

Theory and Algorithms of Physical Design

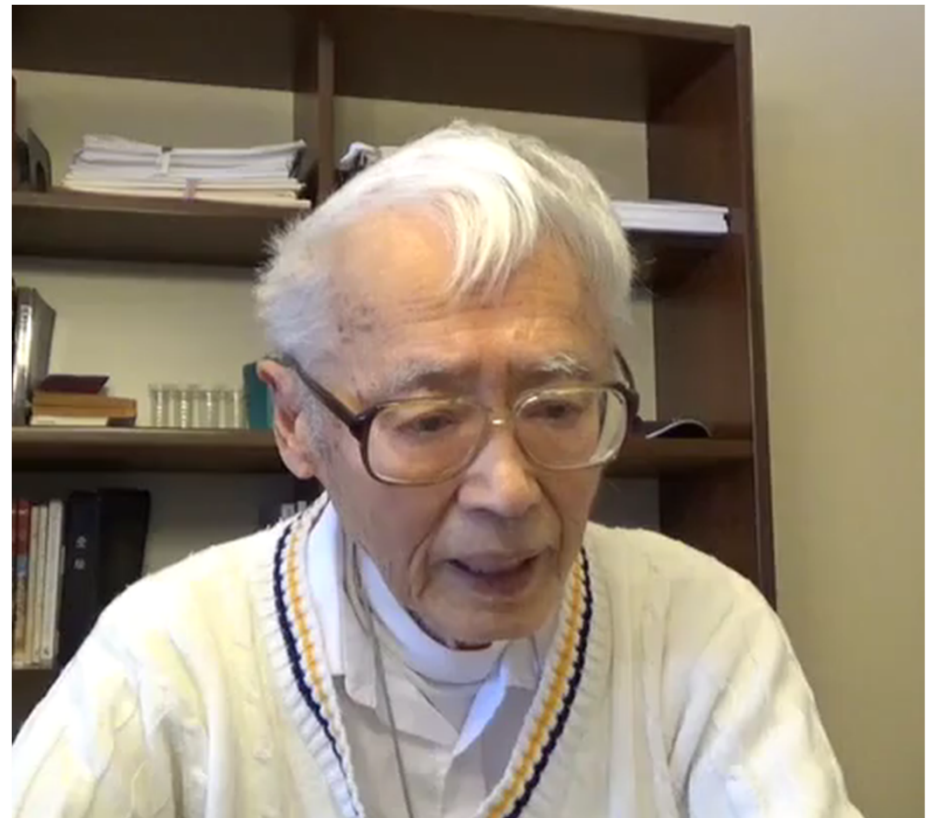
**C.K. Cheng, T.C. Hu, and A.B. Kahng
CSE department
UC San Diego**

OUTLINES

- Biography of T.C. Hu
- Physical Design
- Column Generating Techniques
- Motto
- Sequencing
- Pick's Theorem
- Bin Packing
- Logic and Reasoning
- Min Cut
- Conclusion

BIOGRAPHY OF T.C. HU

- 1954-1956 Programmer, University of Illinois
- 1964-1965 Visiting Associate Professor, Electrical Engineering and Operations Research Center, University of California, Berkeley (on leave from IBM)
- 1965-1966 Adjunct Associate Professor, Columbia University (part-time)
- 1966-1968 Associate Professor, University of Wisconsin
- 1968-1974 Professor, Computer Sciences Department and Mathematics Research Center, University of Wisconsin-Madison
- 1974-1998 Professor, Department of Computer Science and Engineering, University of California, San Diego
- 1998-2007 Professor, Above-Scale, Department of Computer Science and Engineering, University of California, San Diego



T.C. HU: PHYSICAL DESIGN

- A pioneer in combinatorial algorithms, mathematical programming and operations research.
- He published the Gomory-Hu cut tree on multi-terminal flows, at IBM Research Center.
- His works cover multicommodity flows, job scheduling, decomposition for distributed computation, integer programming, tree structures, matrix chain product, knapsack problems, routing, and many other fundamental topics.
- He and his Ph.D. student M. T. Shing applied routing to VLSI layout problems, 1984.

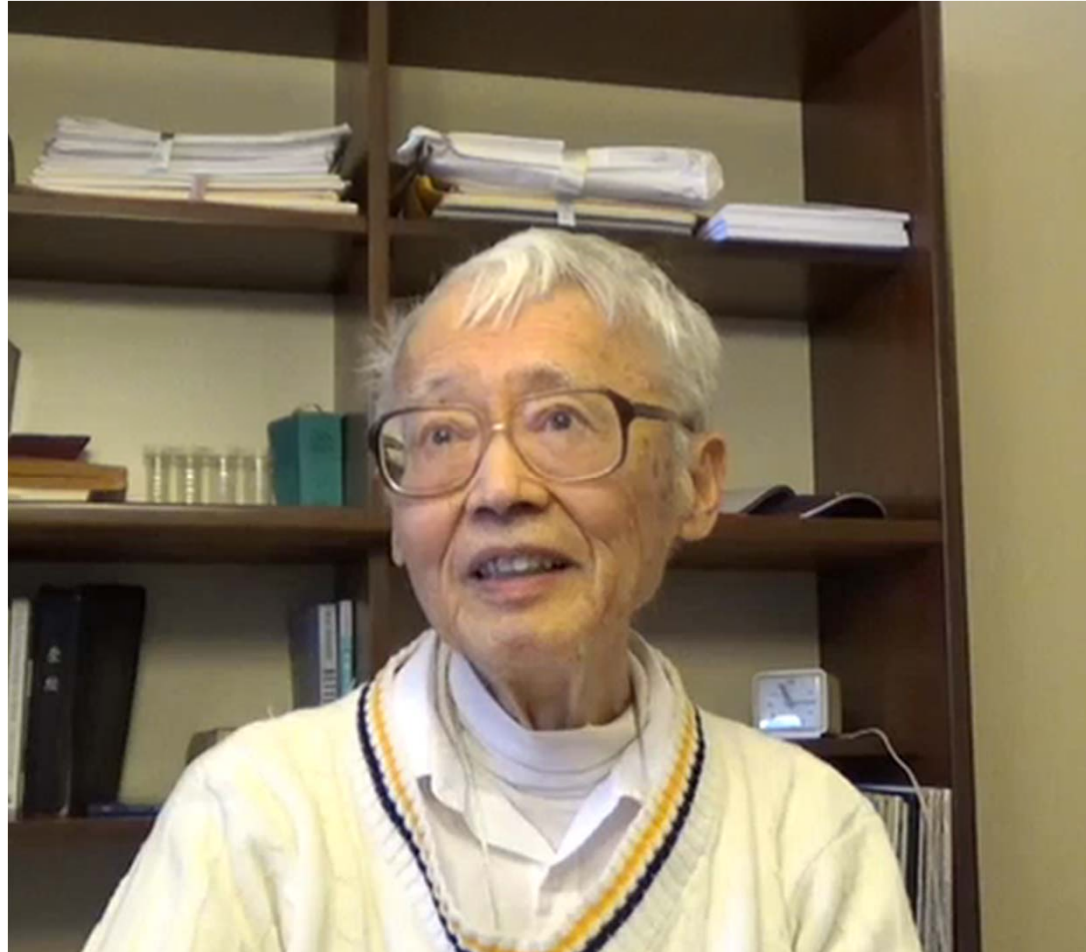
COLUMN GENERATING TECHNIQUES

In T.C. Hu and E. S. Kuh, “VLSI Circuit Layout: Theory and Design”, IEEE Press, 1985, he raised the question, “Is there an algorithm which can be proved mathematically?” Since many physical design problems are NP-complete, most of the proposed ingenious algorithms tend to be heuristic. The question was met with a positive, “yes” response using an example of column-generating techniques for global routing. The analogy of traffic congestion was used to formulate the routing problem as a multicommodity network flow problem with duality and shadow price to reflect the cost of the traffic jams on each channel (street). A column generating technique was introduced to derive the error bound of the solution.

“ALWAYS START WITH THE SIMPLEST NONTRIVIAL CASES” – T. C. HU

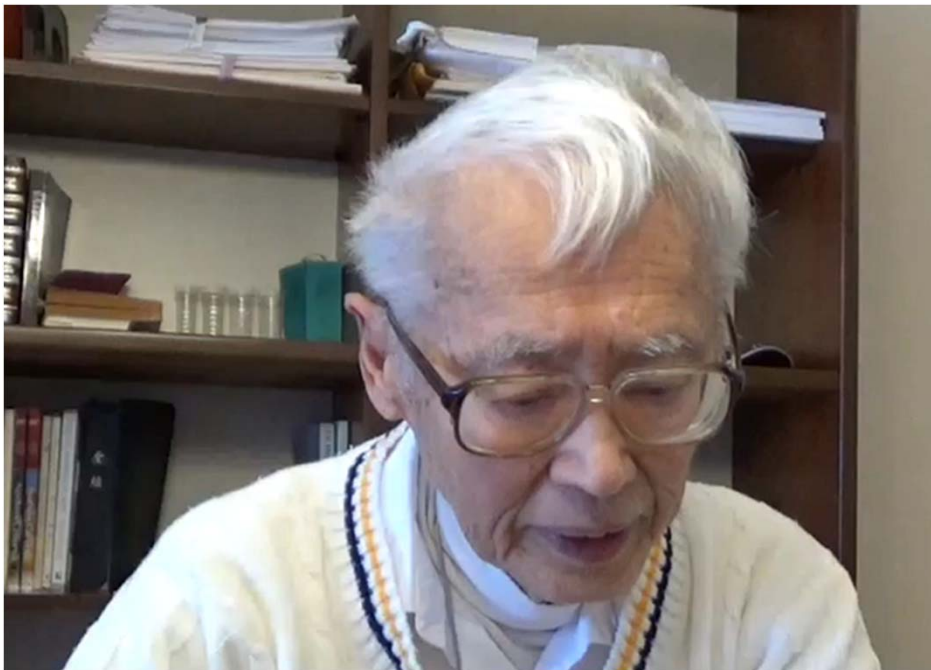
Through his career, Prof. Hu’s techniques of mathematical programming and combinatorics have enriched the theory and methods of physical design. His works contribute to the physical design in tree representation, partitioning, and routing. Moreover, he also provided insight and recipes for successful research. The shadow price highlights the importance to view problems from different angles. His motto, “**always start with the simplest nontrivial cases,**” fits well with physical design, where the problem tends to be complex and at the same time the geometry of the layout provides us with insight into the solution.

QUIZZES (INDIAN LECTURES)



NOT ALL SEQUENCES ARE CREATED EQUAL

A coin has two faces. A toss of the coin lands either Head or Tail. Two sequences, say HHHH, or HHTH. Then the subsequence appears first wins.

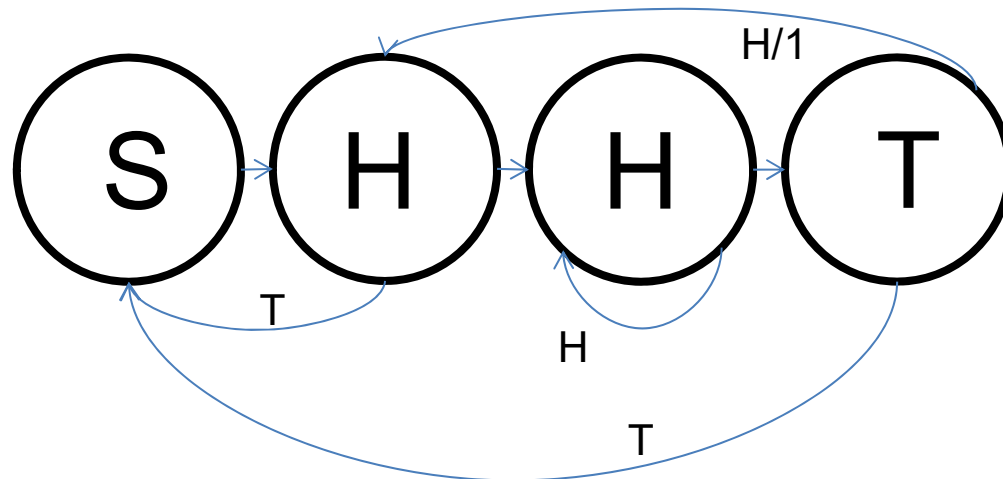
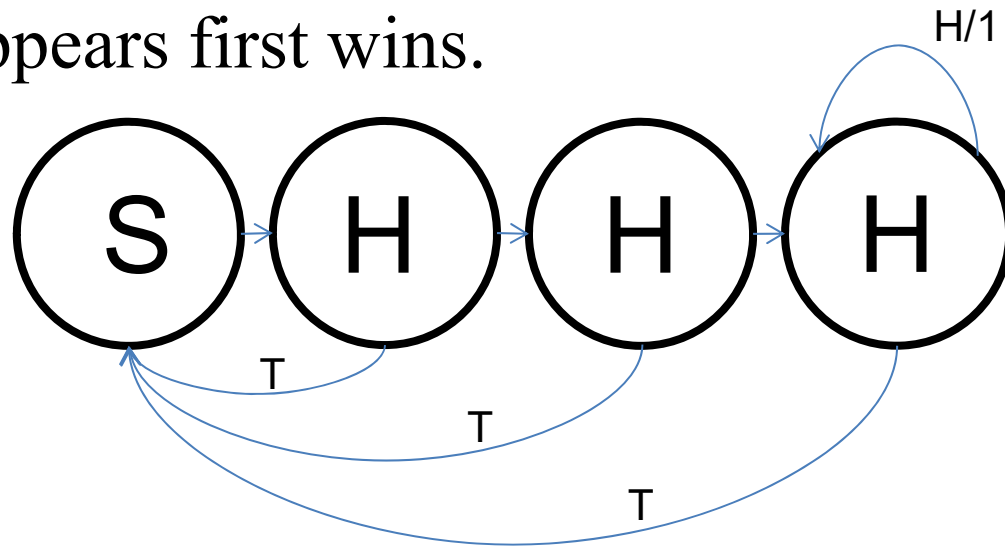


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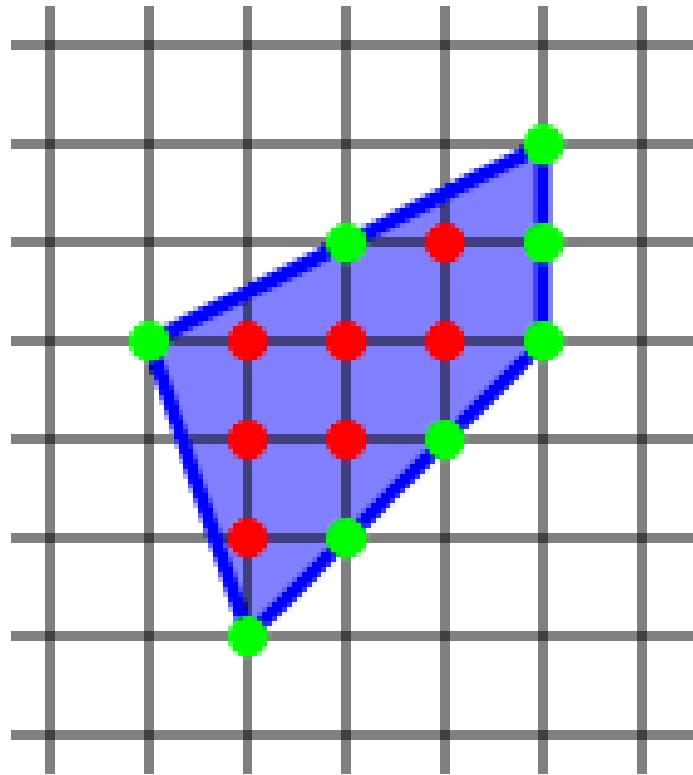
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Different diagrams
yield different
expectations

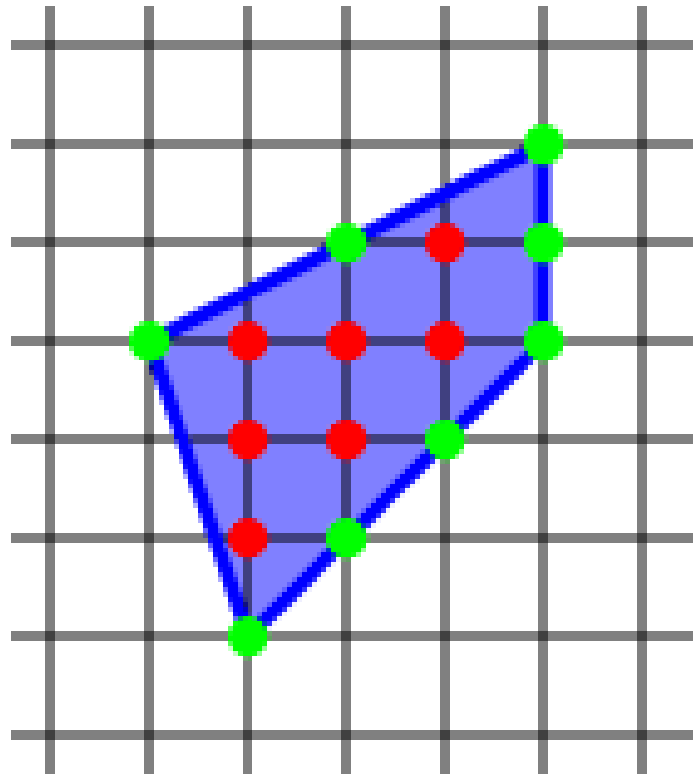
PICK'S THEOREM

What is the area of a room? Count the number of adults inside, add half of the boys on the wall, and subtract the one just left.



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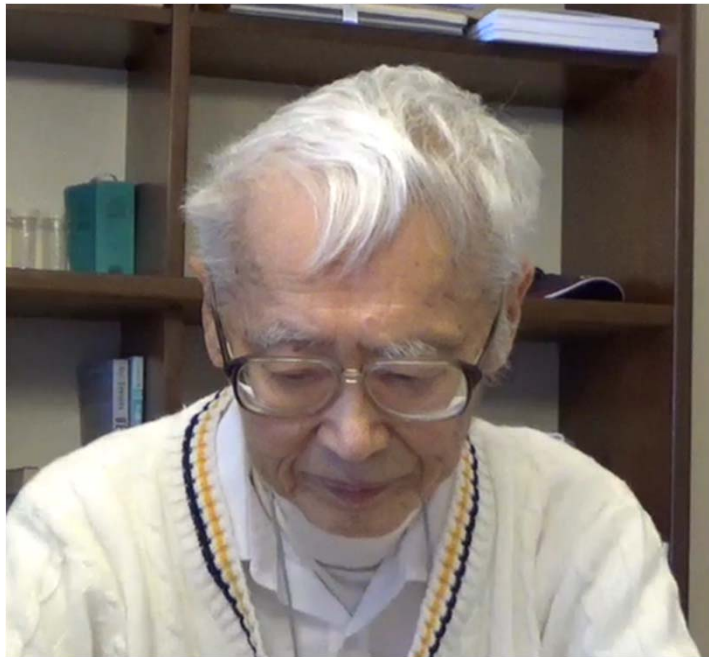
7 adults

8 boys

$$7 + 8/2 - 1 = 10$$

BIN PACKING

Mother bought back five cakes each weighing one ounce, two weighing two ounces, and one weighing four ounces. Mother said eat as much as you can, but do not pick up another piece until you have finished the one you have. Assume that two children have the same speed of eating.



BIN PACKING

Mother bought back five cakes each weighing one ounce, two weighing two ounces, and one weighing four ounces.

1, 2, 2, 4

Pick 1 first?



LOGIC AND REASONING

There is an island occupied by two tribes, the truth teller and the liar. Once, a visitor came to the island meeting two persons, A and B from each tribe, respectively. A said “**one of us is a liar.**” B said “**he is a liar.**” Based on the above conversation, can you find out who is the liar?



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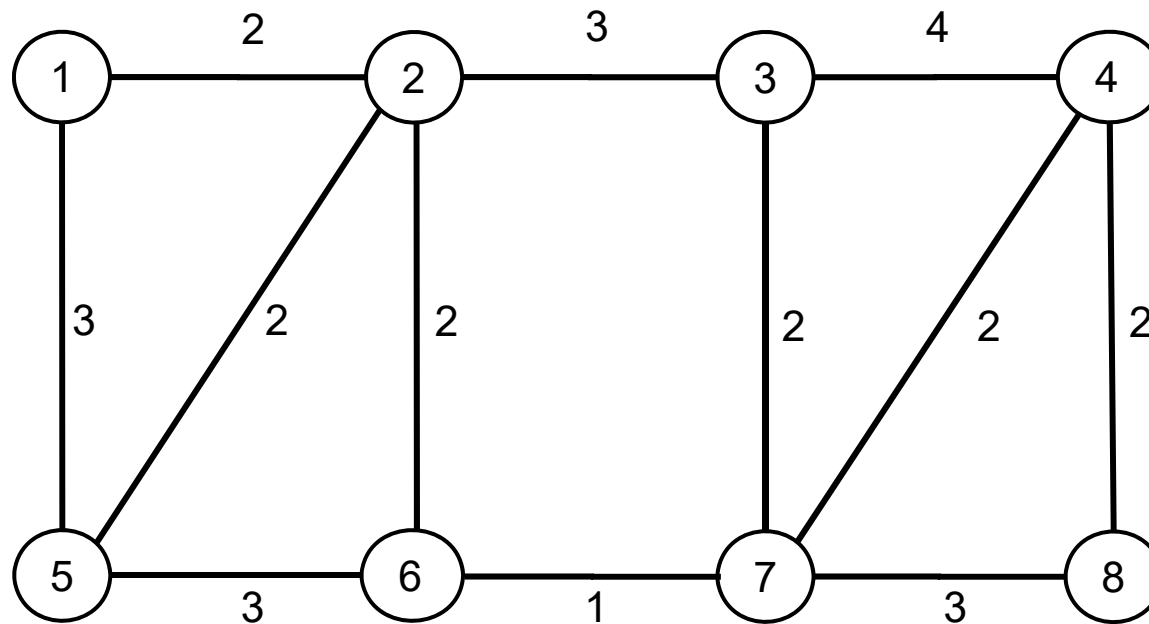
Derive by Contradiction:

If B tells the truth, then A's statement is also true, which hints A is not a liar. Thus, B is a liar.



MINIMUM CUT (MAXIMUM FLOW)

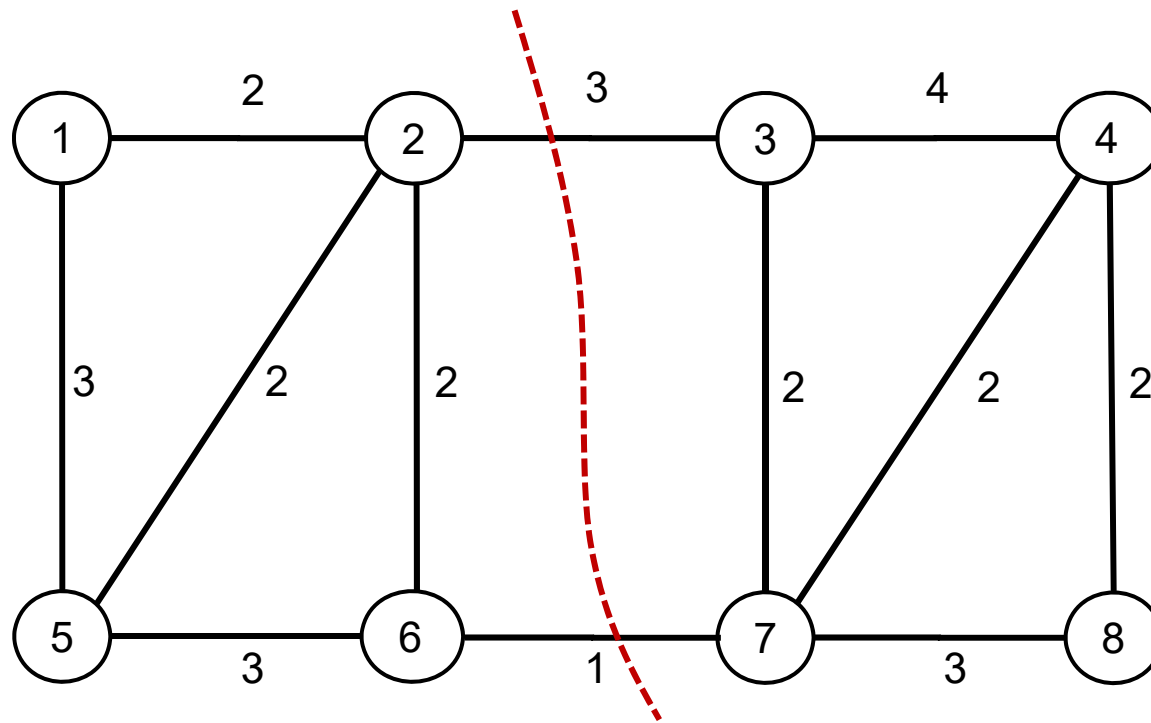
Problem: Find the minimum of the max-flow min-cuts among all pairs (without calculating the network flow!).



A simple cut algorithm by M. Stoer and F. Wagner, Journal of the ACM, pp 585-591, July 1997.

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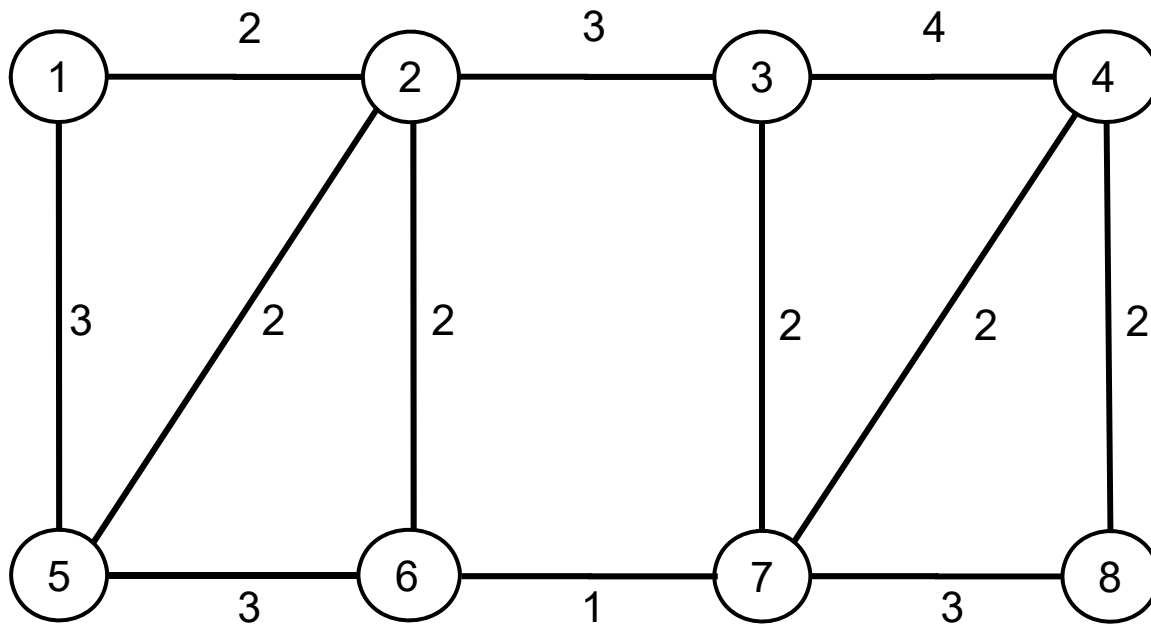
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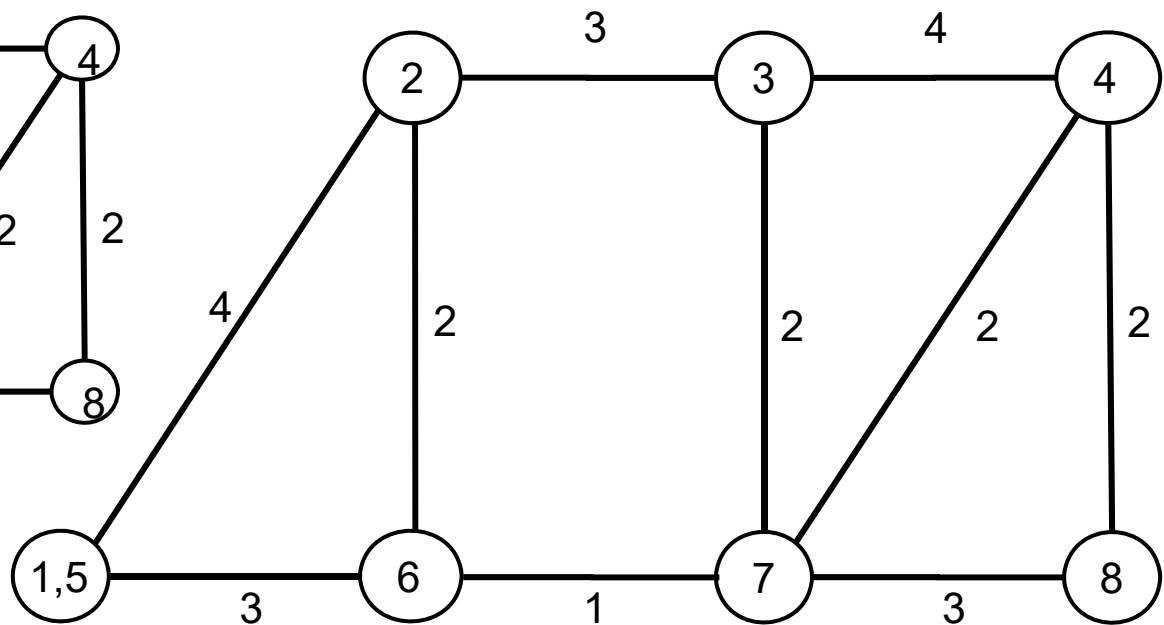
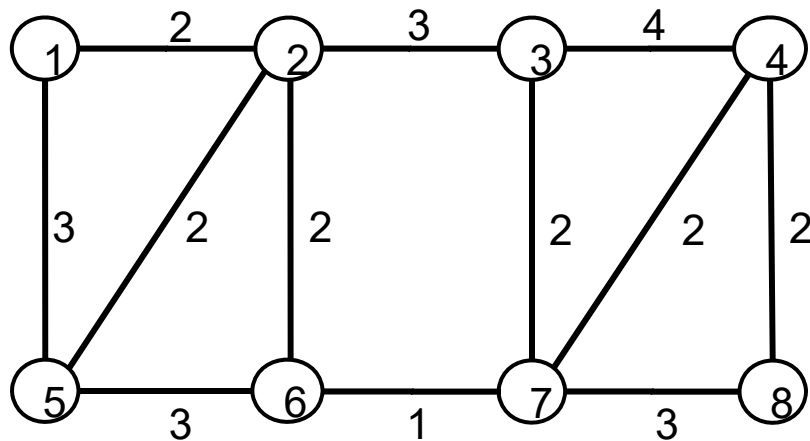


Starting from one node (2), cluster the most adjacent node. Repeat until all the nodes are clustered.

The last two nodes are either on the same side of the minimum cut or forming the cut.

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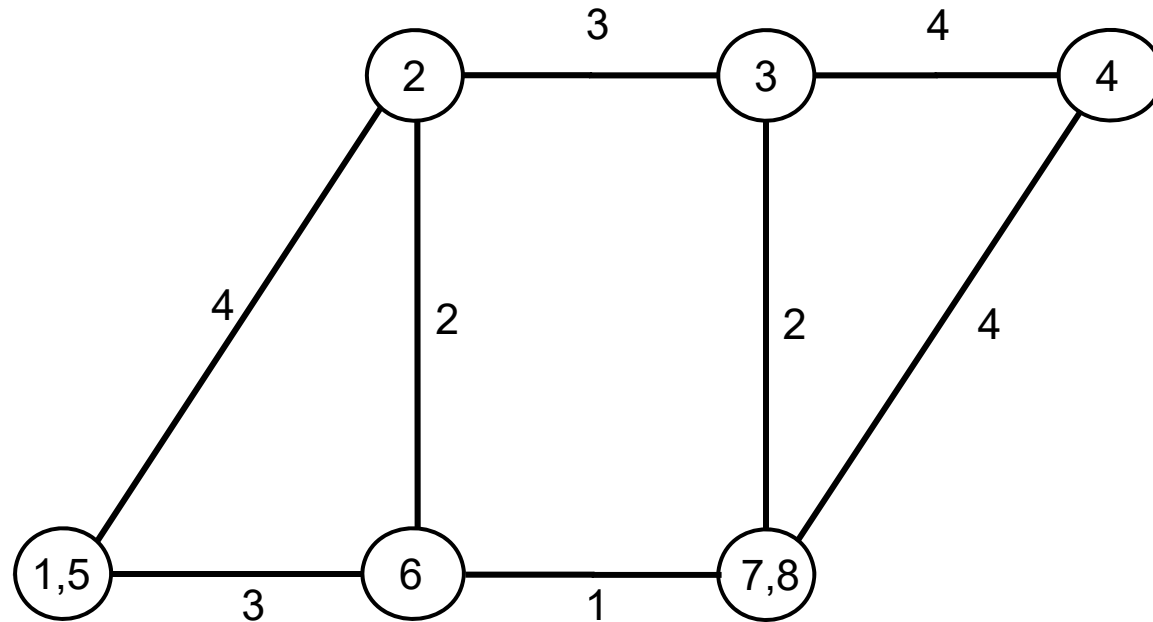
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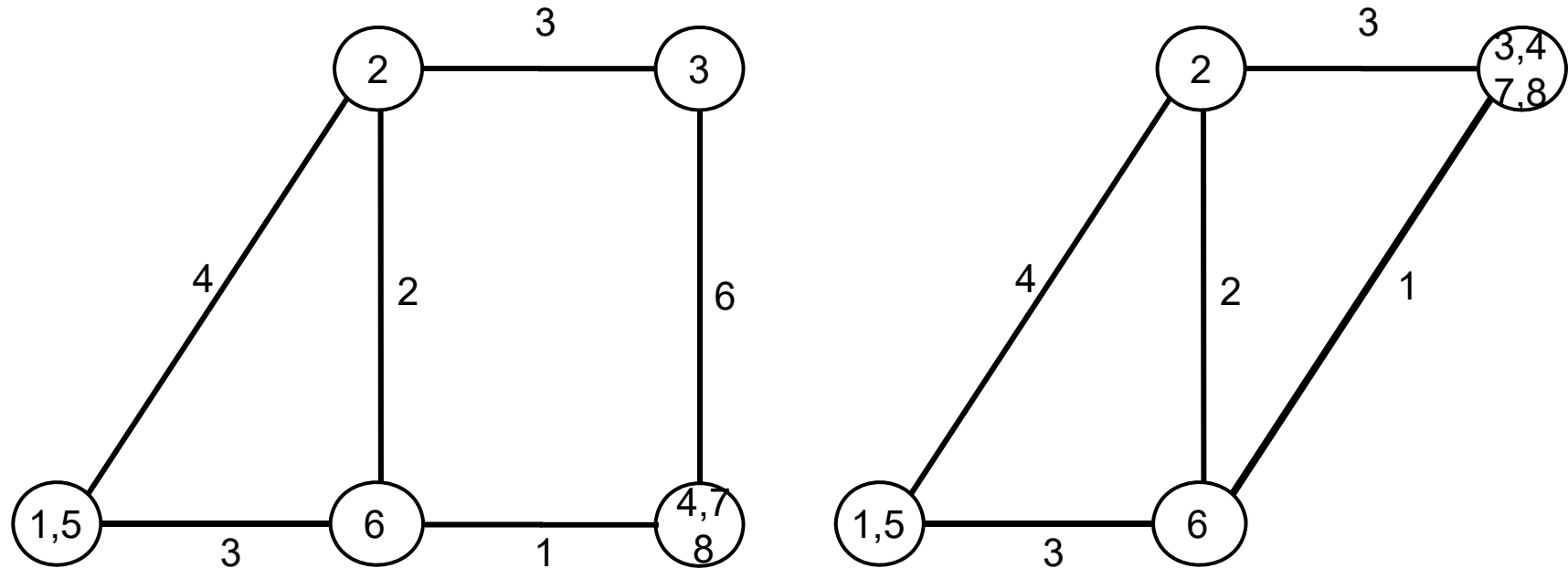
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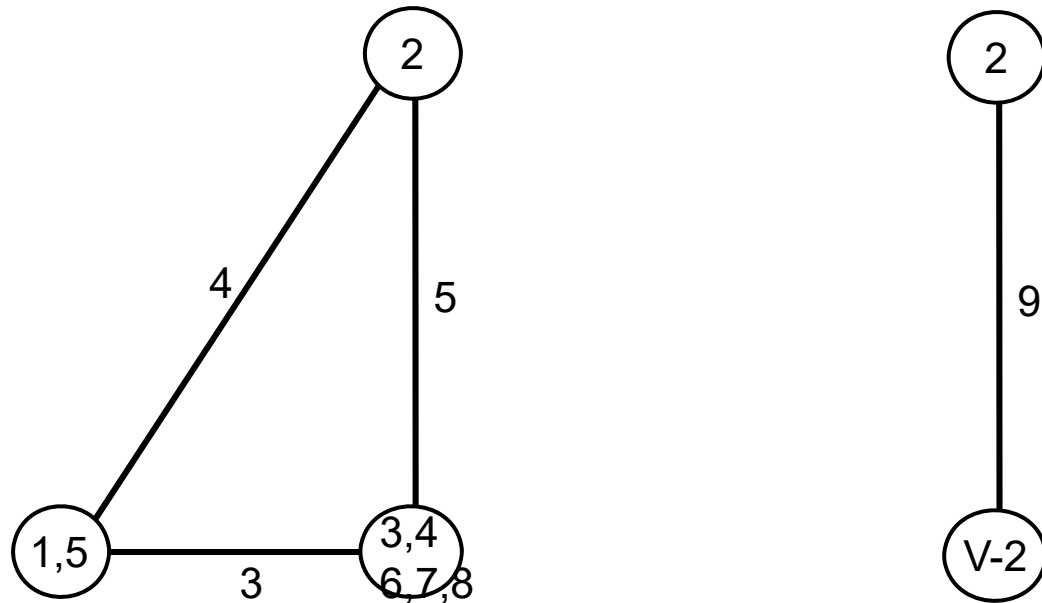
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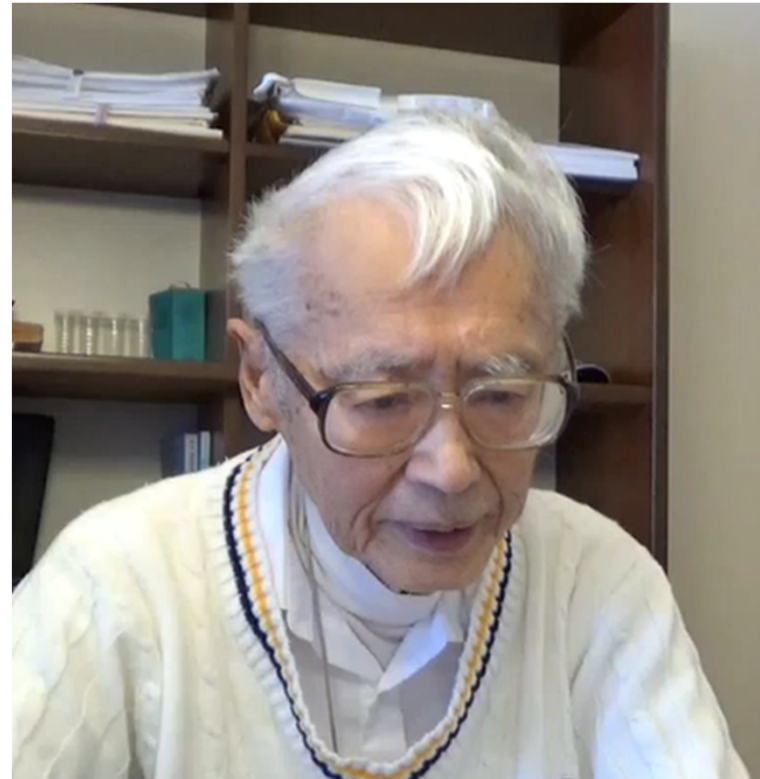
MINIMUM CUT (MAXIMUM FLOW)



Computational Complexity: $O(|V||E| + |V|\log|V|)$

CONCLUSION

- Foundation of theory and algorithms
- Don't be intimidated by NP-Completeness
- Curiosity and fun
- Collaboration
- Always start with the simplest nontrivial cases



Thank you!