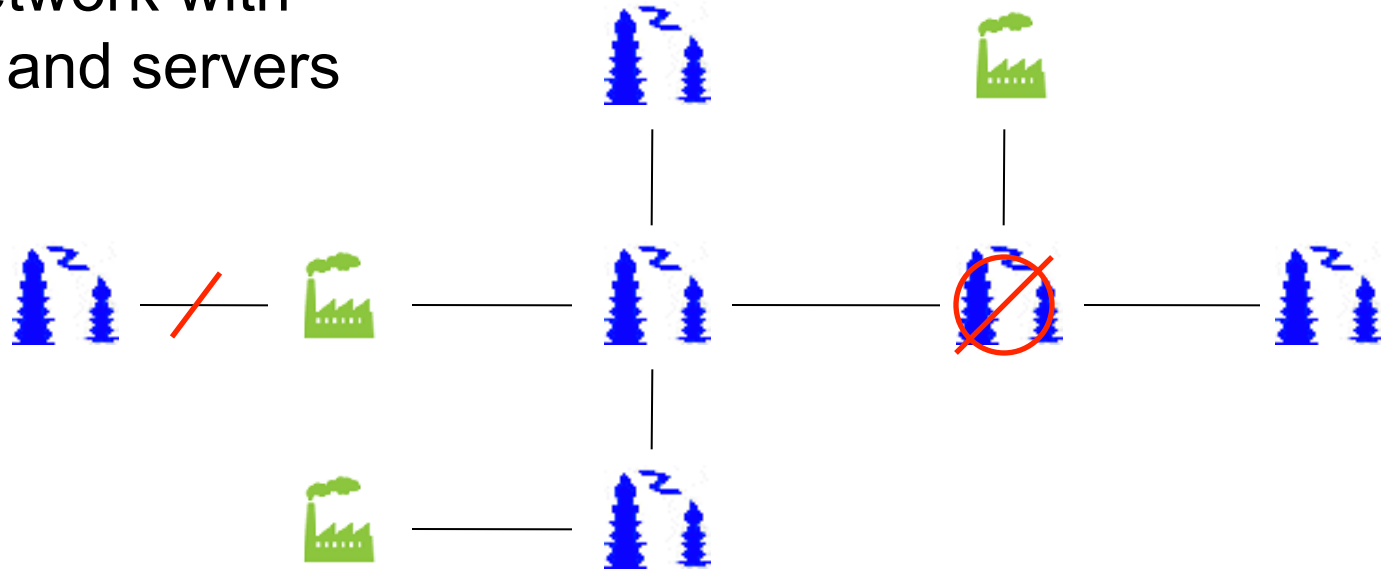


Assessing the Vulnerability of Replicated Network Services

George Dean Bissias, Brian Neil Levine, and
Ramesh K. Sitaraman

Client-Server Problem

Any network with
clients and servers



Disconnect clients
from *all* servers

Other Networks

- Wireless mesh network
- Internet AS Graph
- Airport Access

Client

Server



wireless relay



Internet access



tier 2



tier 1



waypoint



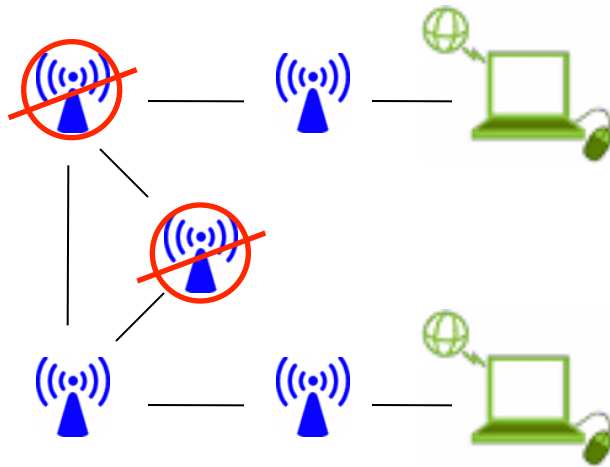
airport

Motivation

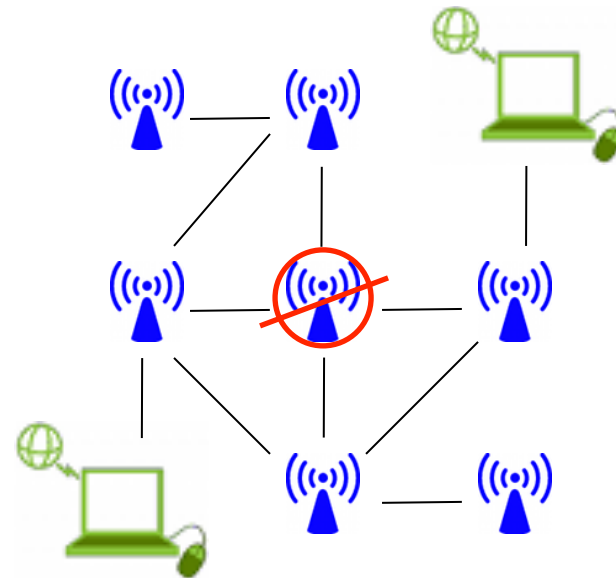
- Links difficult to secure
- Node often unguarded
- Historical precedent for attack

Prior Work

- Heuristics don't identify worst cases



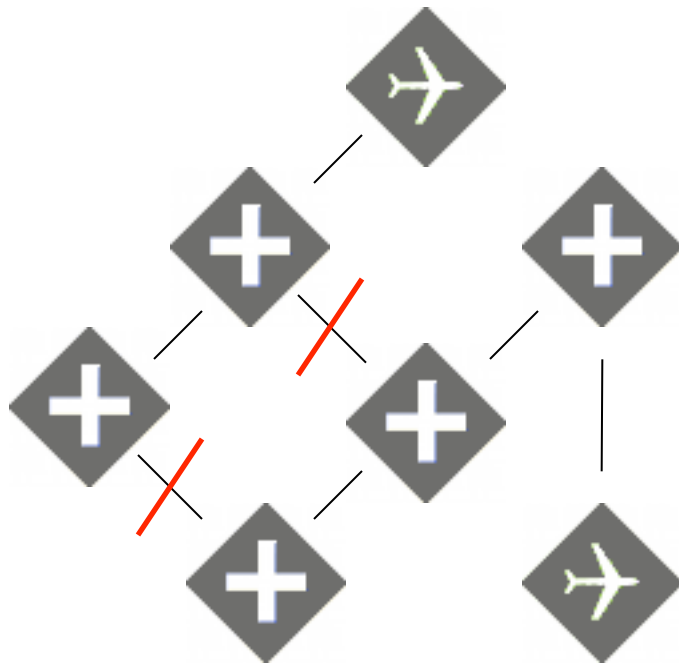
Highest Degree First



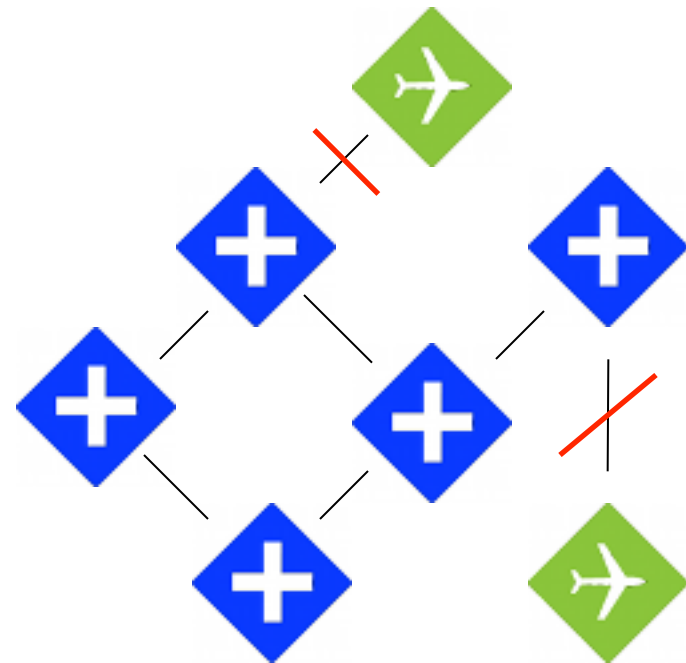
Most Central First

Prior Work

Graph separators ignore hierarchy



Separator Problem

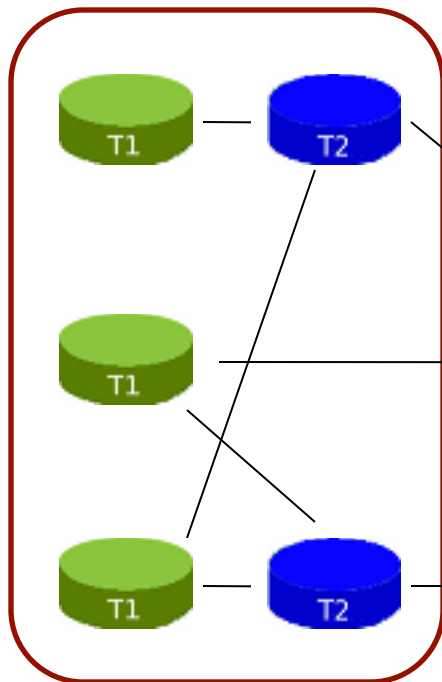


Client-Server Problem

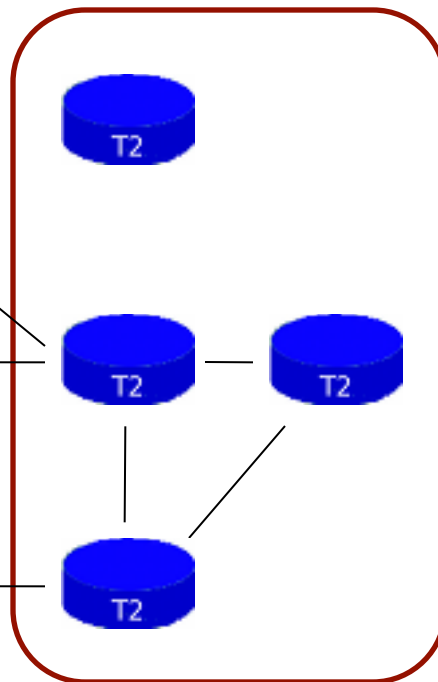
Framework

Think in terms of blocks

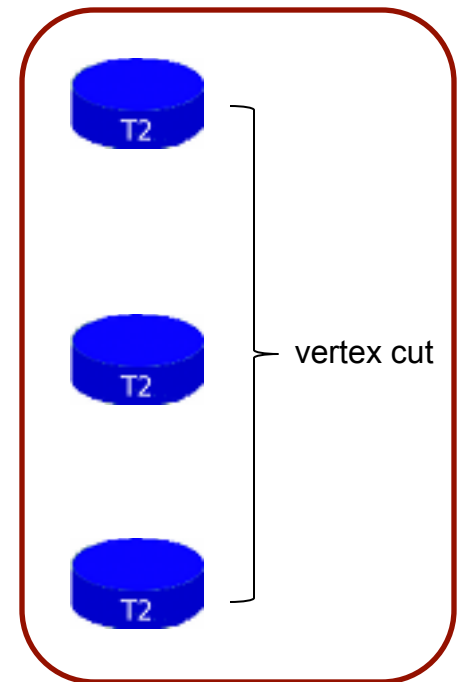
Block 1



Block 2



Block 3

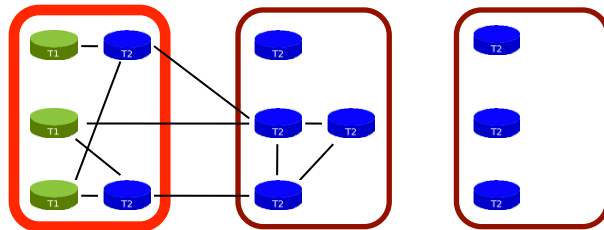


edge cut

vertex cut

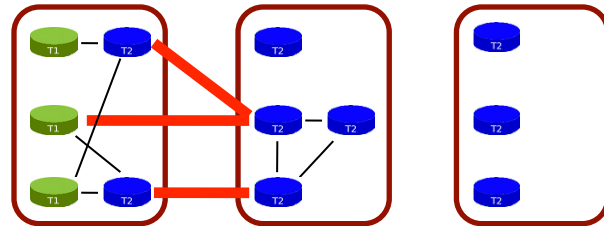
Problem Statement

Minimize:

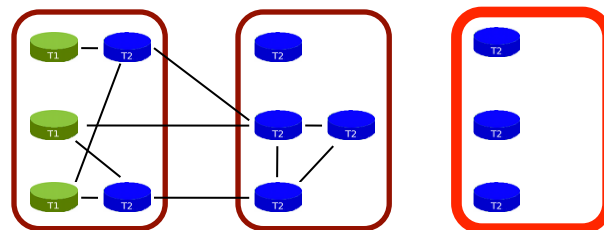


*NP-hard via
edge-separators

Subject To:



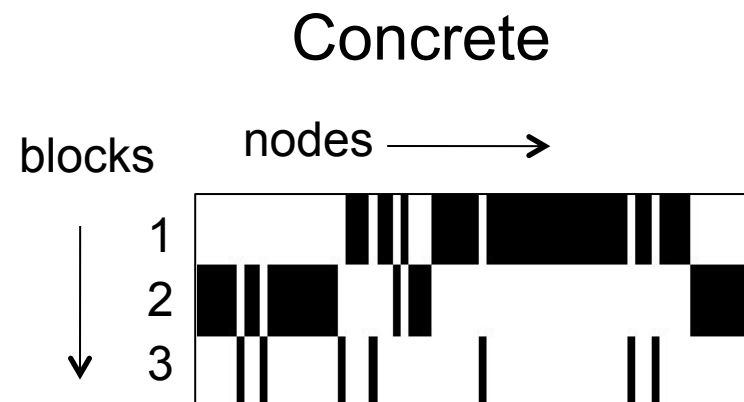
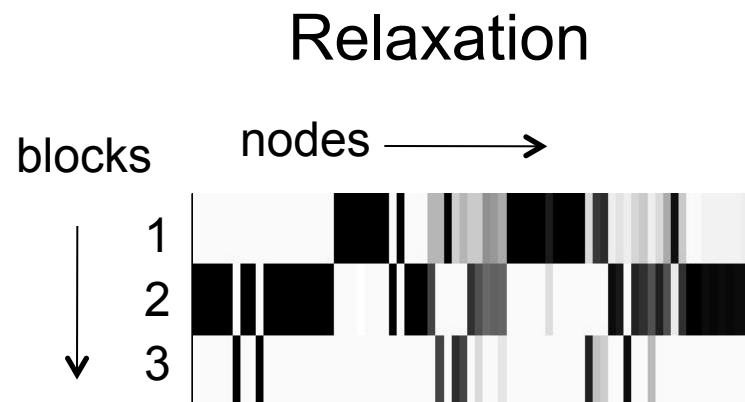
(edge cut size)



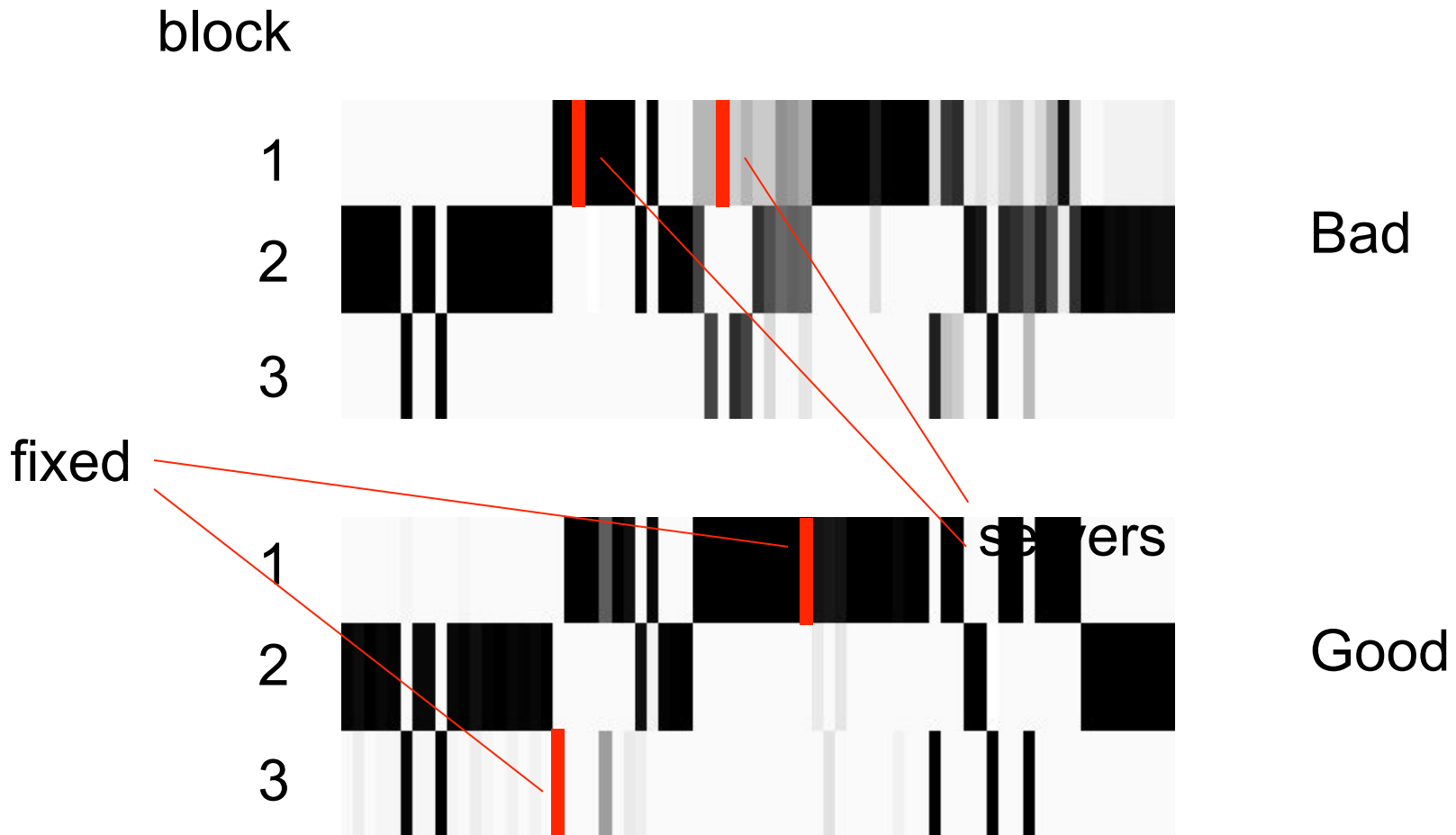
(vertex cut size)

Solution

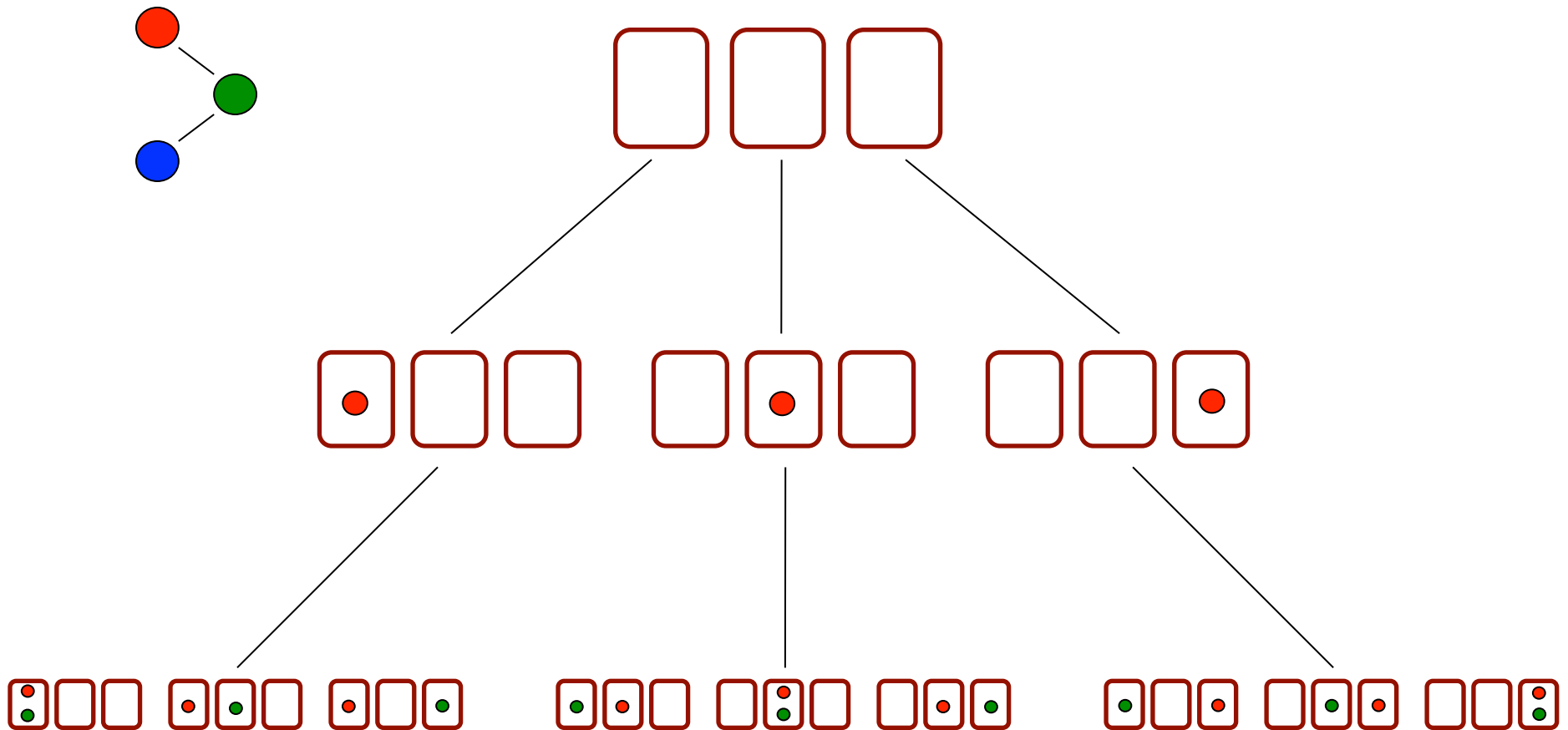
- Lower bound via SDP: Relaxation
- Upper bound via rounding: Concrete



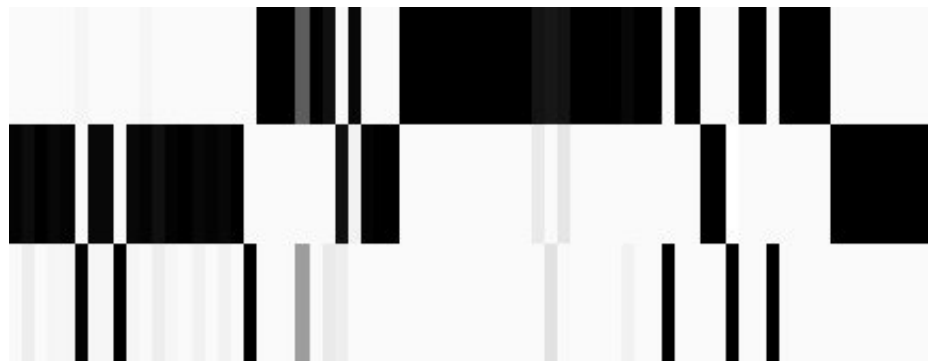
SDP Solution



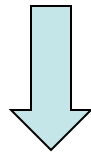
Branch-and-cut: Lower Bound



Rounding: Upper Bound



Good

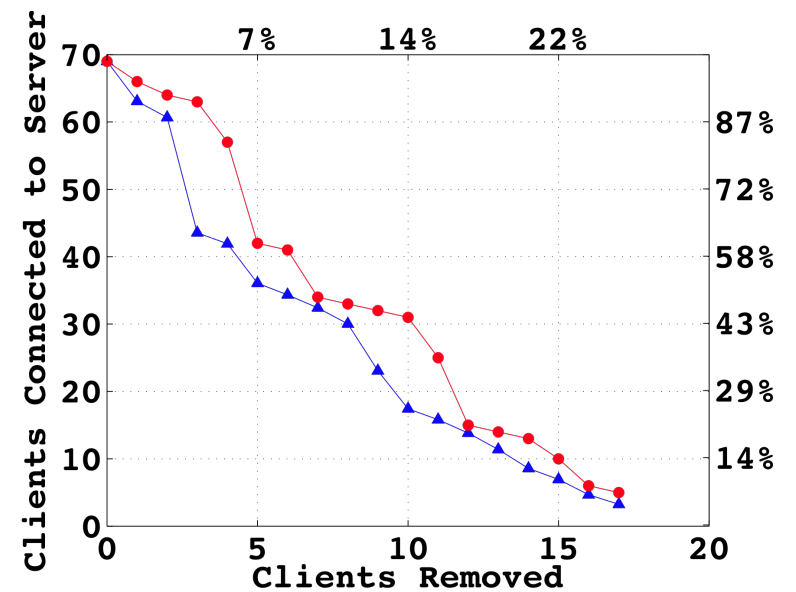
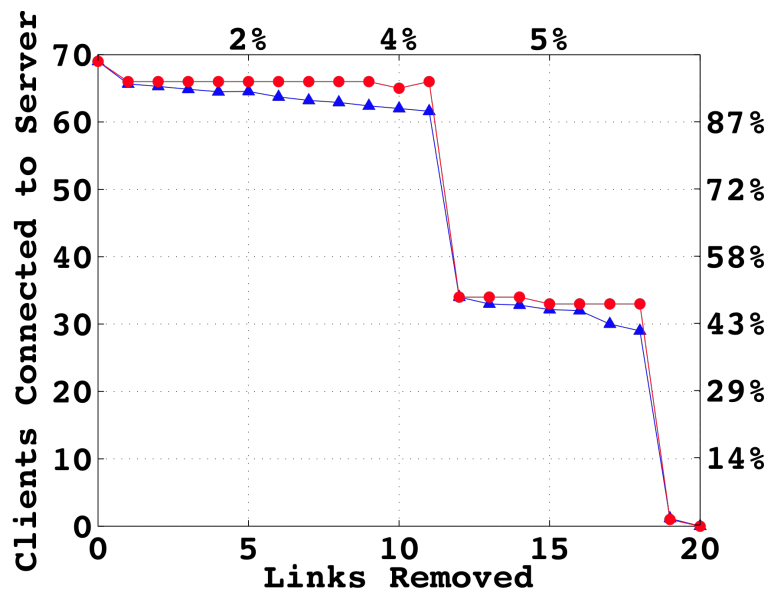
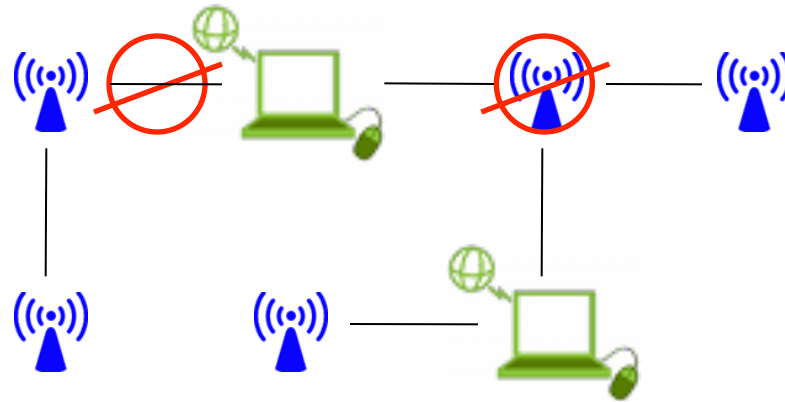


Basic rounding + Kernighan-Lin

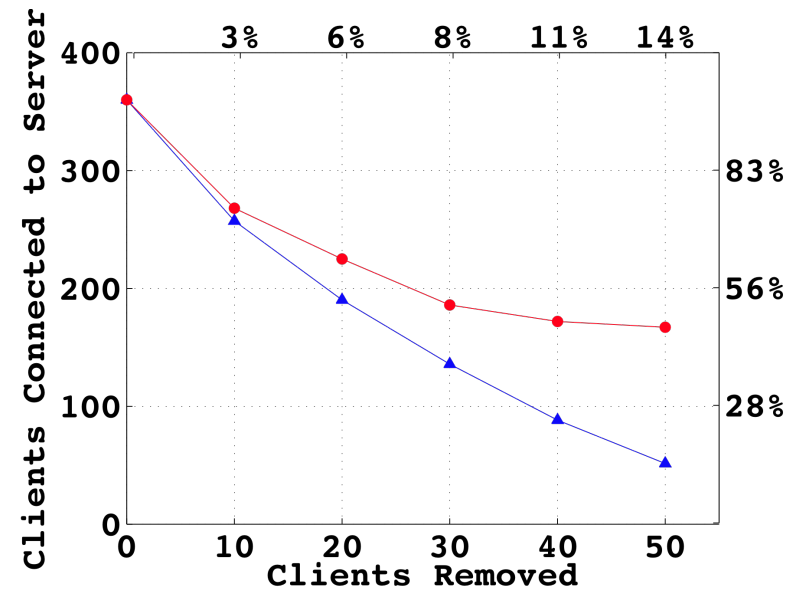
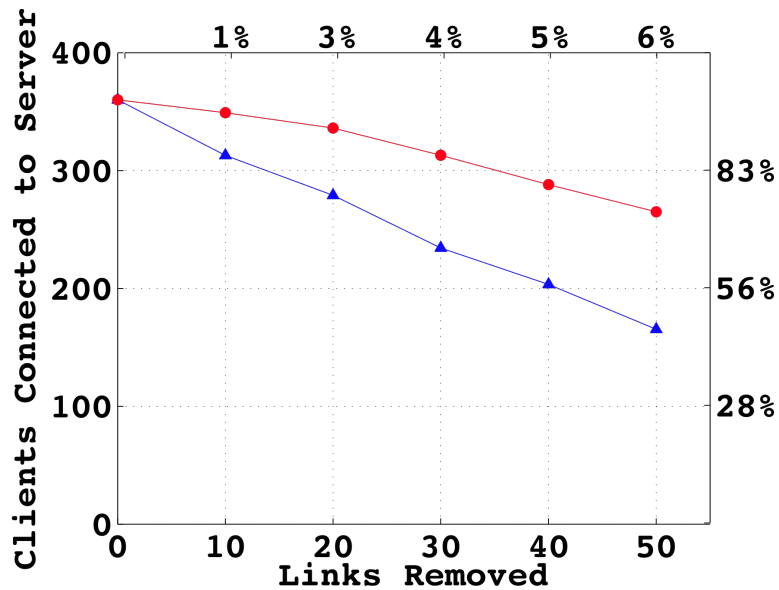
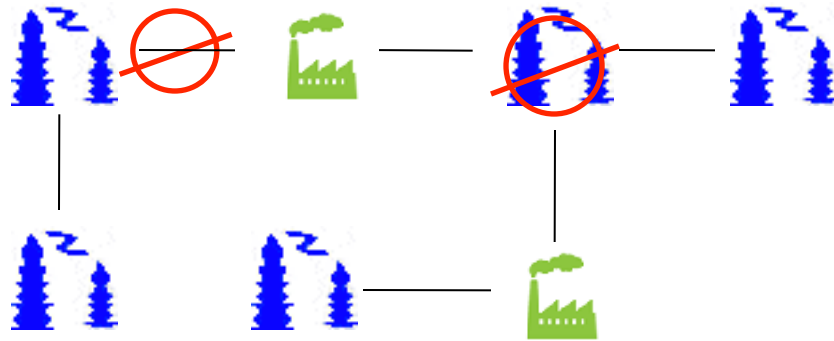


Binary

Wireless Mesh Network



Power Grid of Philippines



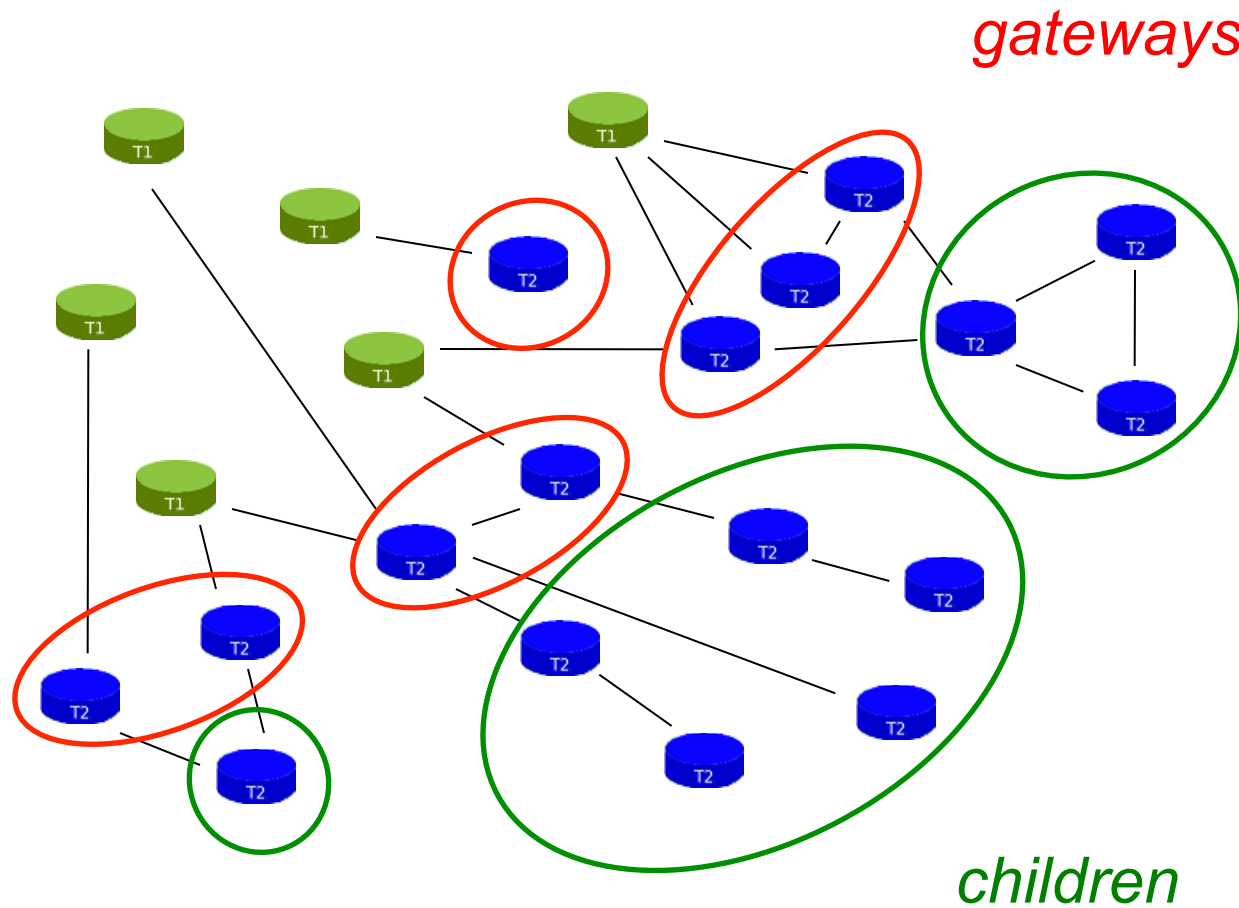
Perspective

- Strengths
 - Edge and vertex cuts
- Weaknesses
 - Weakens with large graphs
 - Computationally intense

Large Graphs

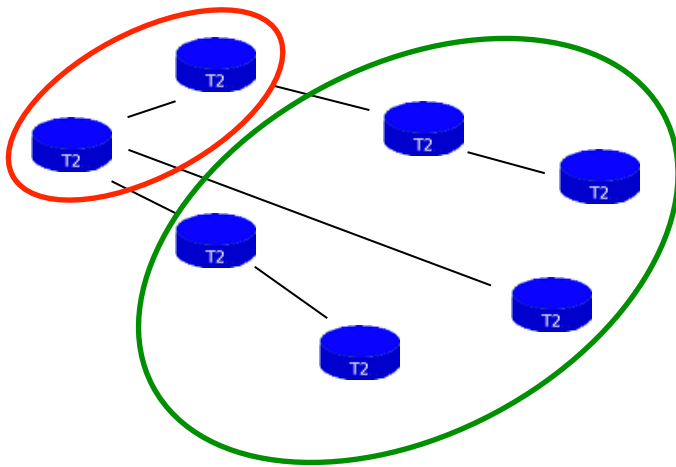
- Use divide-and-conquer approach
- Strengths
 - Appropriate for larger graphs
- Weaknesses
 - Only applies to vertex cuts
 - Performance depends on topology

Exploiting Topology

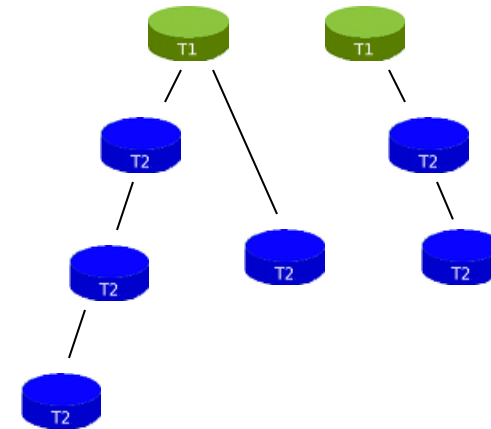


Subproblem

family



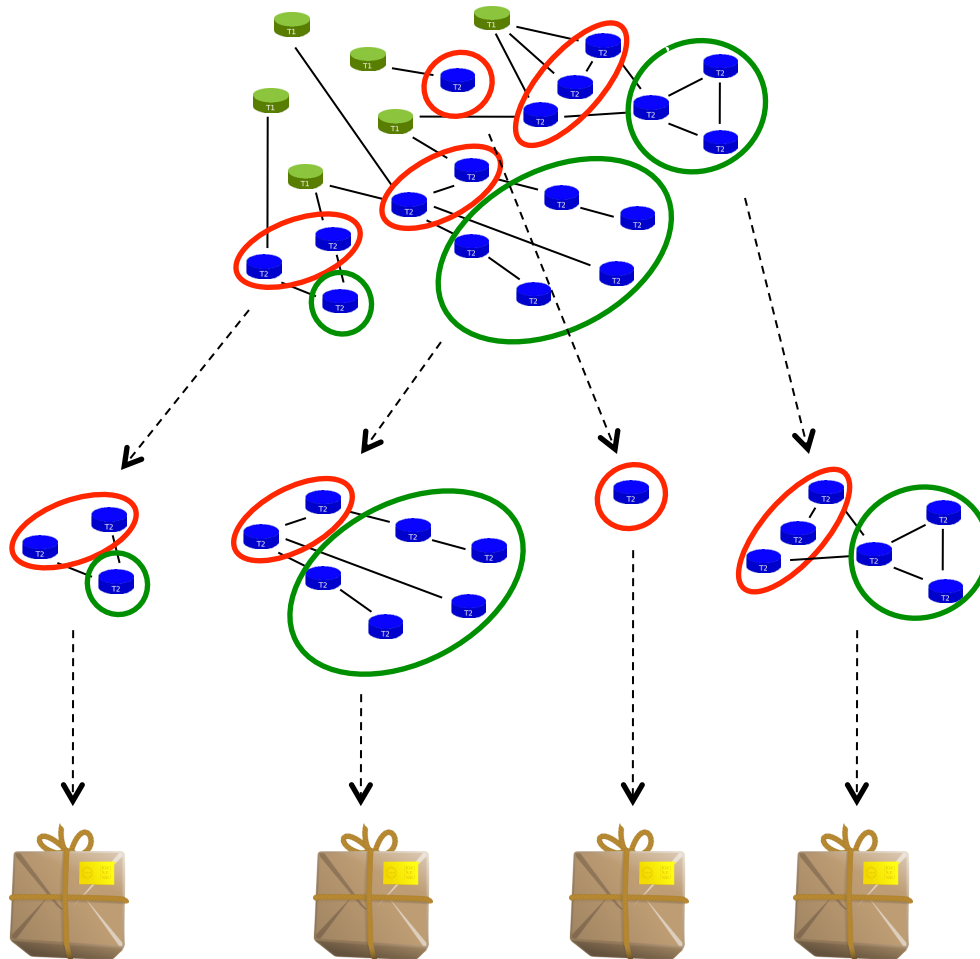
new client-server graph



Knapsack

Decompose

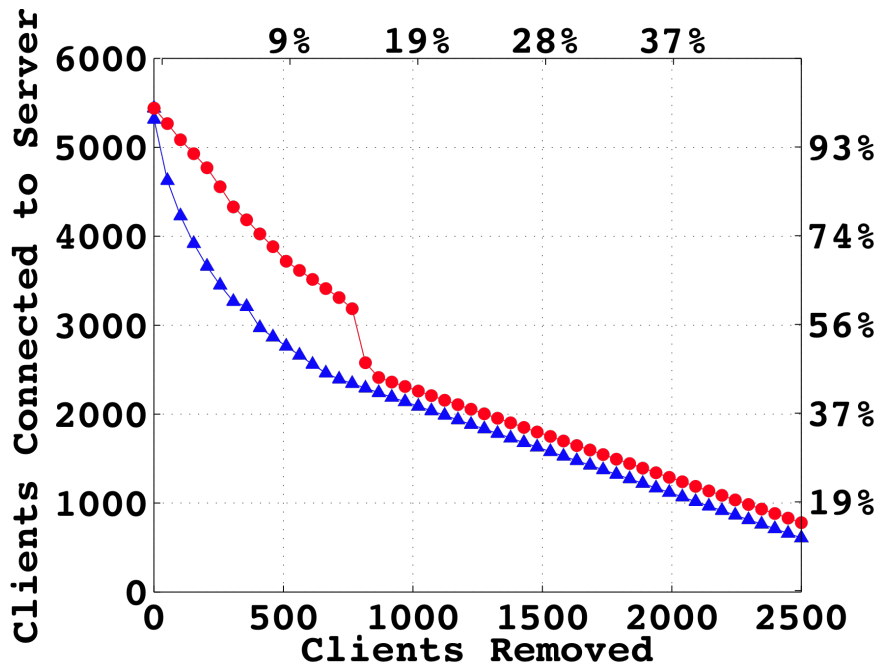
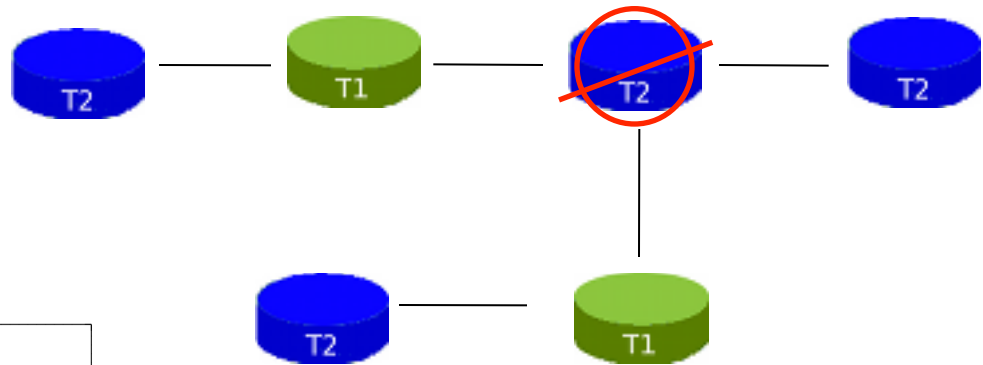
Subproblems



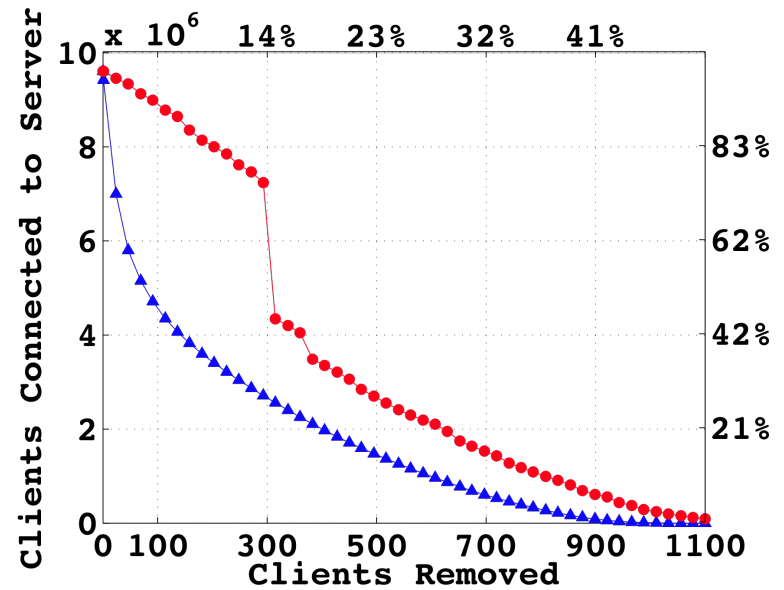
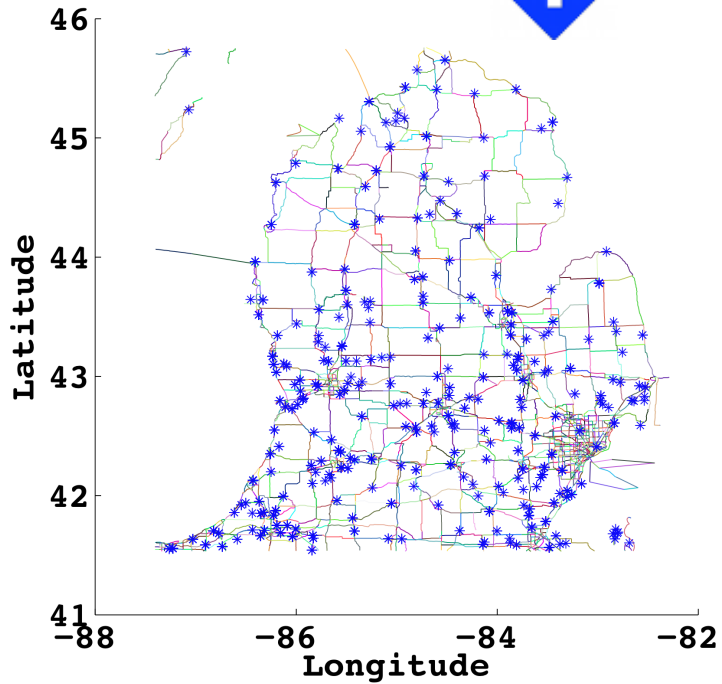
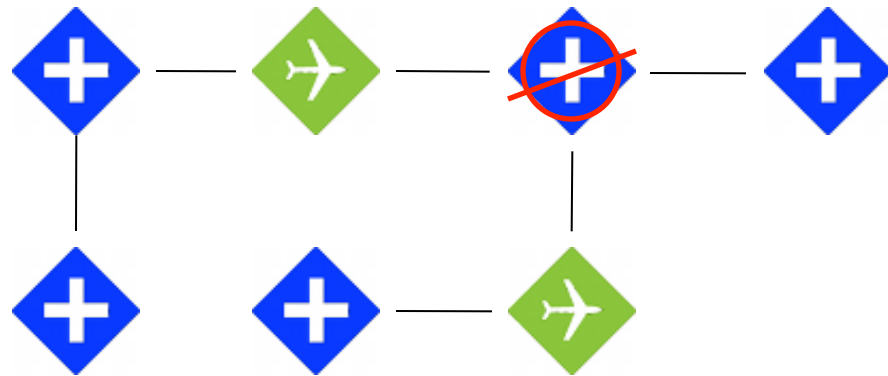
Solution

- Lower bound via linear programming
- Upper bound via greedy choice

Internet AS Graph



Airport Access: Michigan

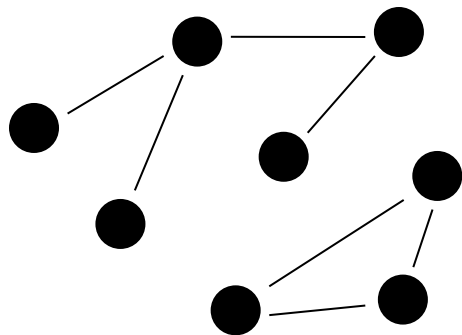
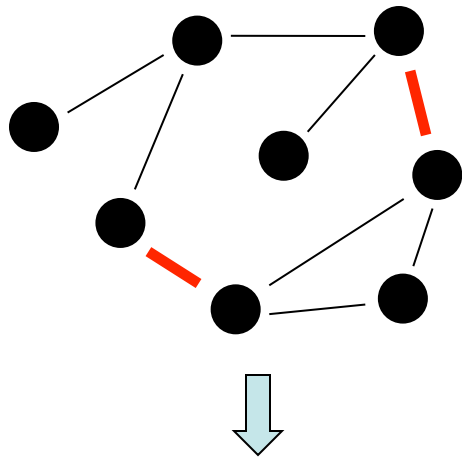


Conclusion

- Many client-server networks
- Difficult to secure
- We can quantify vulnerability
 - Any small network (edge and vertex cuts)
 - Some large networks (vertex cuts)

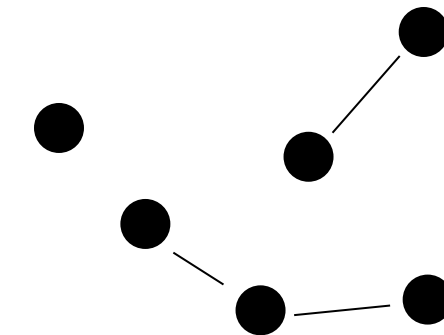
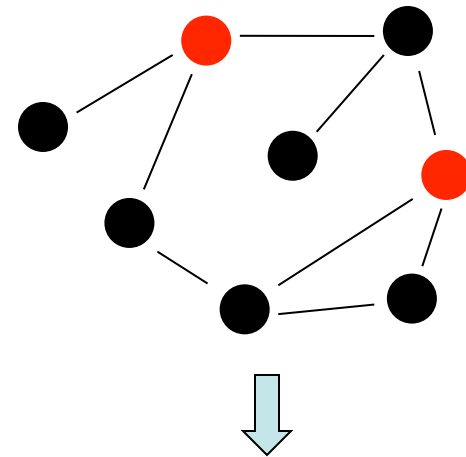
Basics

Edge Cut



} Connected Components

Vertex Cut



Basics

- Lower bounds represent worst-case
- Upper bounds are observable

