 20_15 benchmark are as shown.
- The thick black line indicates the computed route between the source and destination of the net.
- The big black dots represent the nodes in the channel intersection graph that the route passes through.



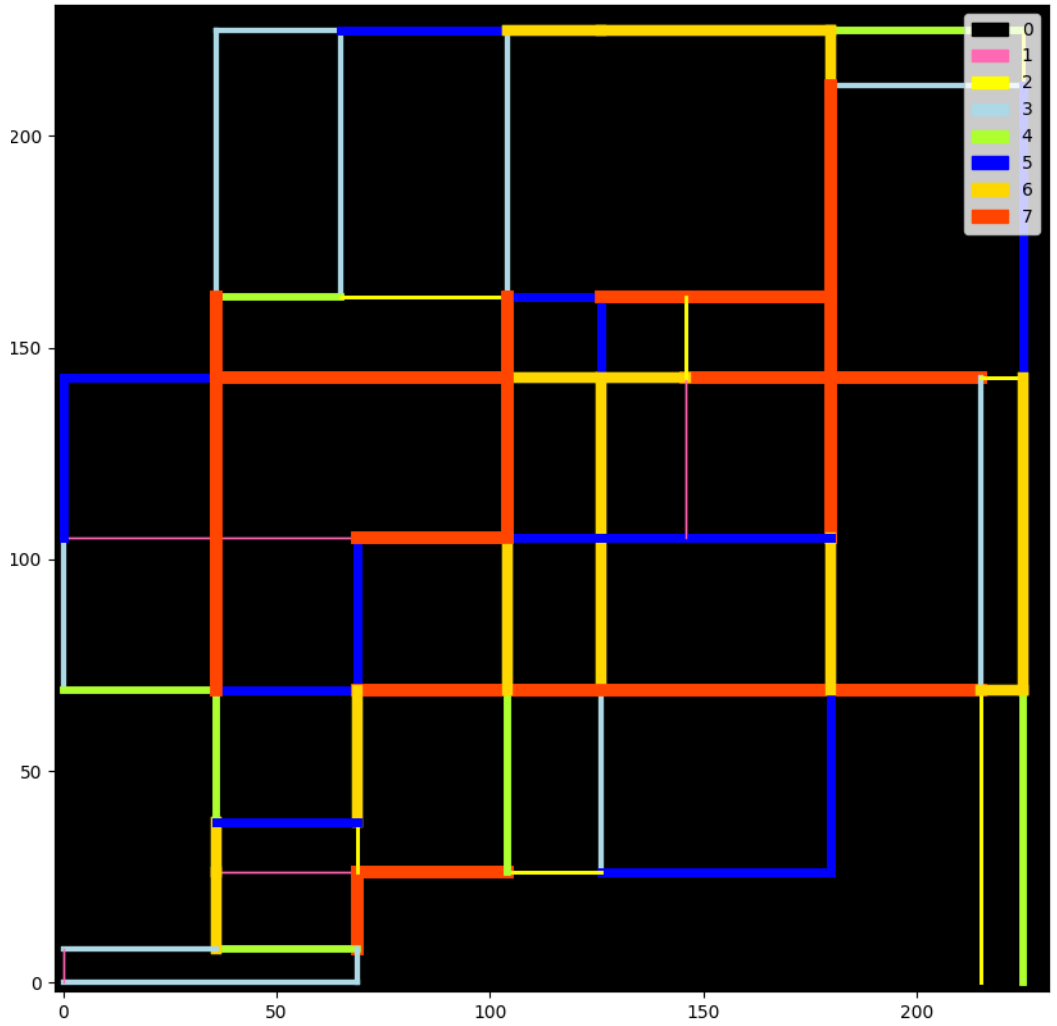
ILP Results 40_30 congestion map



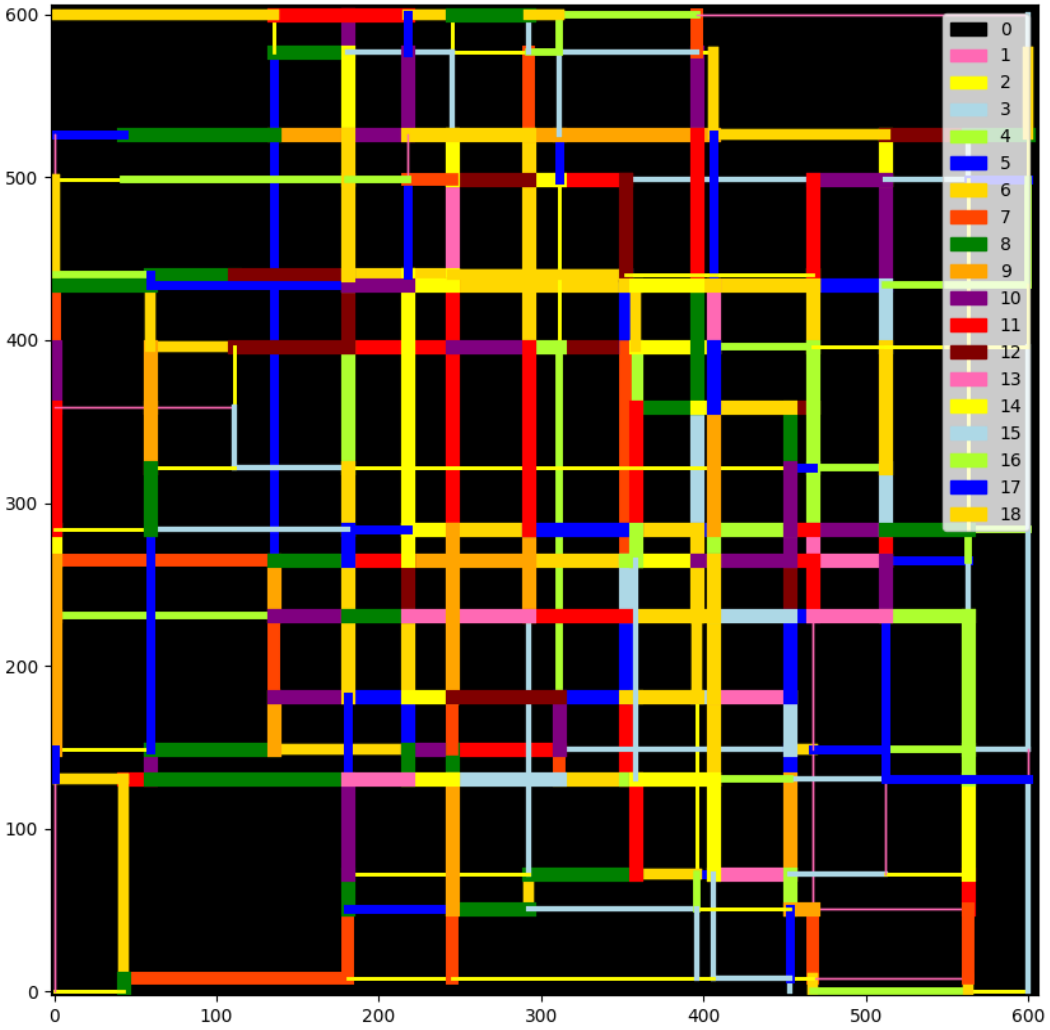
ILP Results 80_60 congestion map



ILP Results 225_75 congestion map

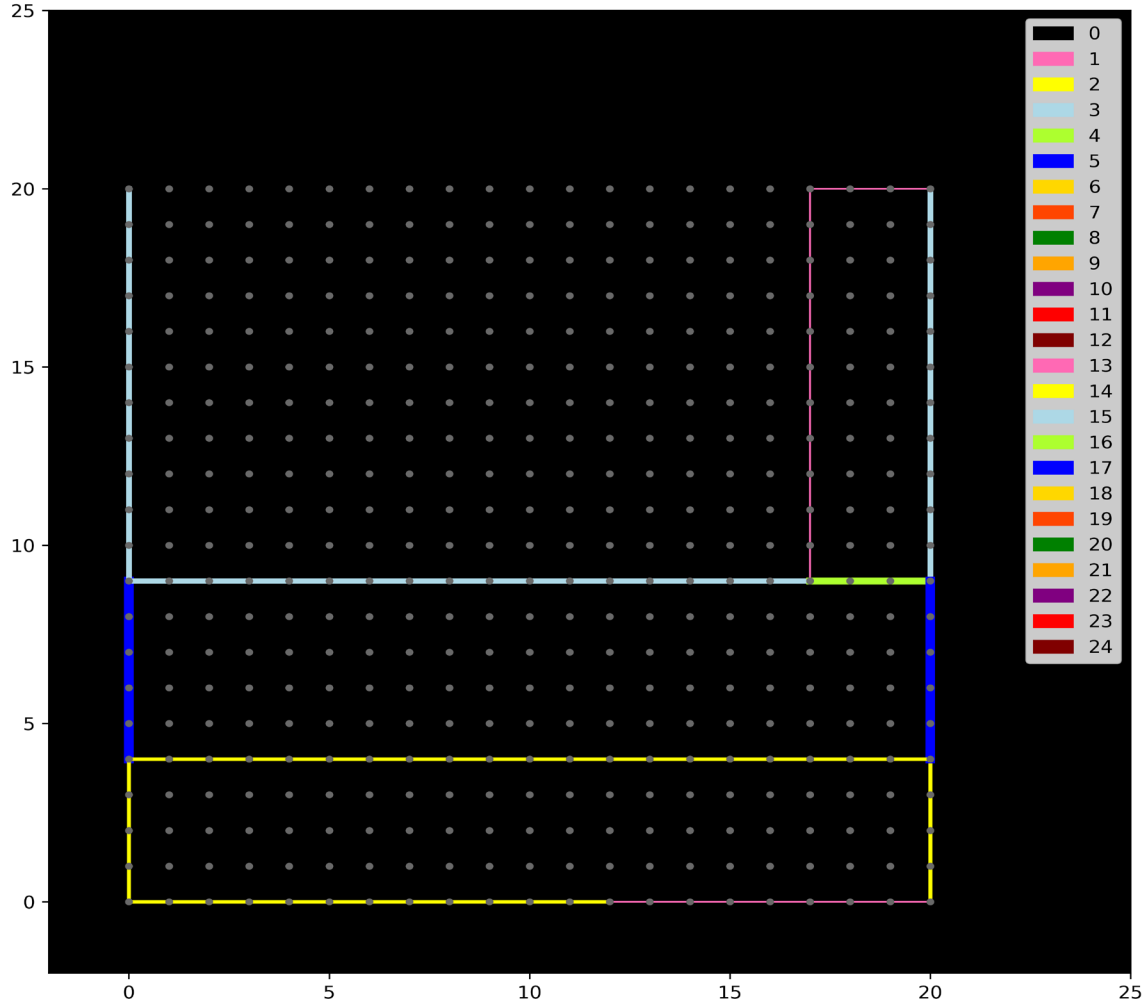


ILP Results 600_350 congestion map

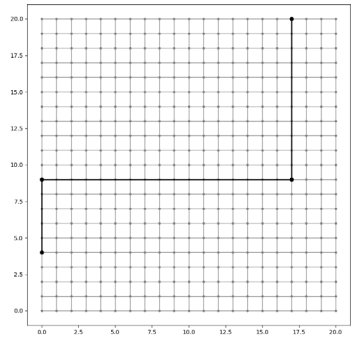
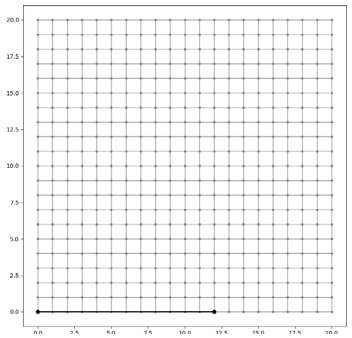
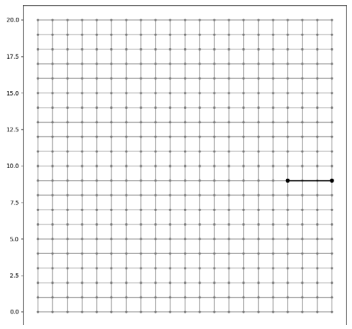
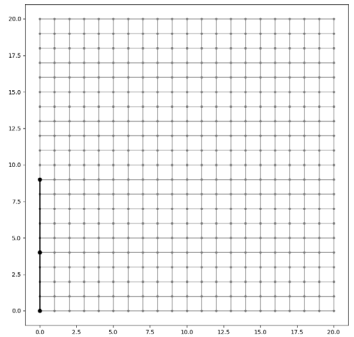
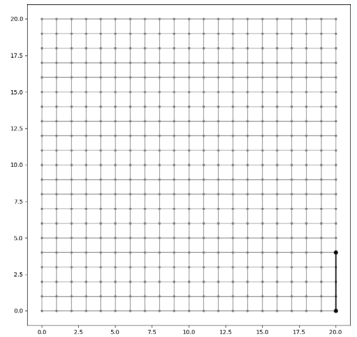
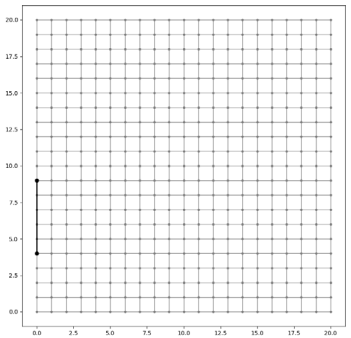
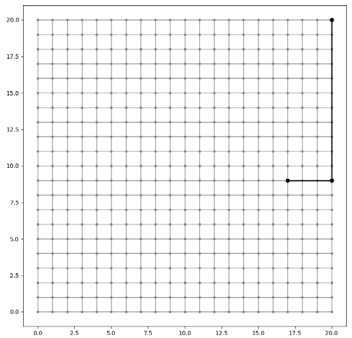
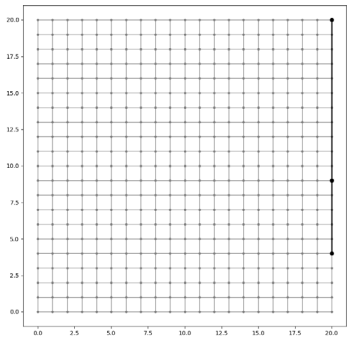
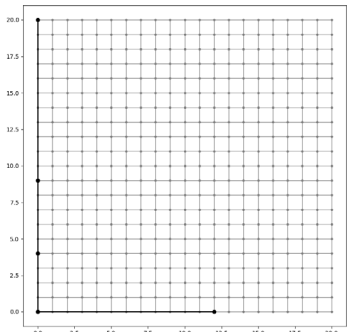
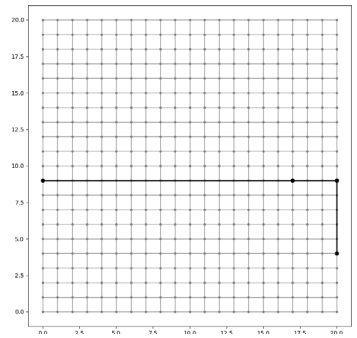
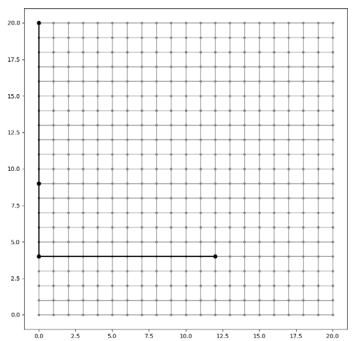
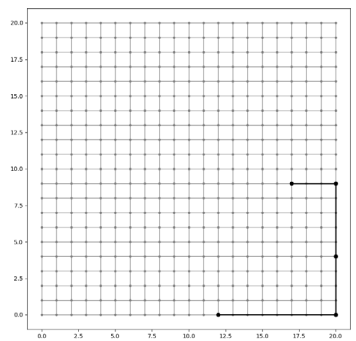
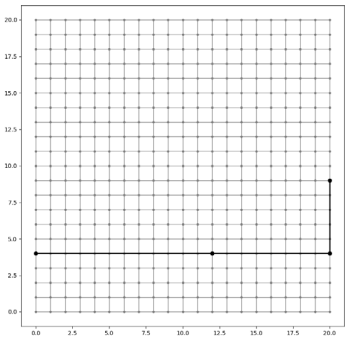
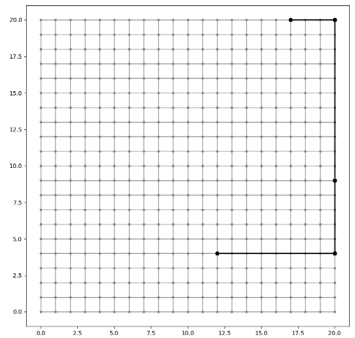
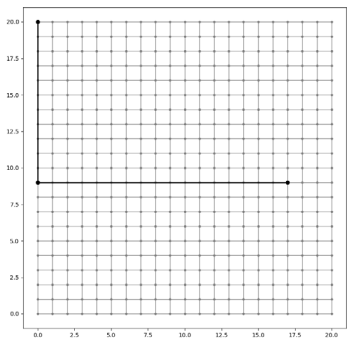


MM Heuristics-based Routing GUI

20_15.mcf final congestion map

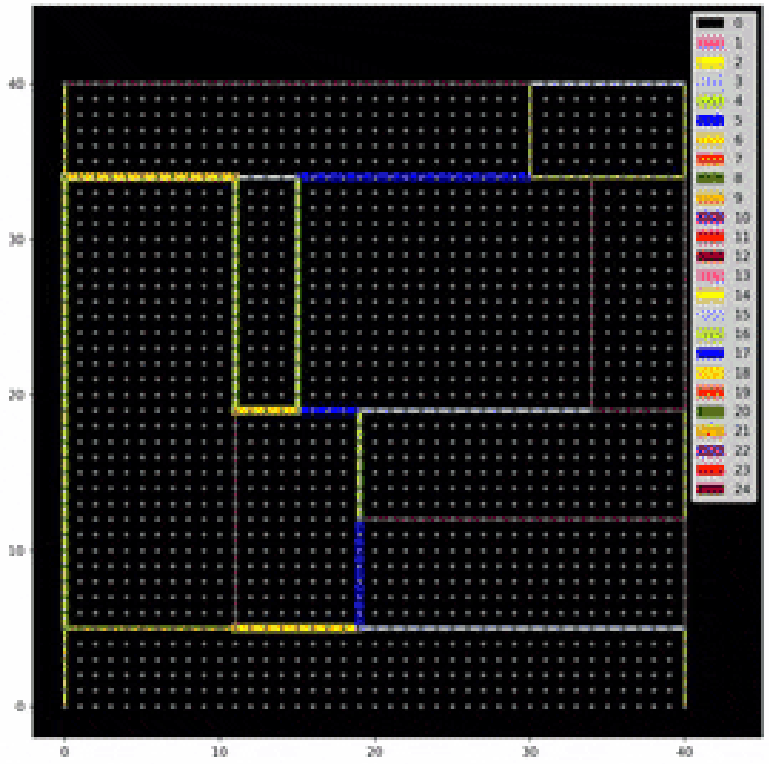


20_15.mcf net routing

40_30 MM Animation

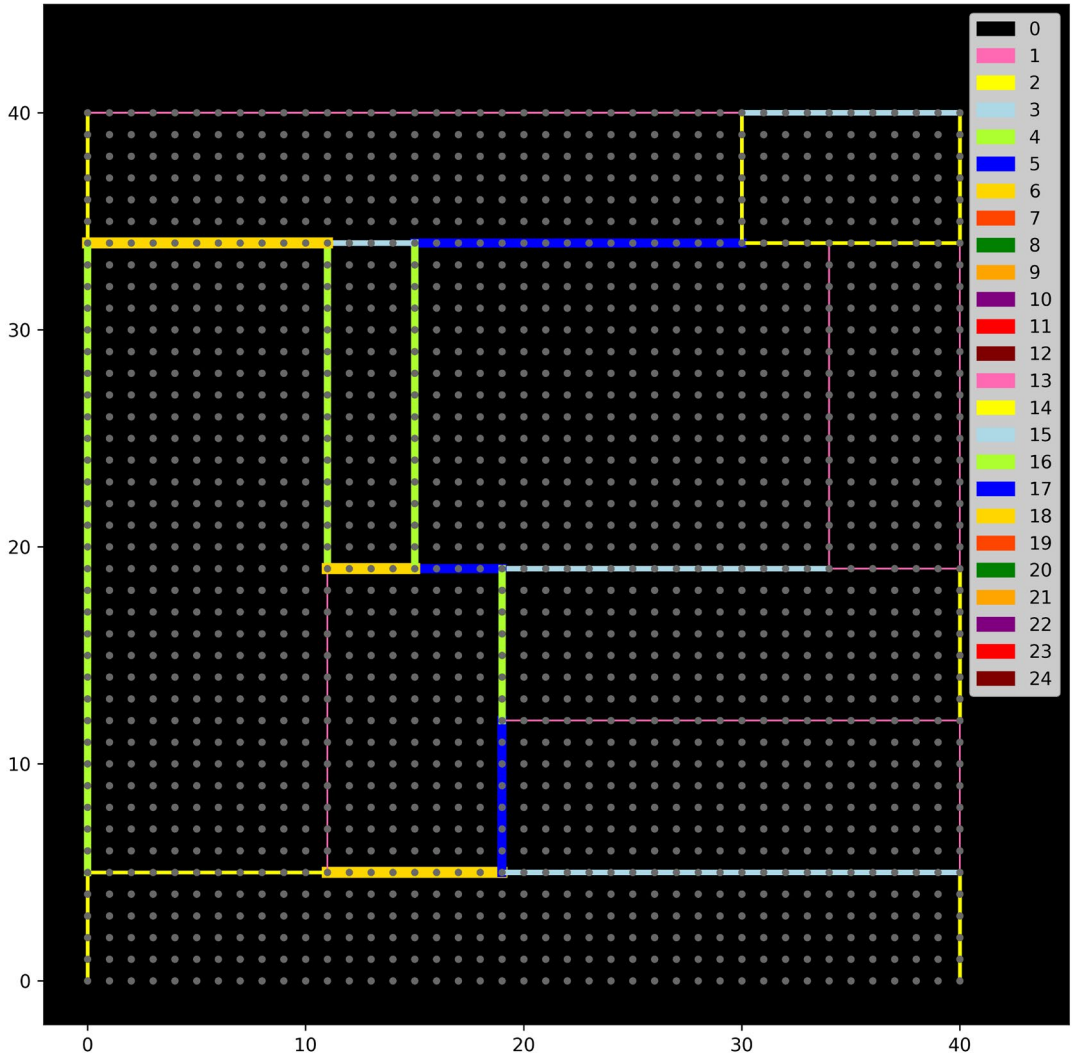
40_30.mcf Initial solution



Max Overflow = 2

Total Overflow = 9

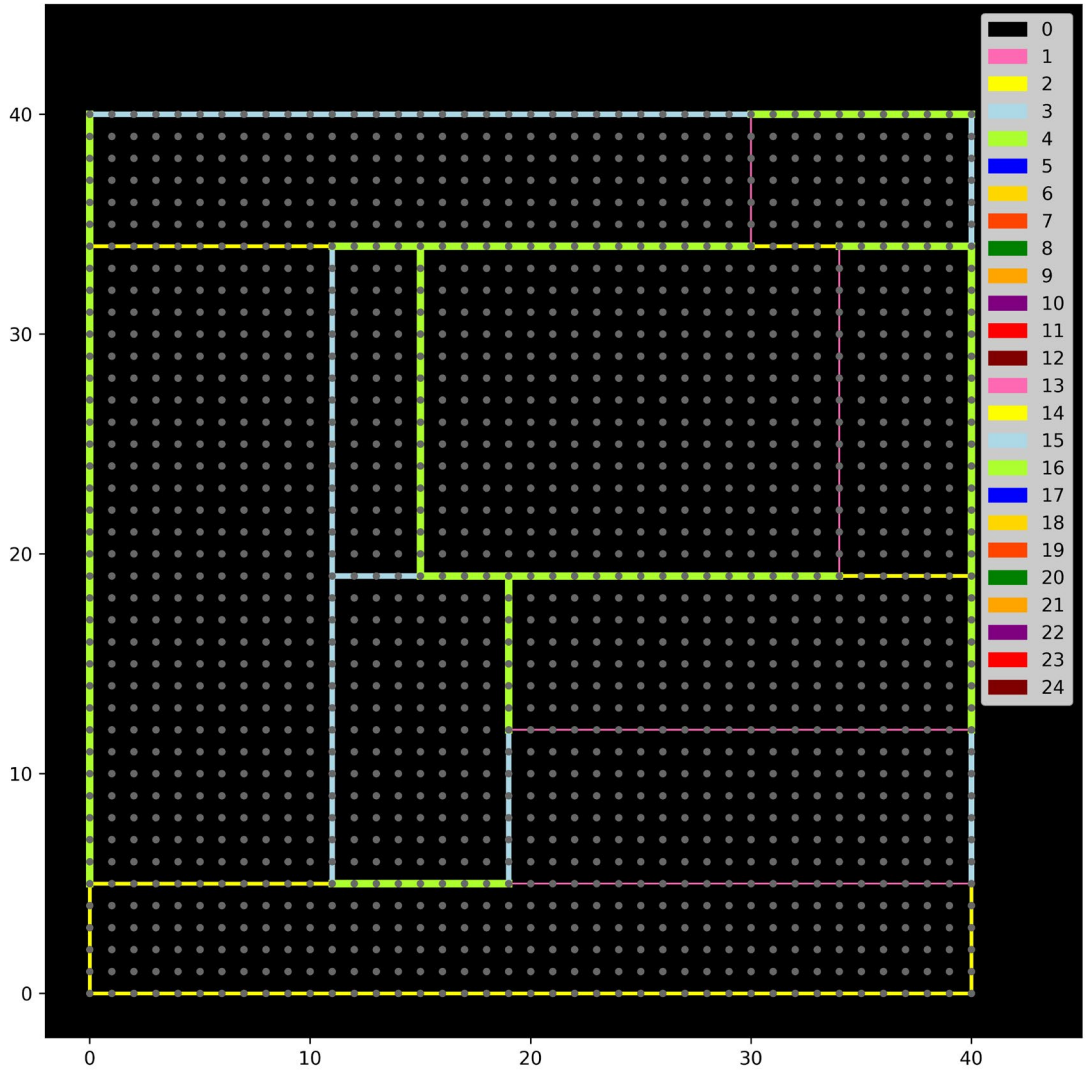
40_30.mcf Initial solution



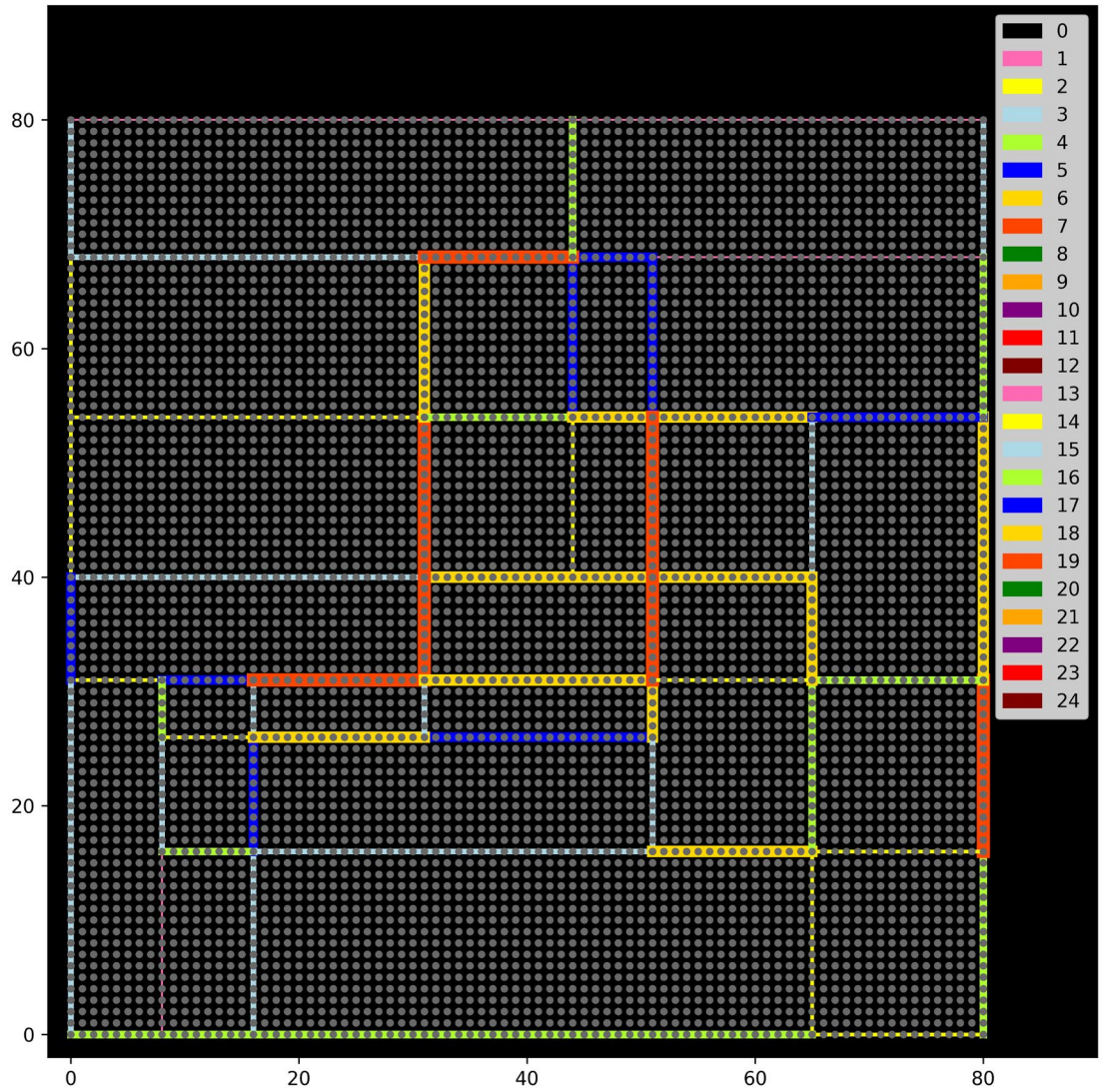
Max Overflow = 2

Total Overflow = 9

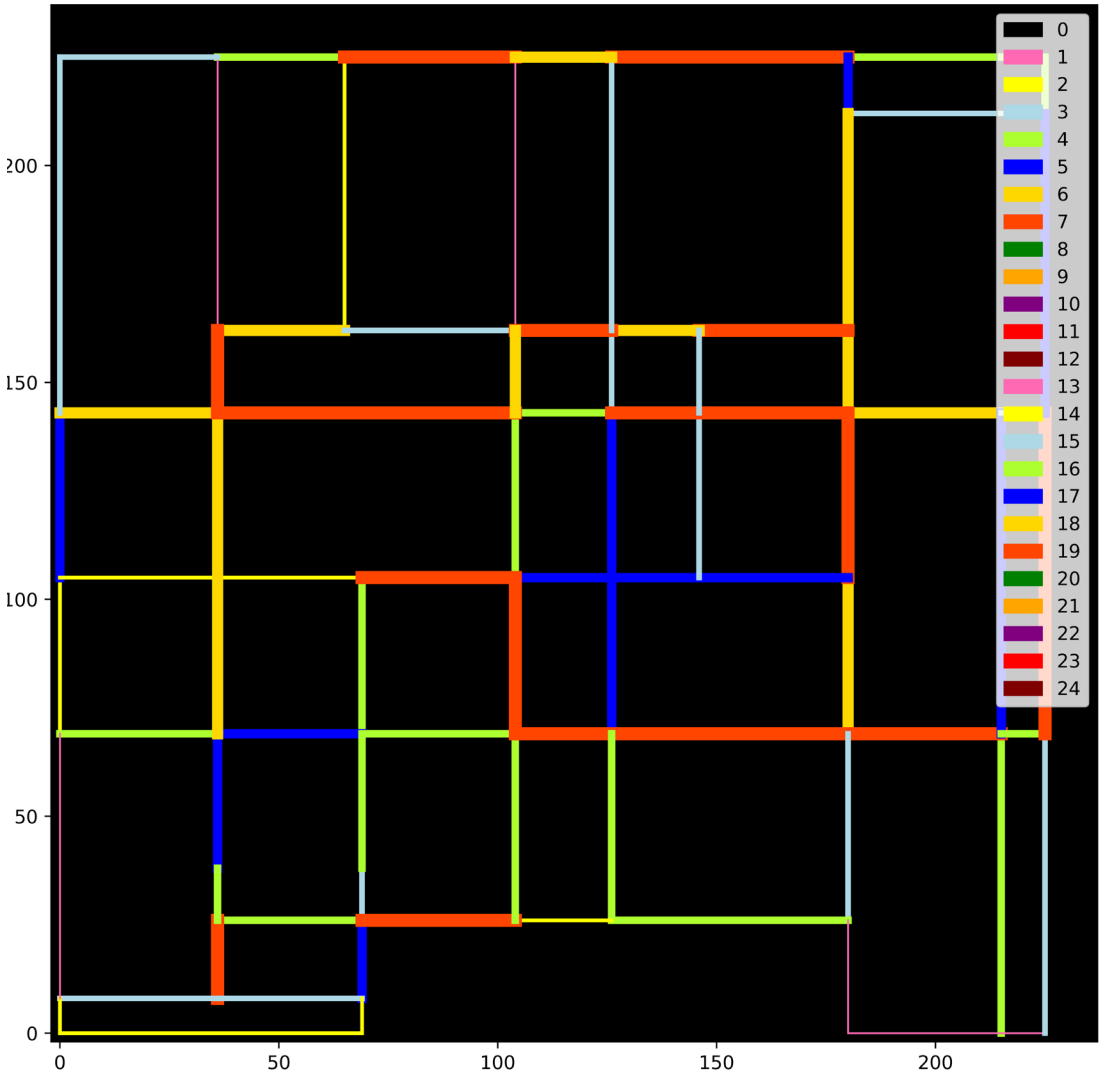
40_30.mcf final congestion map



80_60.mcf final congestion map



225_75 final congestion map



600_350.mcf final congestion map