Assessing the Vulnerability of Replicated Network Services

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Client-Server Problem

Any network with clients and servers

Disconnect clients from all servers
Other Networks

- Wireless mesh network
- Internet AS Graph
- Airport Access
Motivation

• Links difficult to secure
• Node often unguarded
• Historical precedent for attack
Prior Work

- Heuristics don’t identify worst cases
Prior Work

Graph separators ignore hierarchy

Separator Problem

Client-Server Problem
Framework

Think in terms of blocks

Block 1

Block 2

edge cut

Block 3

vertex cut
Problem Statement

Minimize:

Subject To:

*NP-hard via edge-separators

(edge cut size)

(vertex cut size)
Solution

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

block

1
2
3

fixed

1
2
3

servers

Bad

Good
Branch-and-cut: Lower Bound
Rounding: Upper Bound

Basic rounding + Kernighan-Lin

Good

Binary
Wireless Mesh Network

[Diagram of wireless mesh network]

[Graphs showing clients connected to server as links or clients removed]
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
Exploiting Topology

gateways

children
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

Vertex Cut

Connected Components
Basics

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

Observed Clients Connected
Cut Set: \{ e_1, e_2, \ldots \}

Minimum Clients Connected