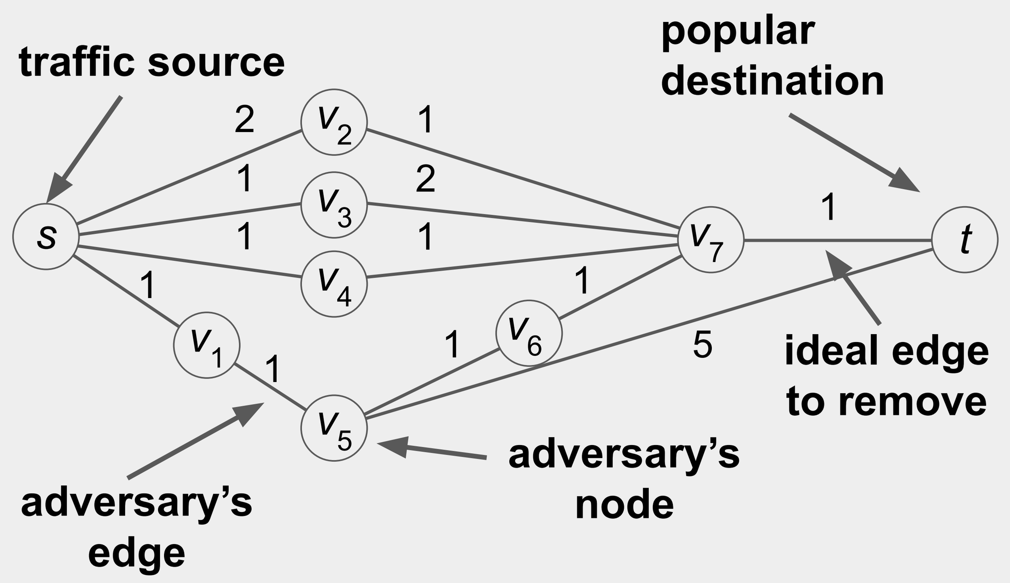
PATHATTACK: Attacking Shortest Paths in Complex Networks

Benjamin A. Miller[1], Zohair Shafi[1], Wheeler Ruml[2], Yevgeniy Vorobeychik[3], Tina Eliassi-Rad[1], and Scott Alfeld[4]

[1]Northeastern University, Boston, MA, USA
[2]University of New Hampshire, Durham, NH, USA
[3]Washington University in St. Louis, St. Louis, MO, USA
[4]Amherst College, Amherst, MA, USA

Problem Statement

Scenario: An adversary diverts traffic to specific parts of a graph by removing edges



***Force Path Cut*: Given**

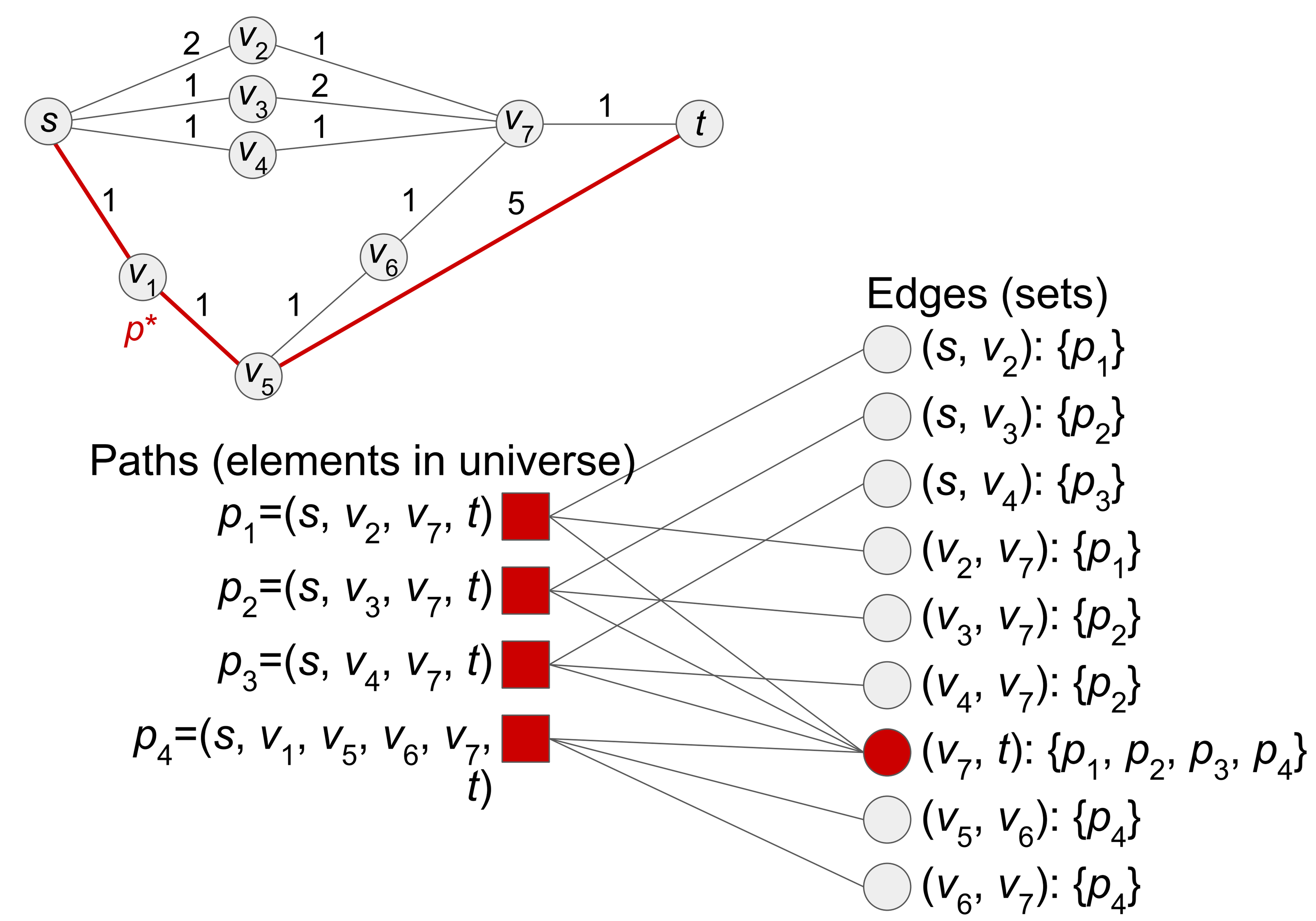
- **a graph $G=(V, E)$**
- **edge weights (distances)**
- **edge removal costs**
- **a path p^* from node s to node t**
- **a budget b**

can edges be removed with total cost less than b such that p^* is the shortest path from s to t?

***Theorem*: Force Path Cut is NP-complete**

Research Questions

- **Can Force Path Cut be approximately solved in polynomial time?**
- **What is the time/cost tradeoff between a greedy baseline and a more sophisticated algorithm?**



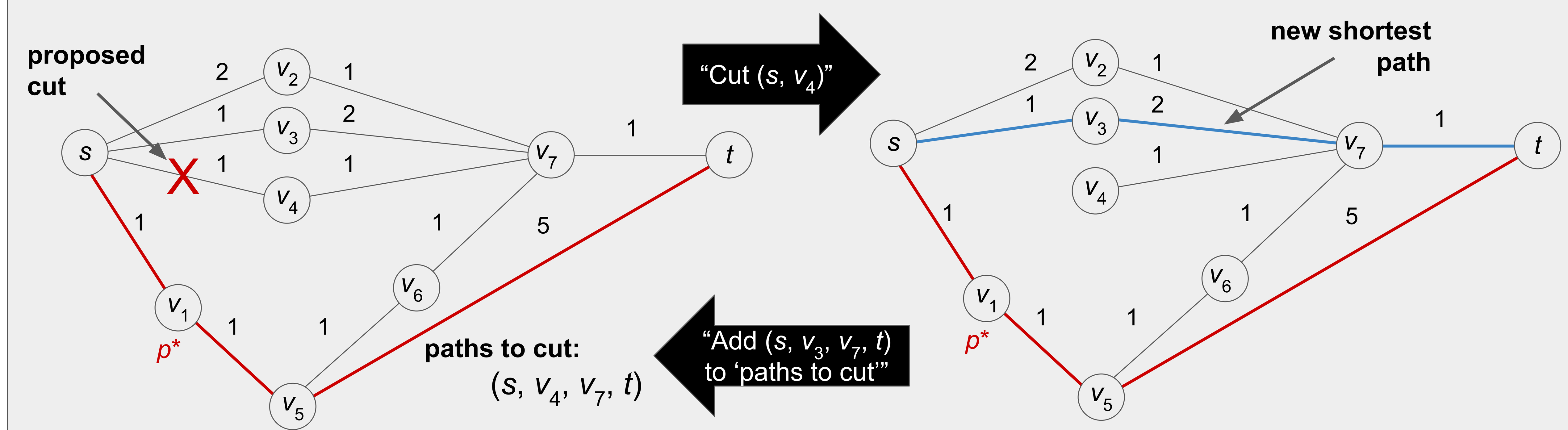
***Key Observation:* Force Path Cut is an instance of Set Cover**

- **Short paths from s to t are elements, edges are sets (including all paths using the edge)**
- **There are known approximation algorithms for Set Cover**
- **Challenge: Enumerating all such paths may be intractable**

Algorithm: PATHATTACK

https://arxiv.org/abs/2104.03761

Combine constraint generation with approximation algorithms for Set Cover

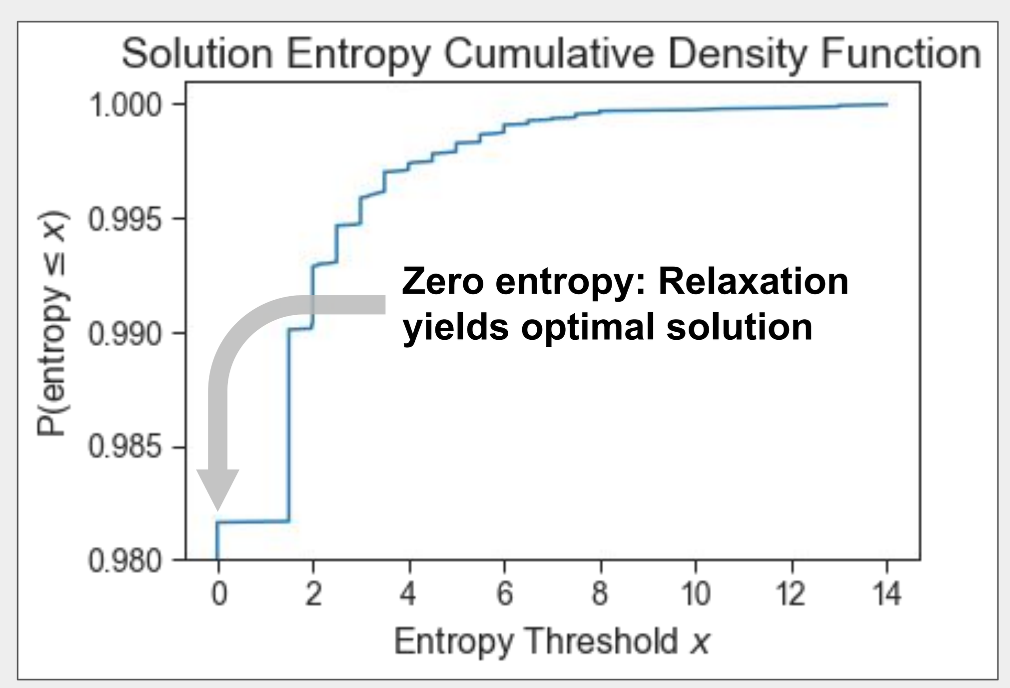


- **Consider only a subset of paths at each step**
- **Use an approximation algorithm to minimize the cost to cut all considered paths**
- **Use an oracle to determine whether to stop**
- **Oracle: find shortest path from s to t in graph with proposed cuts**
- **If the path is not longer than p^*, add it as a constraint**
- **Oracle implies existence of a polynomial time approximation algorithm**

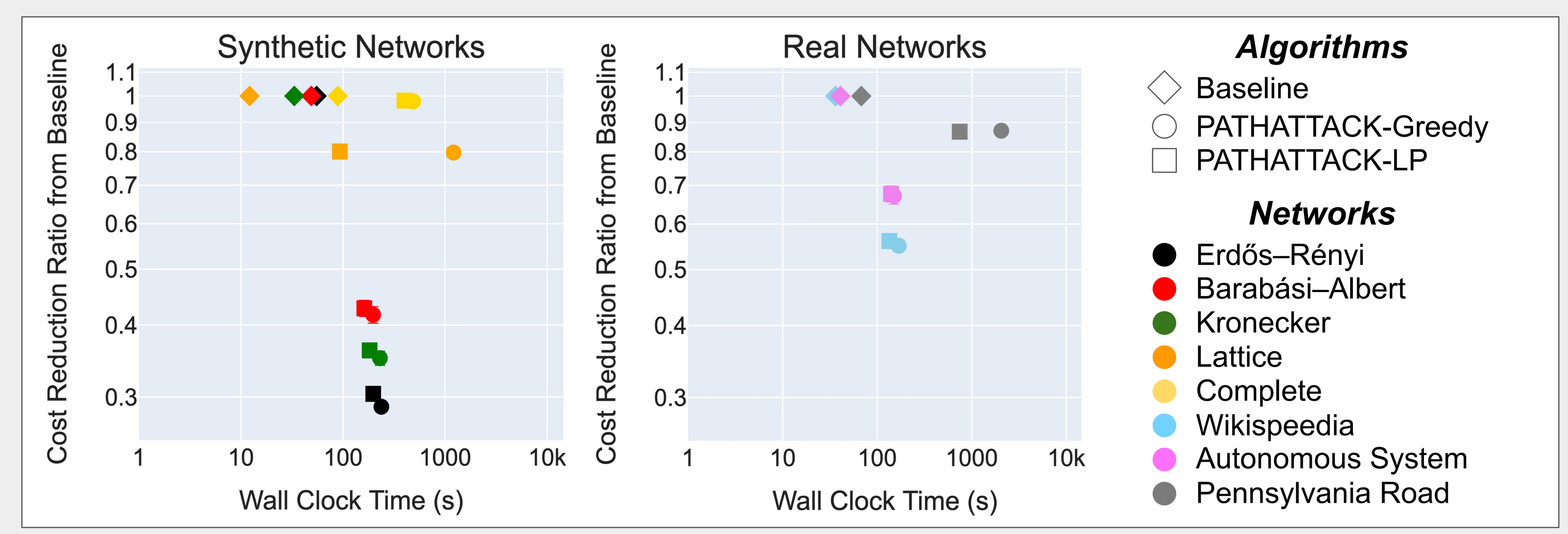
***Result:* We can achieve a worst-case ln|*E*| approximation of optimal cost**

Results

- **Five synthetic topologies and seven real graphs**
- **Either natural distances or randomly drawn weights**
- **Used 800th shortest path as p^***
- **Baseline iteratively removes first edge on shortest path not on p^***



PATHATTACK yields optimal cost in >98% of experiments



- ***Both approximation algorithms yield similar cost***
- ***Large running time difference in grid-like networks***

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