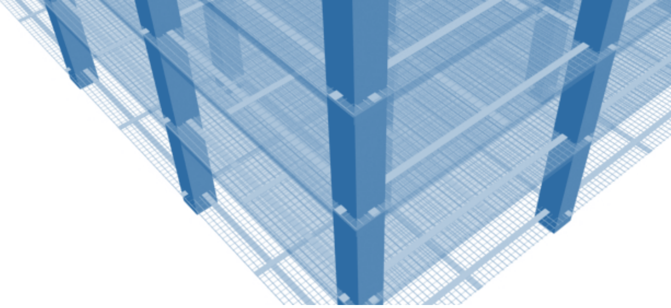
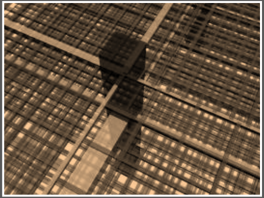
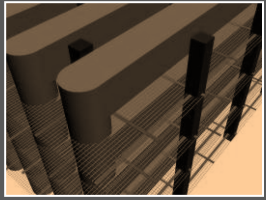
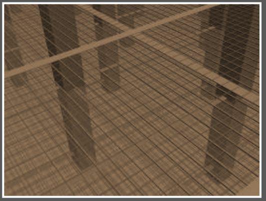
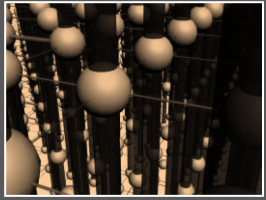


ECE 6133 Project Overview

Spring 2025

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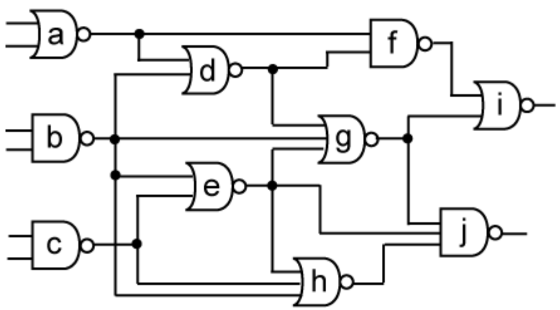
1/5. EIG Partitioning

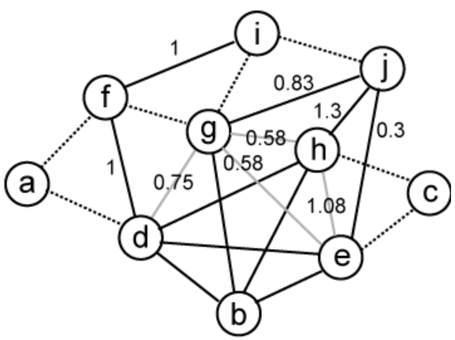
- **Circuit partitioning using matrices and eigenvectors**



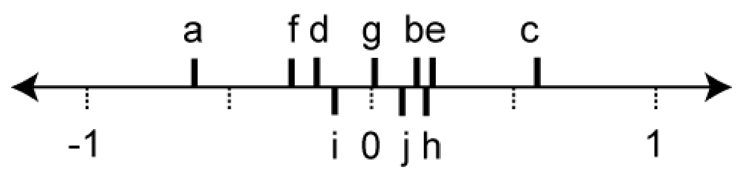
circuit

	a	b	c	d	e	f	g	h	i	j
a	1.0	0	0	-0.5	0	-0.5	0	0	0	0
b	0	1.0	0	-0.25	-0.25	0	-0.25	-0.25	0	0
c	0	0	1.0	0	-0.5	0	0	-0.5	0	0
d	-0.5	-0.25	0	3.0	-0.25	-1.0	-0.75	-0.25	0	0
e	0	-0.25	-0.5	-0.25	2.99	0	-0.58	-1.08	0	-0.33
f	-0.5	0	0	-1.0	0	3.0	-0.5	0	-1.0	0
g	0	-0.25	0	-0.75	-0.58	-0.5	3.99	-0.58	-0.5	-0.83
h	0	-0.25	-0.5	-0.25	-1.08	0	-0.58	3.99	0	-1.33
i	0	0	0	0	0	-1.0	-0.5	0	2.0	-0.5
j	0	0	0	0	-0.33	0	-0.83	-1.33	-0.5	2.99

Laplacian matrix L



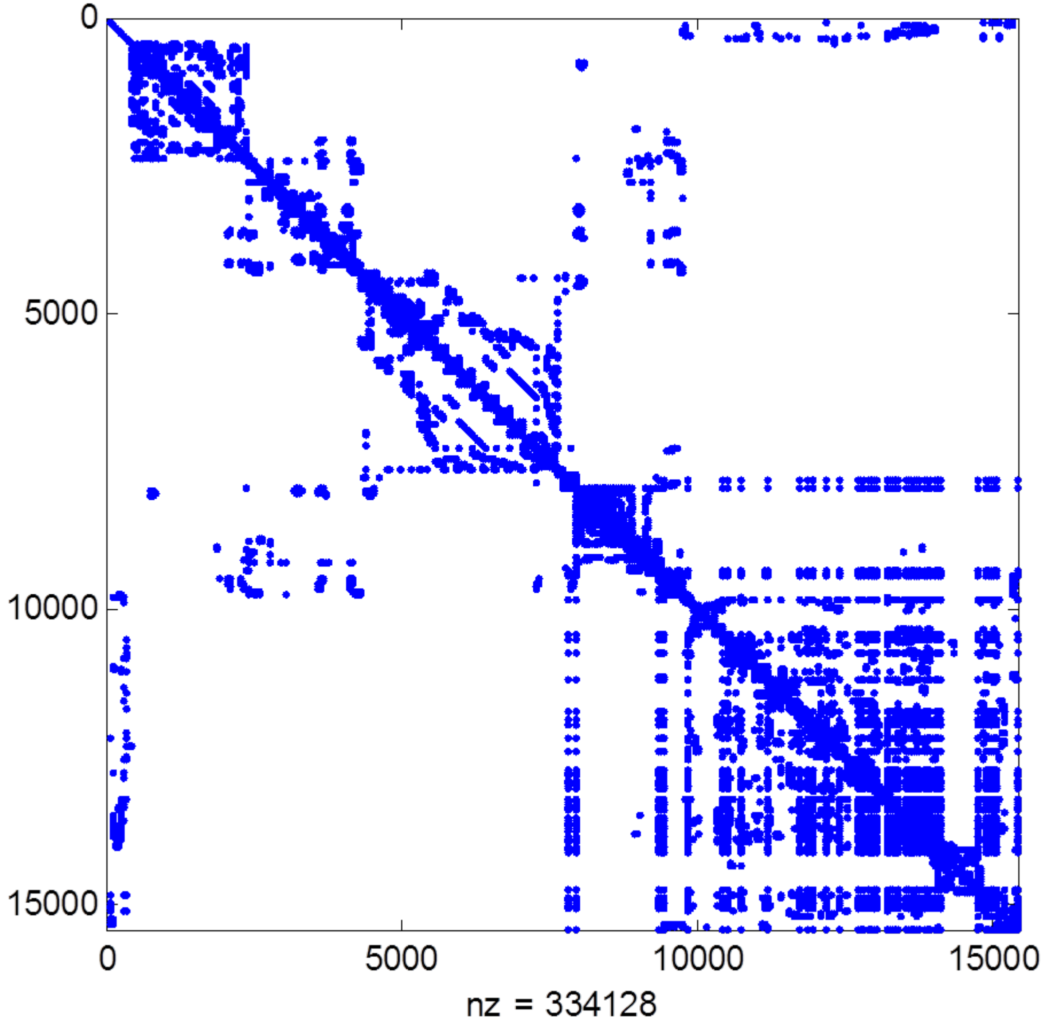
clique-based model



2nd smallest eigenvector of L gives linear placement

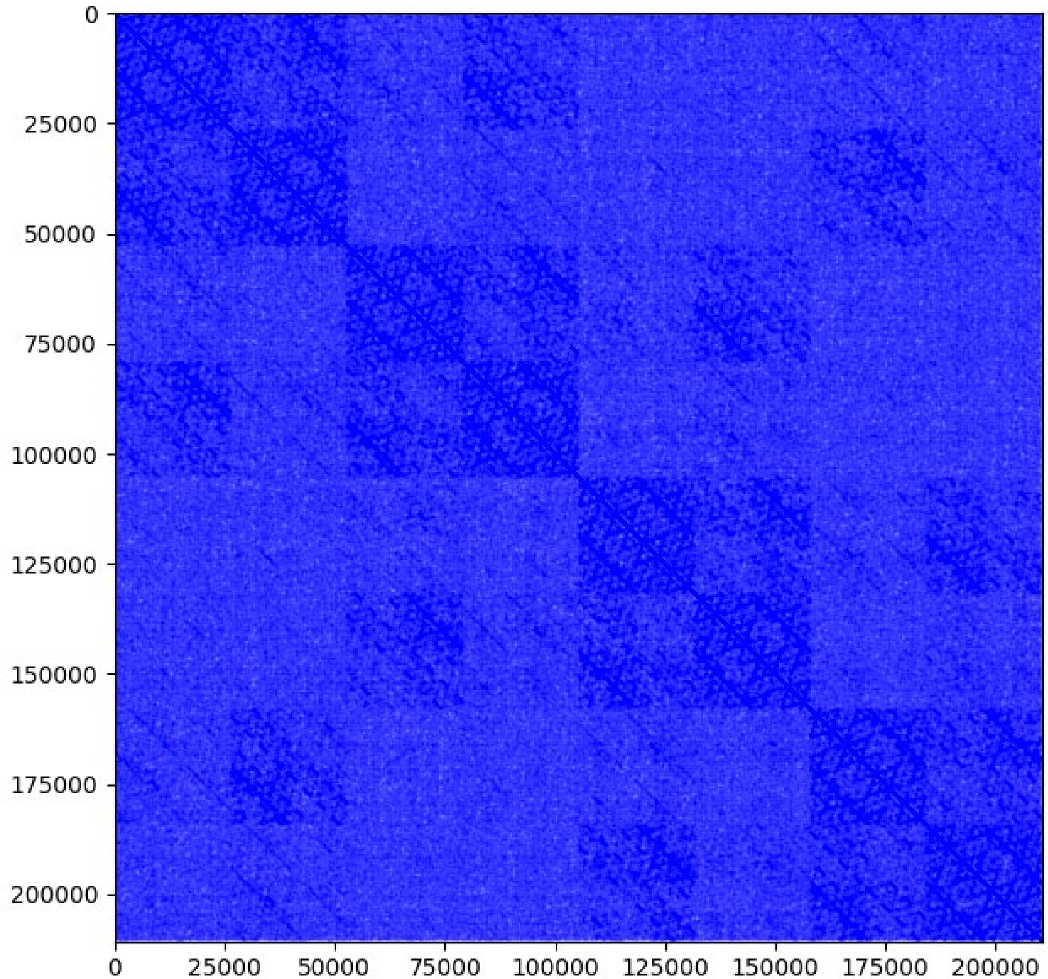
Laplacian Sparsity: Small Circuit

- industry3.hgr
  - 15,406 nodes
  - 21,923 nets
  - 237M entries in matrix
  - 334k nonzero entries
  - 0.14% fill factor
- Sparse matrix methods
  - enables us to consider systems 700X larger than otherwise possible

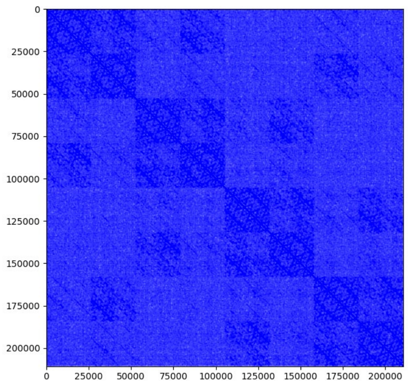


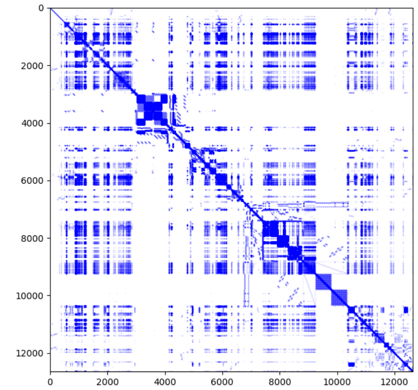
Laplacian Sparsity: Large Circuit

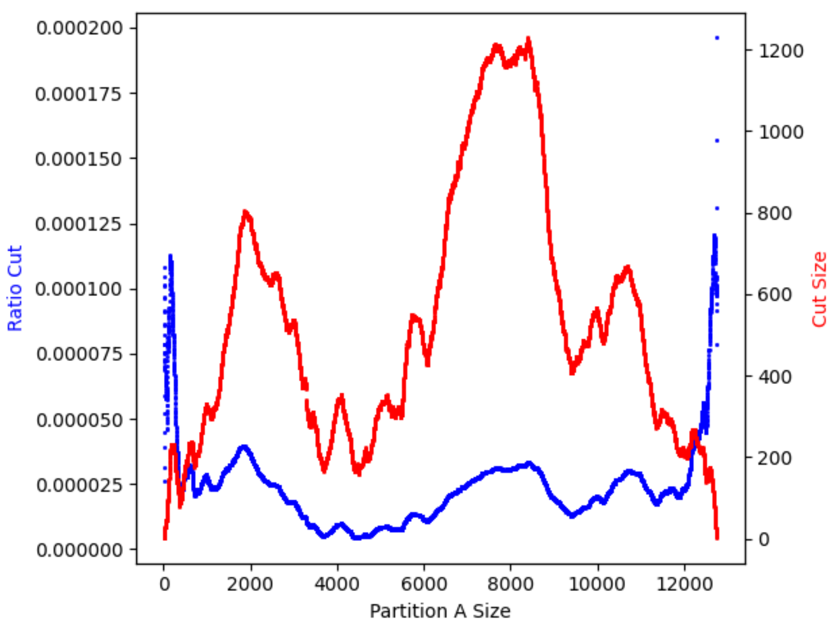
- IBM18 benchmark
  - 210,613 cells
  - Laplacian matrix fill rate: 0.01%!
  - 178 GB of memory required to store in a normal matrix
  - Sparse matrix can bring that down to 2.5 MB

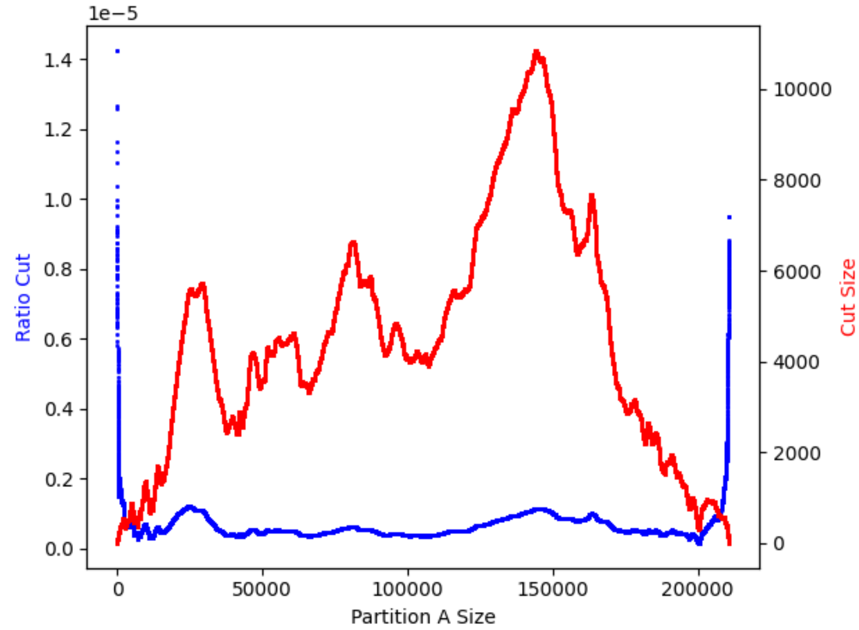


Cutsize vs. Ratio Cut Landscape







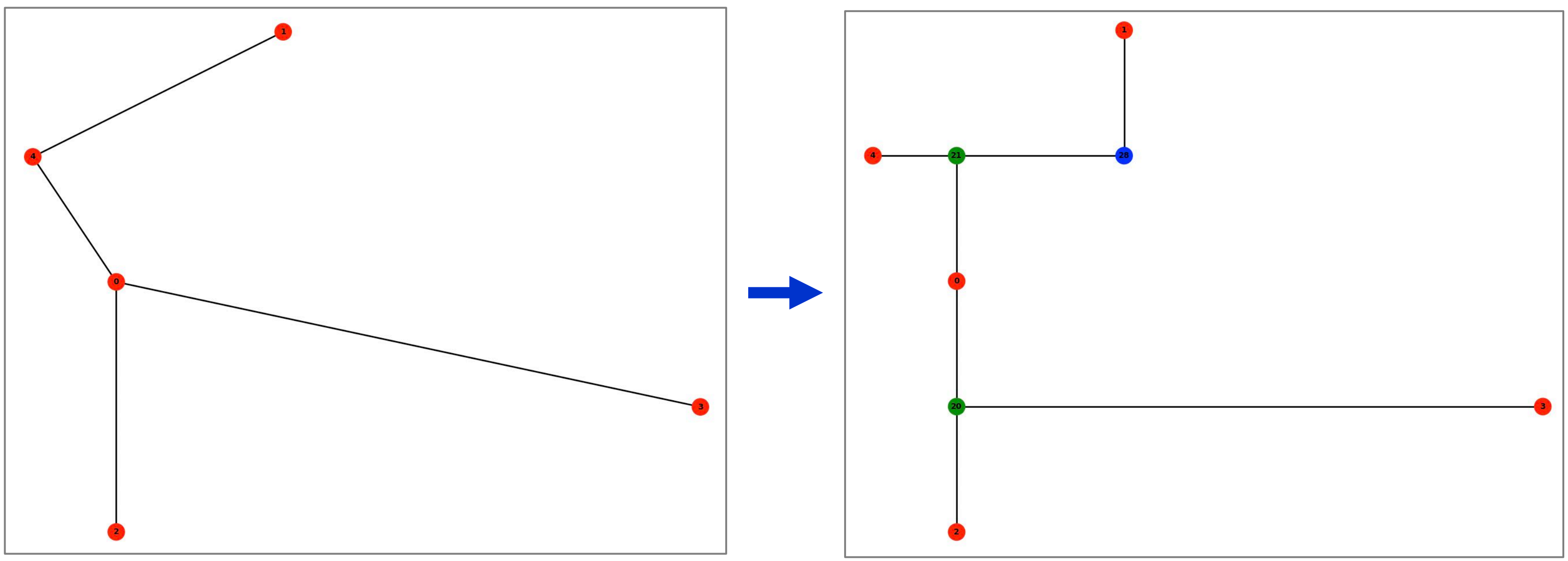


2/5. ILP Floorplanning

3/5. Gordian Placement

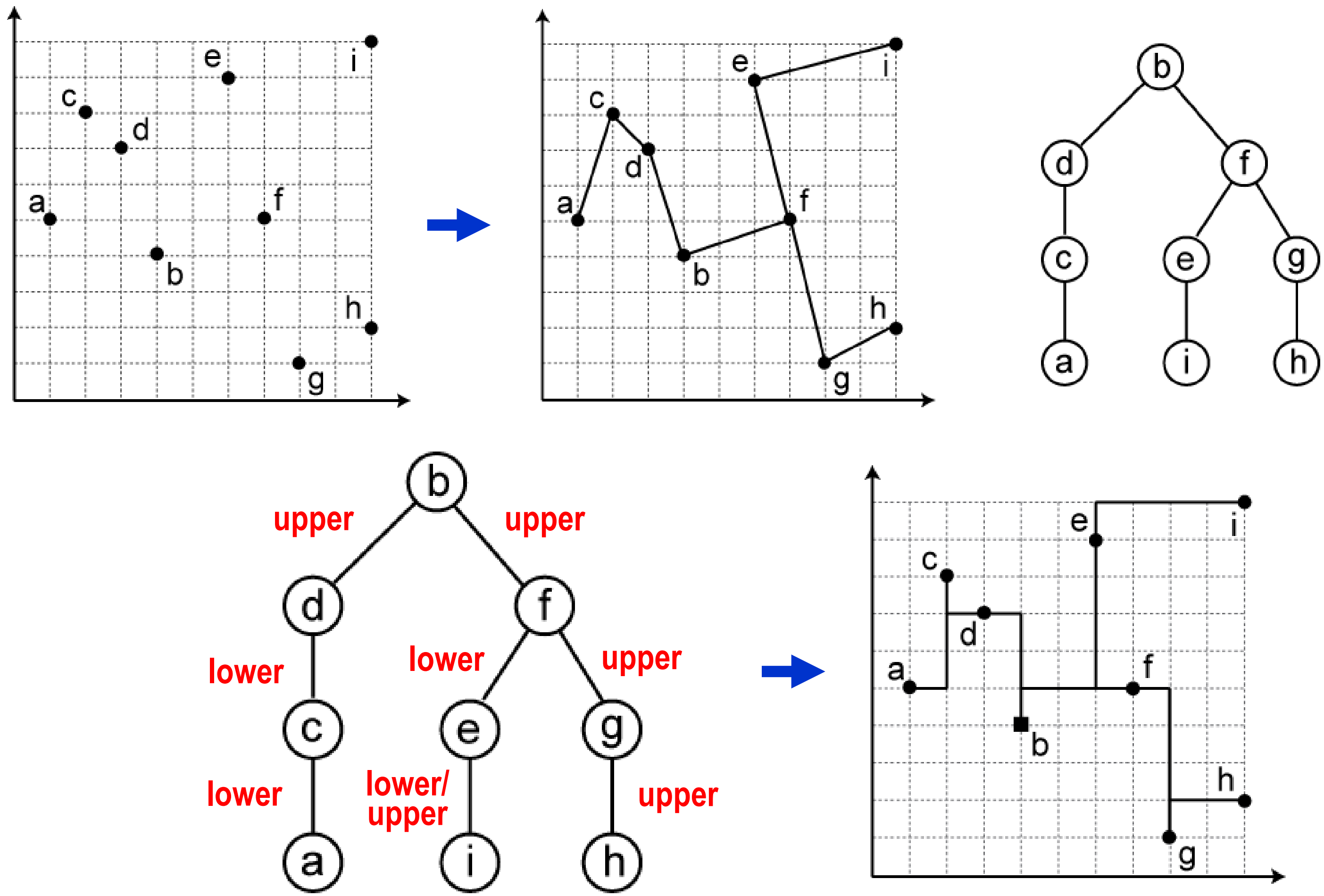
4/5. L-Shaped vs. Borah Routing

- **Steiner points**
  - **Reduce the overall wirelength**
  - **Finding Steiner points is NP-hard….**
  - **So, we rely on heuristics**



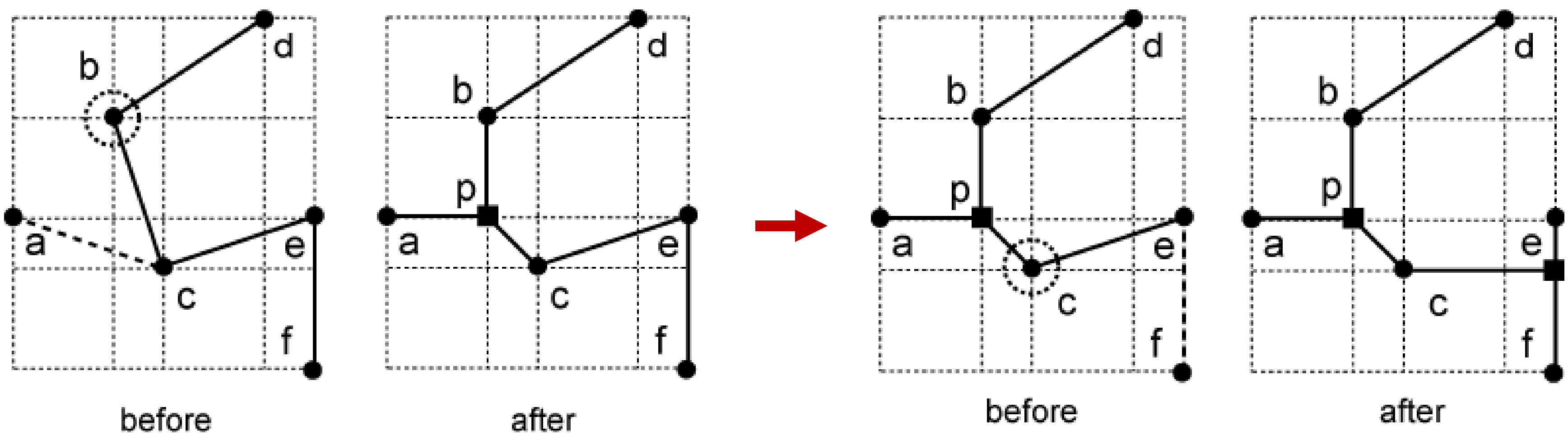
L-Shaped Steiner Routing

- **Strategy: build separable MST and improve with L-edges**



Borah Routing

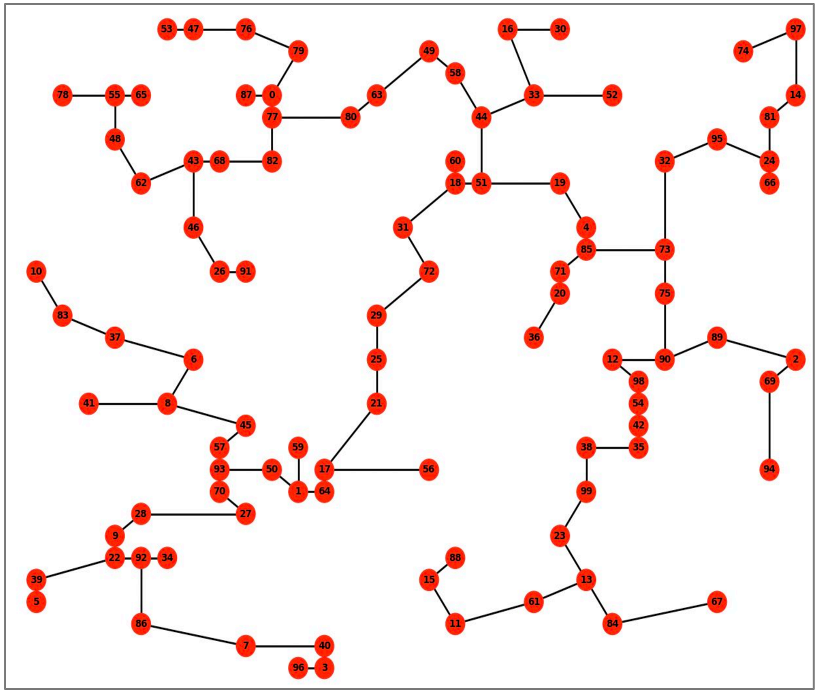
- Based on node/edge pairing



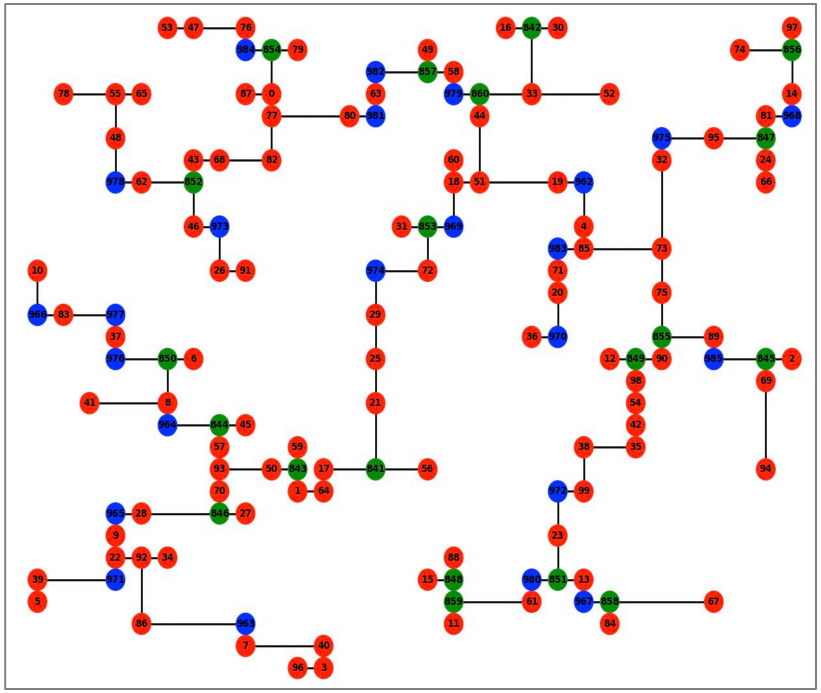
WL reduces from 20 to 18

WL reduces from 18 to 17

Borah Routing Sample



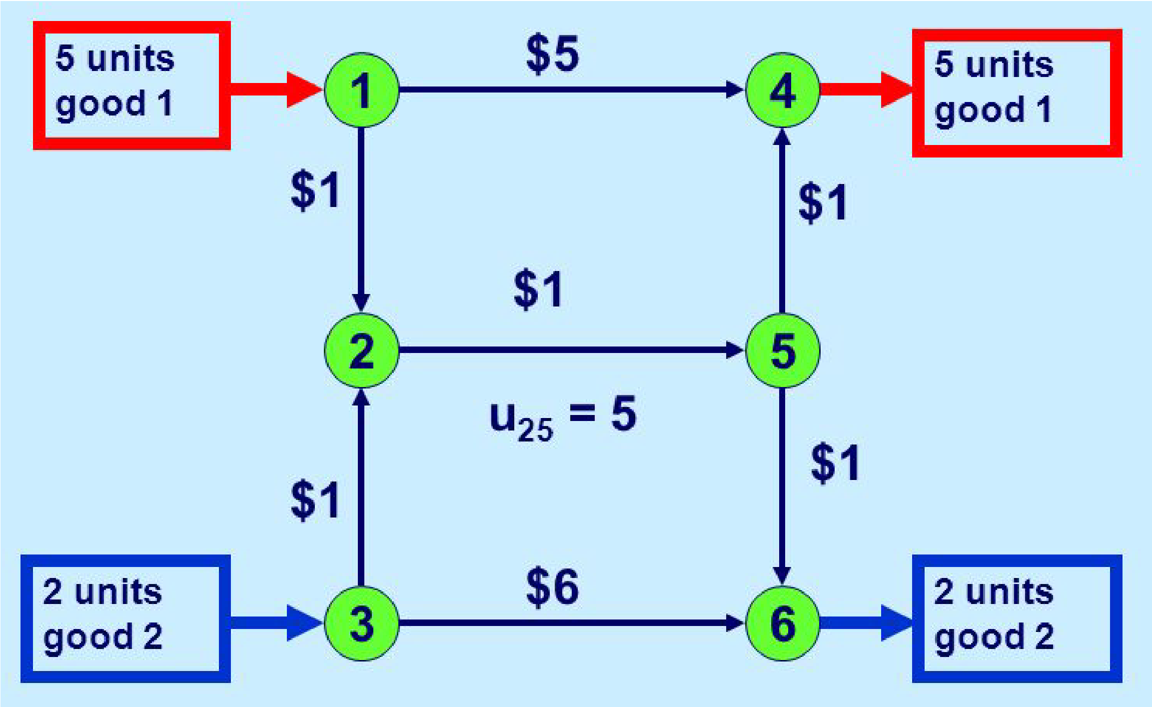
initial (WL = 242)



final (WL = 221), 20 Steiner pt added
Took 1.2 sec

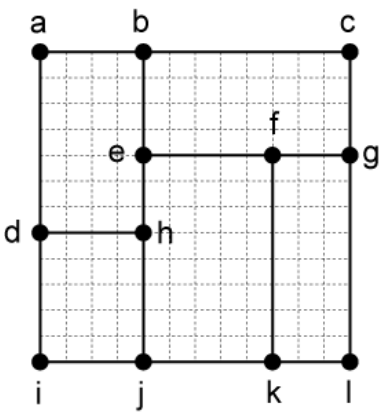
5/5. Multi-Commodity Flow Routing

- **Cost minimization problem**
  - How do we ship the units so that the overall cost is minimized?
  - Assume the capacity of each edge is 5 units

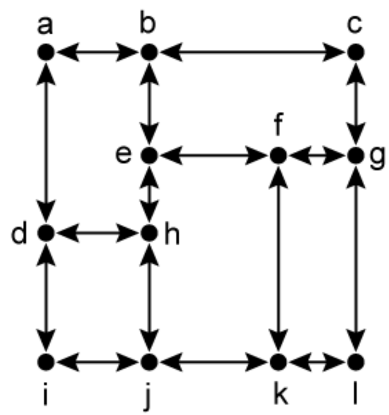


MCF-based Multi-net Routing

- **Set up ILP for MCF routing**
  - **Capacity of each edge in *G* is 2**
  - **Each edge in *G* becomes a pair of bi-directional arcs in *F***
  - $n_1 = \{a,l\}$, $n_2 = \{i,c\}$, $n_3 = \{d,f\}$, $n_4 = \{k,d\}$, $n_5 = \{g,h\}$, $n_6 = \{b,k\}$



routing graph G



flow network F

arc	cost	arc	cost	arc	cost	arc	cost
(a, b)	4	(b, a)	4	(b, c)	8	(c, b)	8
(d, h)	4	(h, d)	4	(e, f)	5	(f, e)	5
(f, g)	3	(g, f)	3	(i, j)	4	(j, i)	4
(j, k)	5	(k, j)	5	(k, l)	3	(l, k)	3
(a, d)	7	(d, a)	7	(d, i)	5	(i, d)	5
(b, e)	4	(e, b)	4	(e, h)	3	(h, e)	3
(h, j)	5	(j, h)	5	(f, k)	8	(k, f)	8
(c, g)	4	(g, c)	4	(g, l)	8	(l, g)	8

ILP Formulation

$$4(x^1_{a,b} + \cdots + x^6_{a,b}) + 4(x^1_{b,a} + \cdots + x^6_{b,a}) + 8(x^1_{b,c} + \cdots + x^6_{b,c}) +$$
$$8(x^1_{c,b} + \cdots + x^6_{c,b}) + 4(x^1_{d,h} + \cdots + x^6_{d,h}) + 4(x^1_{h,d} + \cdots + x^6_{h,d}) +$$
$$5(x^1_{e,f} + \cdots + x^6_{e,f}) + 5(x^1_{f,e} + \cdots + x^6_{f,e}) + 3(x^1_{f,g} + \cdots + x^6_{f,g}) +$$
$$3(x^1_{g,f} + \cdots + x^6_{g,f}) + 4(x^1_{i,j} + \cdots + x^6_{i,j}) + 4(x^1_{j,i} + \cdots + x^6_{j,i}) +$$
$$5(x^1_{j,k} + \cdots + x^6_{j,k}) + 5(x^1_{k,j} + \cdots + x^6_{k,j}) + 3(x^1_{k,l} + \cdots + x^6_{k,l}) +$$
$$3(x^1_{l,k} + \cdots + x^6_{l,k}) + 7(x^1_{a,d} + \cdots + x^6_{a,d}) + 7(x^1_{d,a} + \cdots + x^6_{d,a}) +$$
$$5(x^1_{d,i} + \cdots + x^6_{d,i}) + 5(x^1_{i,d} + \cdots + x^6_{i,d}) + 4(x^1_{b,e} + \cdots + x^6_{b,e}) +$$
$$4(x^1_{e,b} + \cdots + x^6_{e,b}) + 3(x^1_{e,h} + \cdots + x^6_{e,h}) + 3(x^1_{h,e} + \cdots + x^6_{h,e}) +$$
$$5(x^1_{h,j} + \cdots + x^6_{h,j}) + 5(x^1_{j,h} + \cdots + x^6_{j,h}) + 8(x^1_{f,k} + \cdots + x^6_{f,k}) +$$
$$8(x^1_{k,f} + \cdots + x^6_{k,f}) + 4(x^1_{c,g} + \cdots + x^6_{c,g}) + 4(x^1_{g,c} + \cdots + x^6_{g,c}) +$$
$$8(x^1_{g,l} + \cdots + x^6_{g,l}) + 8(x^1_{l,g} + \cdots + x^6_{l,g})$$

objective function

$$x^1_{a,b} + x^1_{a,d} - x^1_{b,a} - x^1_{d,a} = 1$$
$$x^2_{a,b} + x^2_{a,d} - x^2_{b,a} - x^2_{d,a} = 0$$
$$x^3_{a,b} + x^3_{a,d} - x^3_{b,a} - x^3_{d,a} = 0$$
$$x^4_{a,b} + x^4_{a,d} - x^4_{b,a} - x^4_{d,a} = 0$$
$$x^5_{a,b} + x^5_{a,d} - x^5_{b,a} - x^5_{d,a} = 0$$
$$x^6_{a,b} + x^6_{a,d} - x^6_{b,a} - x^6_{d,a} = 0$$

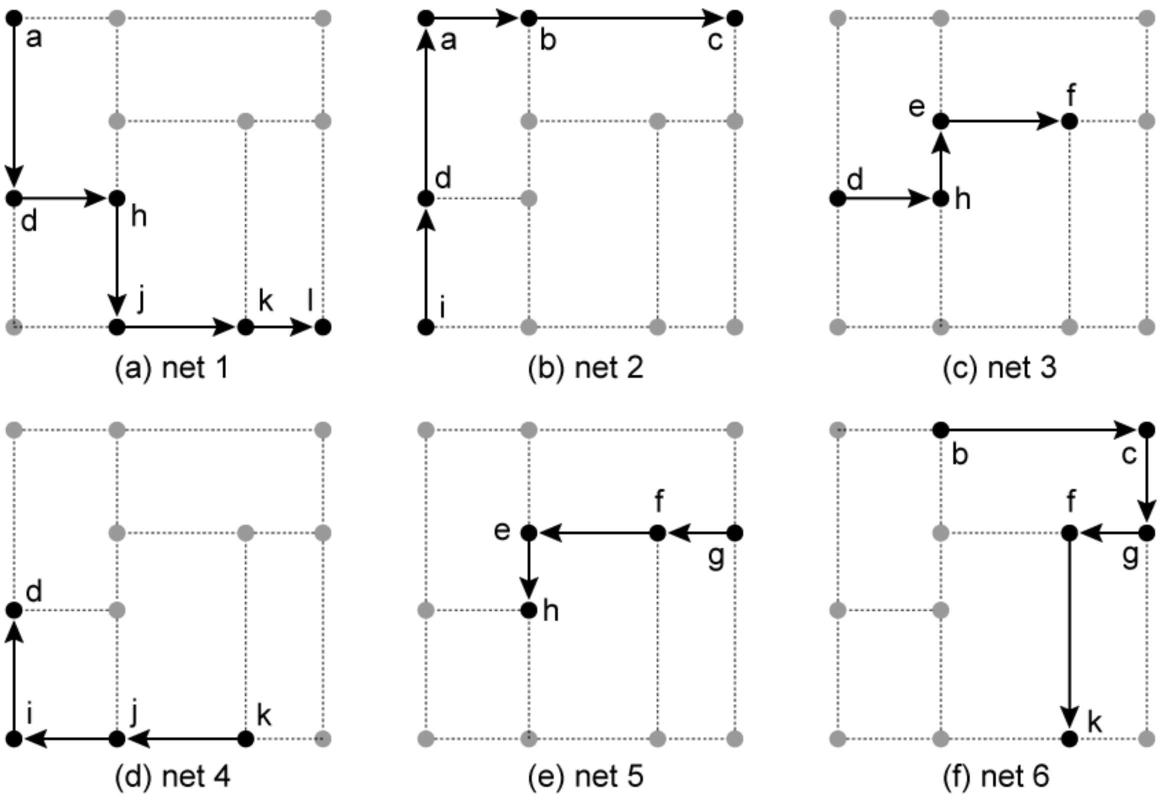
demand constraints

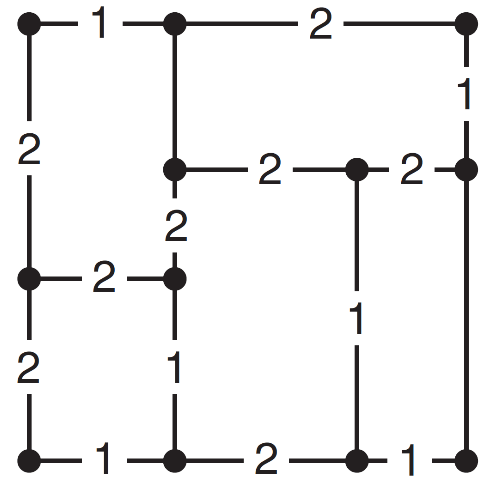
$$x^1_{a,b} + \cdots x^6_{a,b} + x^1_{b,a} + \cdots x^6_{b,a} \le 2$$
$$x^1_{b,c} + \cdots + x^6_{b,c} + x^1_{c,b} + \cdots + x^6_{c,b} \le 2$$
$$x^1_{d,h} + \cdots + x^6_{d,h} + x^1_{h,d} + \cdots + x^6_{h,d} \le 2$$
$$x^1_{e,f} + \cdots + x^6_{e,f} + x^1_{f,e} + \cdots + x^6_{f,e} \le 2$$
$$\cdots$$
$$x^1_{h,j} + \cdots + x^6_{h,j} + x^1_{j,h} + \cdots + x^6_{j,h} \le 2$$
$$x^1_{f,k} + \cdots + x^6_{f,k} + x^1_{k,f} + \cdots + x^6_{k,f} \le 2$$
$$x^1_{c,g} + \cdots + x^6_{c,g} + x^1_{g,c} + \cdots + x^6_{g,c} \le 2$$
$$x^1_{g,l} + \cdots + x^6_{g,l} + x^1_{l,g} + \cdots + x^6_{l,g} \le 2$$

capacity constraints

ILP-based Routing Solution

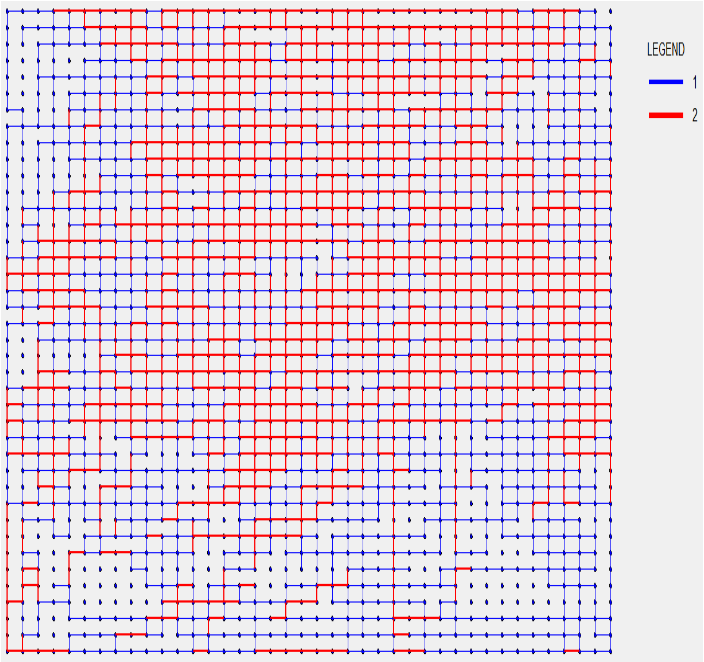
- **Using off-the-shelf ILP solver**



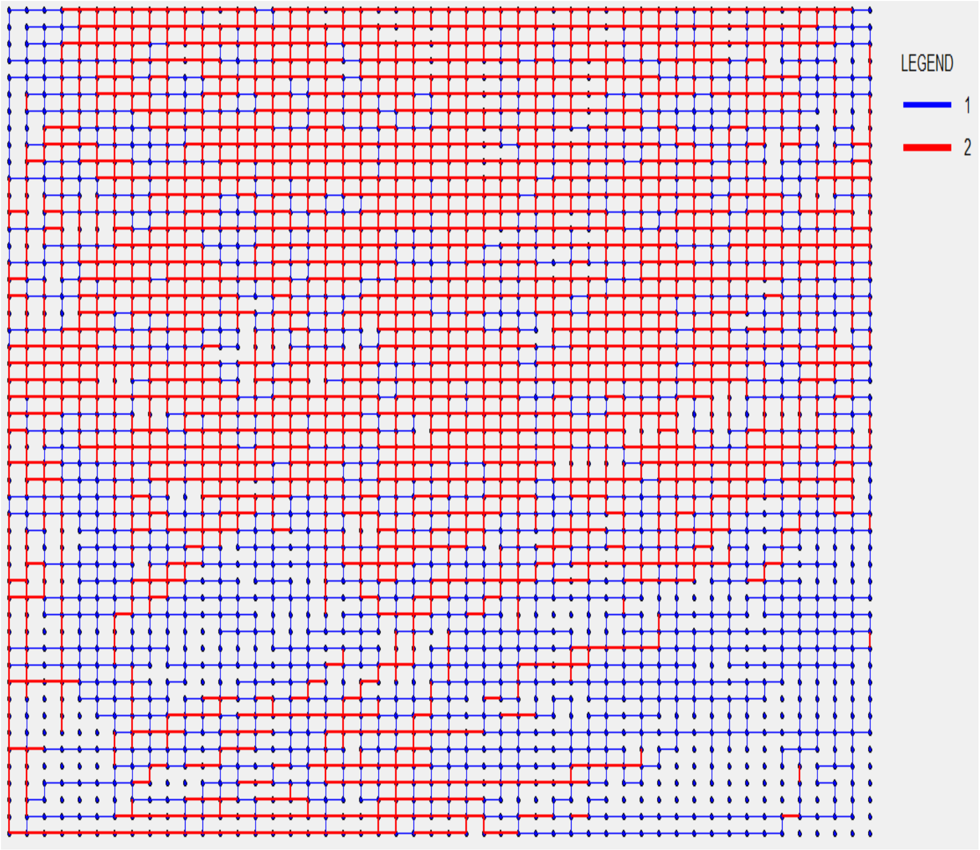


channel usage

Sample Routing Results



200 net benchmark
usage 1:1298 edges
usage 2: 1412 edges



350 net benchmark
usage 1:1849 edges
usage 2:2468 edges