Optimizing Defense Against Shortest Path Attacks

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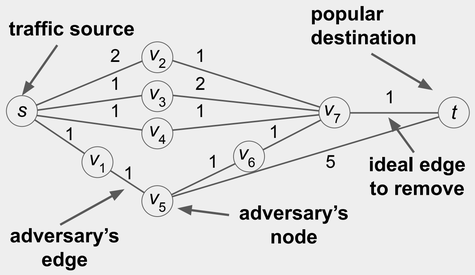
Problem Statement

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



***Goal*: Increase attacker's budget required to successfully attack**

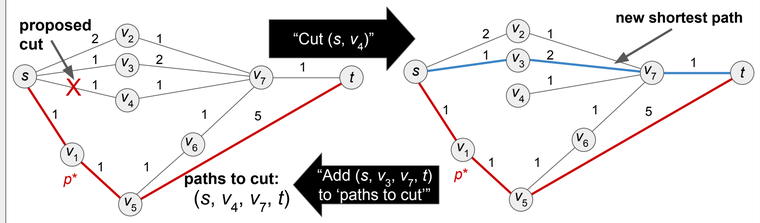
Assumed Context:

- We have a graph and know the true weights
- But we publish *approximate* weights
- Desired outcome: Adversary's required budget is increased
- Constraint: Minimize negative impact on legitimate users

Research Questions:

- What is the impact on legitimate network users when we stop an attack?
- Is it more costly to defend against an attack that targets a path that exits and returns to a community?

Attack: PATHATTACK*

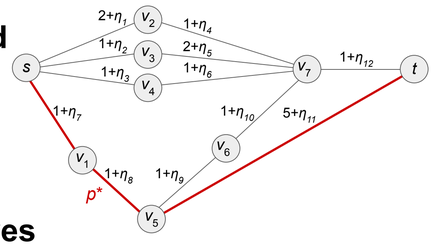


- **Algorithm to approximate optimal path cut cost**
- **Iteratively add constraints until *p** is shortest**

*B. A. Miller et al., "PATHATTACK: Attacking Shortest Paths in Complex Networks," in *ECML PKDD*, 2021

Defense: Modified Weights

- **Prior work† used noisy weights to increase adversarial uncertainty**
- **This work involves optimizing the defender's cost function with modified weights**

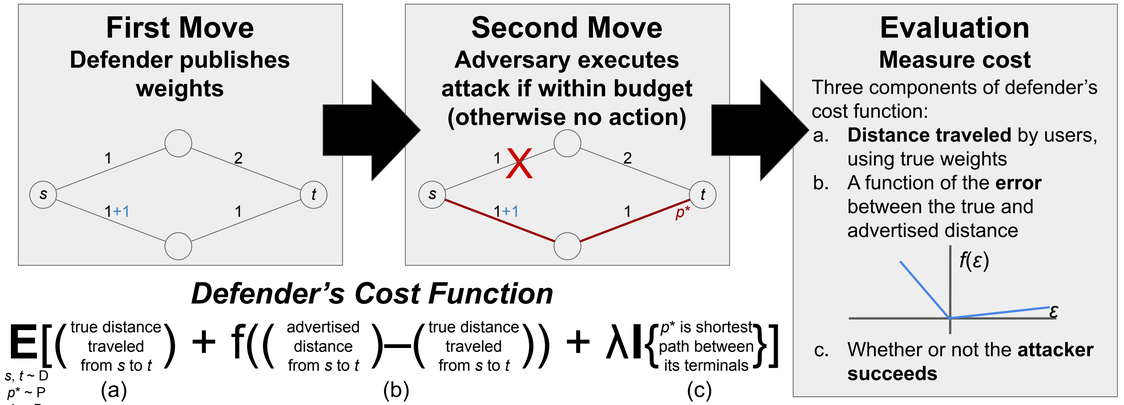


†B. A. Miller et al., "Defense Against Shortest Path Attacks," *GraphEx*, 2022

Optimization Approach

https://arxiv.org/abs/2305.19083

Stackelberg Game



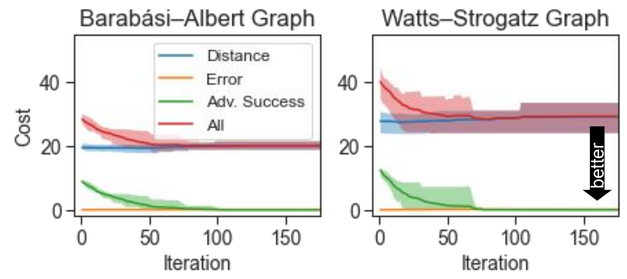
- ***Cut Defense* problem: Optimize defender's cost**
- ***Theorem*: Zero-sum Cut Defense with an attack oracle is NP-hard**

Algorithm: PATHDEFENSE

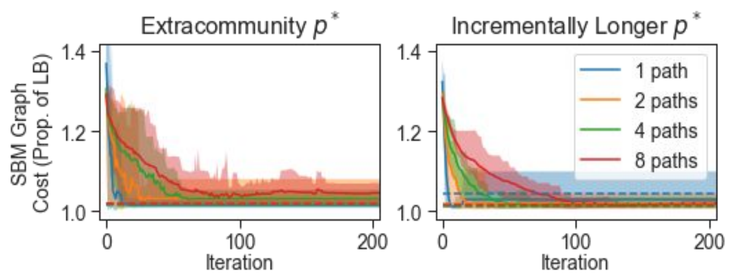
- **Heuristic algorithm to optimize defender cost**
- **Iteratively increment edges on *p** to decrease probability of attack**
- **After termination: Choose lowest-cost weights**

Results

- **Graphs with weights drawn from a Poisson distribution**
- **Edge removal costs are equal**
- **Randomly selected *s* and *t***
- **Defender uncertainty: distribution of target paths and adversary budgets**
- **Users are more likely to travel between nodes on potential target paths**



- **Attack probability becomes negligible with small increase in distance**
- **Cost due to error is extremely low**



Defense is more difficult and costly if it exits and returns to the community of *s* and *t*

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