Perils of Transitive Trust in the Domain Name System

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How to Own the Internet via DNS

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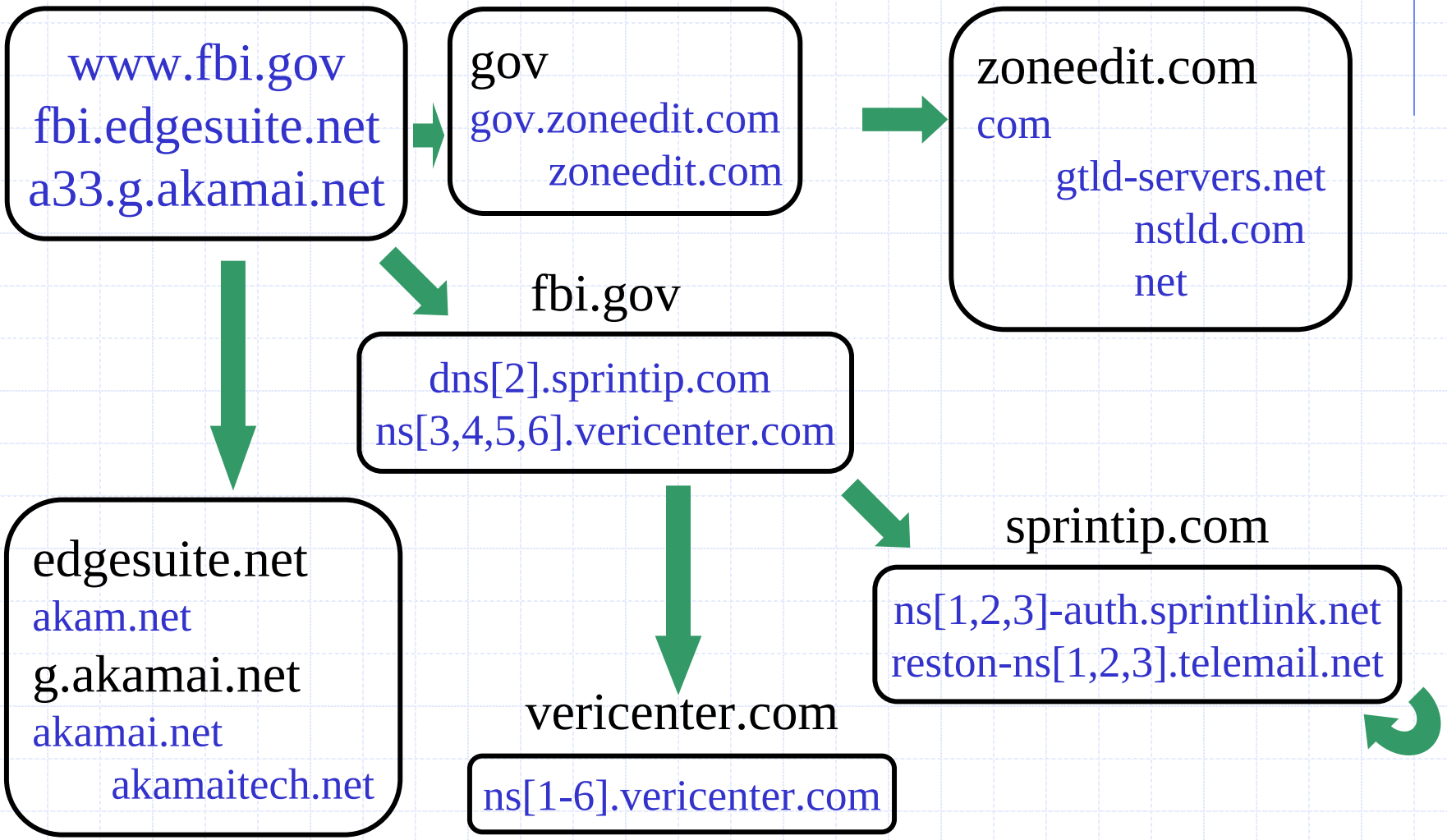
Introduction

- DNS is critical to the Internet
- DNS architecture is based on delegations
  - Control for names is delegated to name servers designated by the name owner
- Delegations decentralize administration and improve fault tolerance
  - But create a dependence

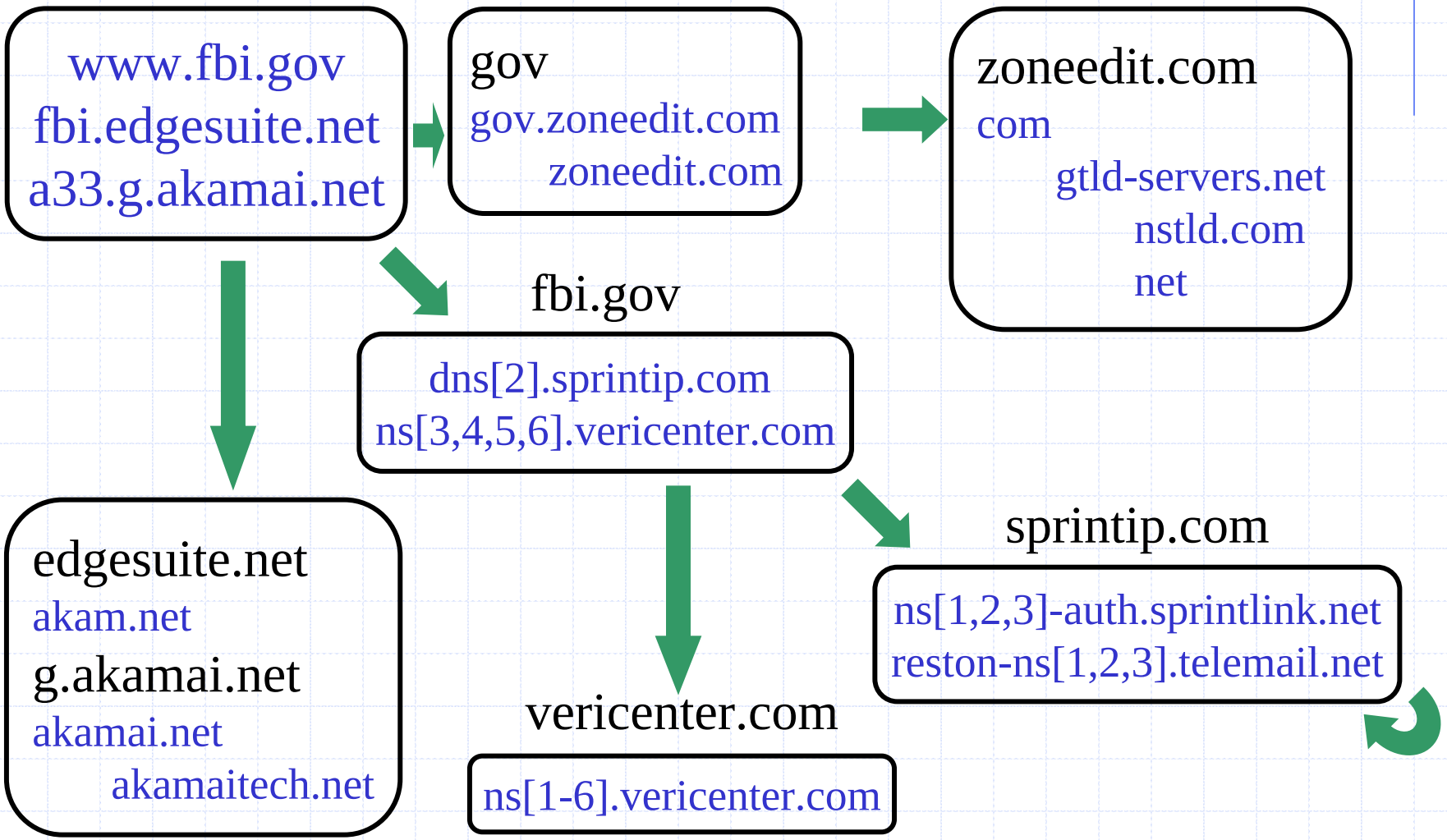
Dependencies for www.fbi.gov



Subtle Dependencies in DNS

- DNS dependencies are subtle and complex
  - www.fbi.gov
    - ➔86 servers, 17 domains
  - www.cs.cornell.edu
    - ➔cs.rochester.edu ➔ cs.wisc.edu ➔ itd.umich.edu
    - ➔48 nameservers, 20 domains
- Conventional wisdom says "add redundant nameservers to mask failures, at no cost"
- Conventional wisdom is wrong
  - Increases risk of domain hijacks

Dependencies for www.fbi.gov



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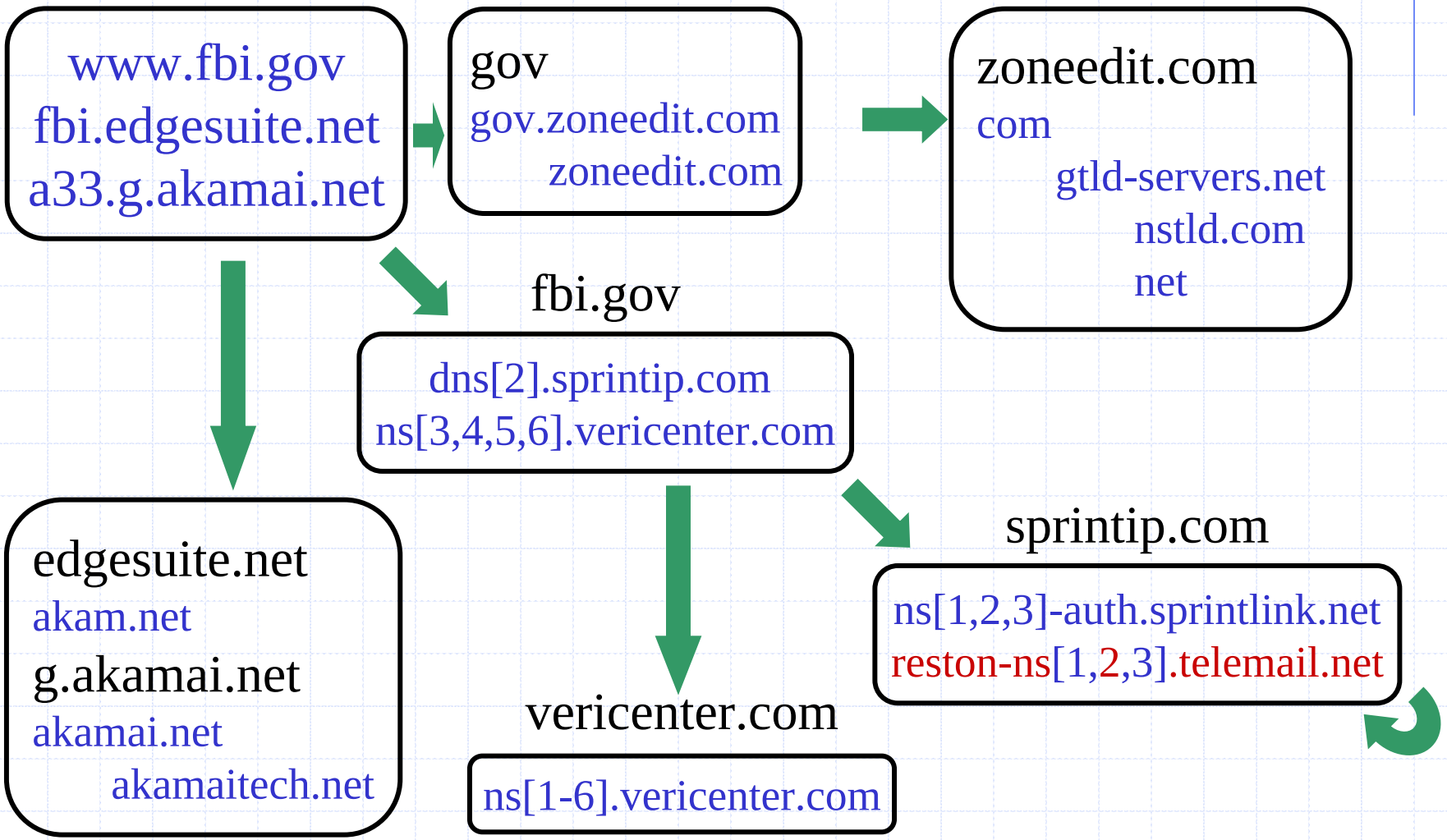

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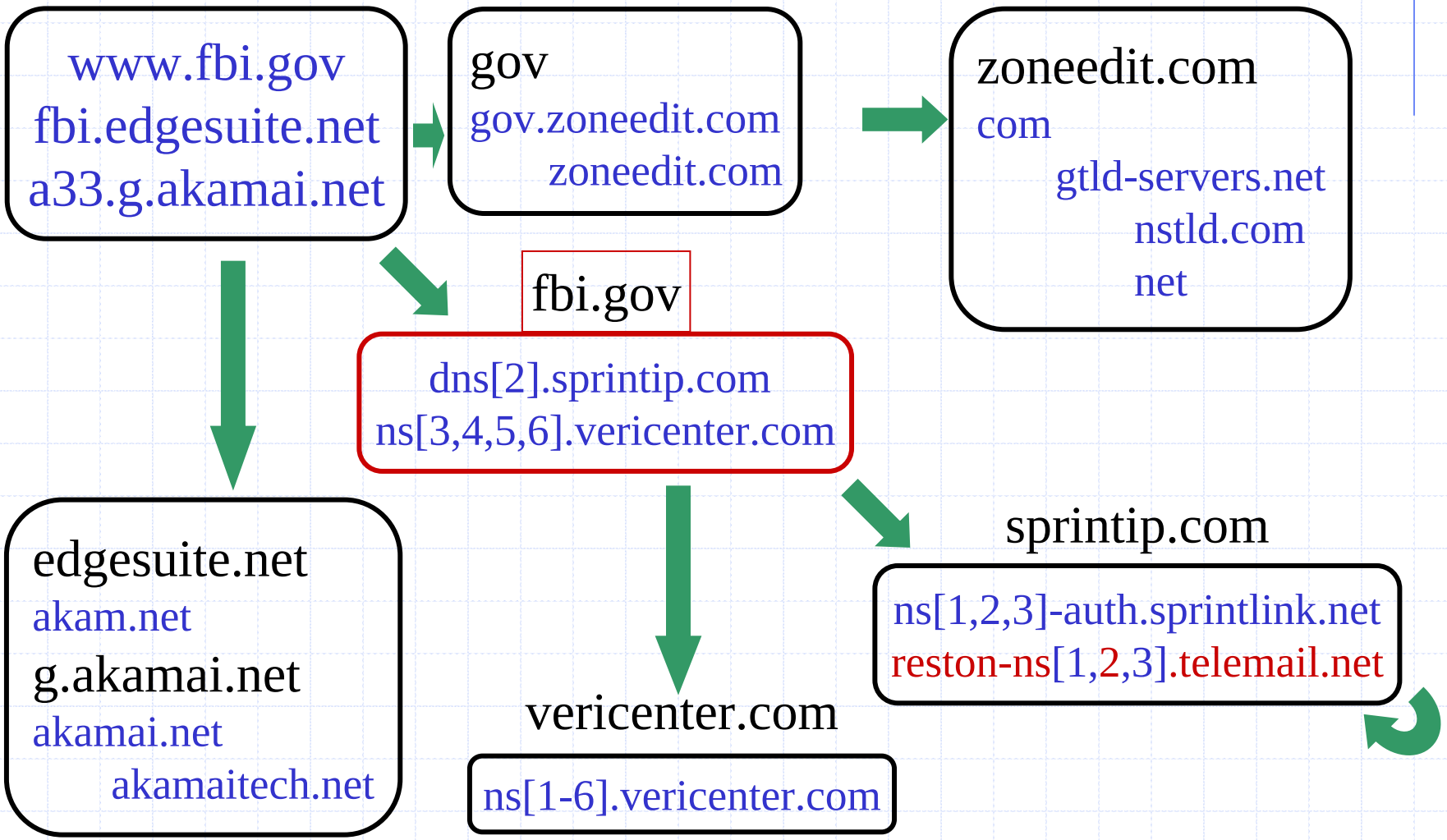

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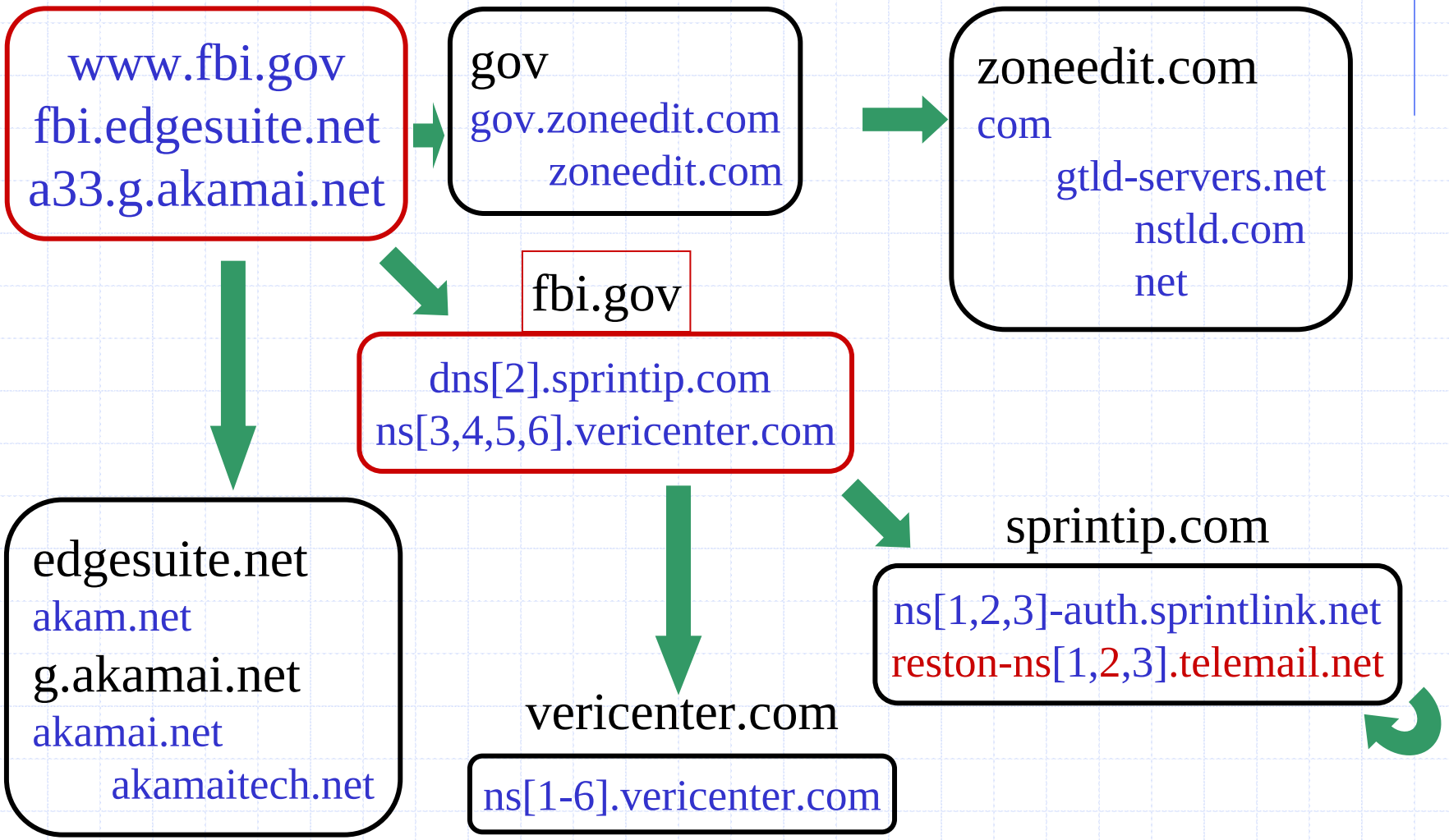

Servers with Security Loopholes

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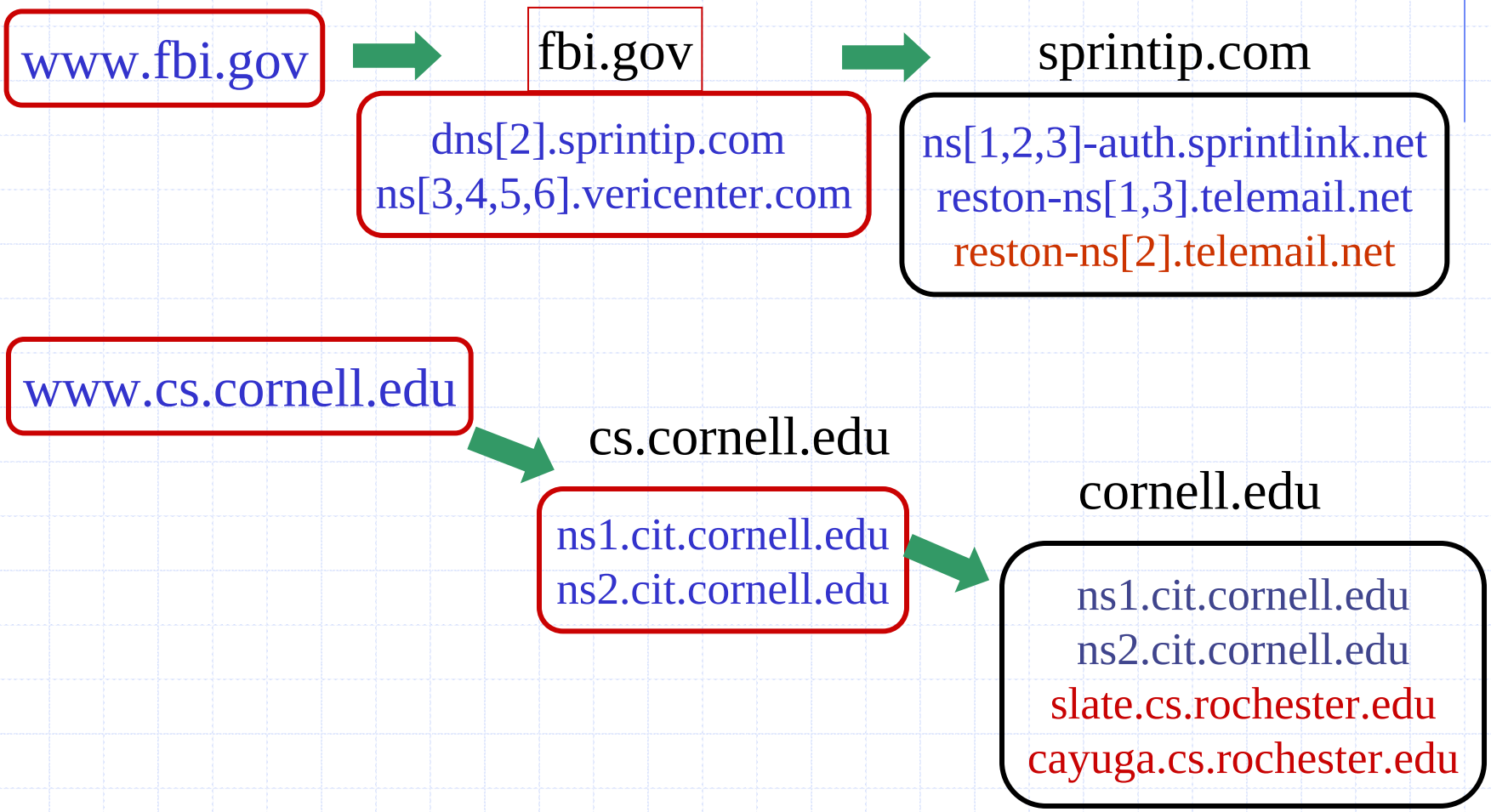
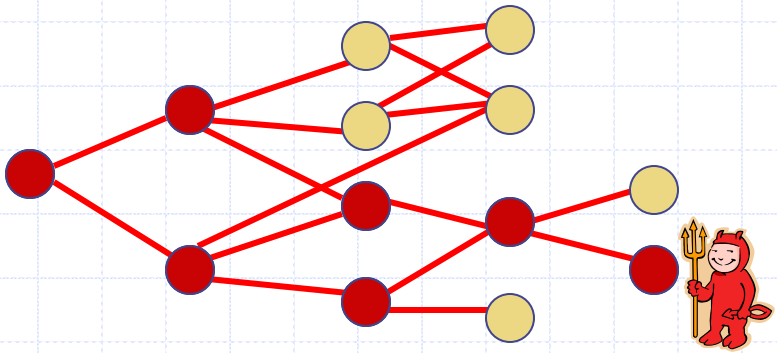


Lessons



- DNS delegations create a directed acyclic graph of dependencies
- This graph forms the trusted computing base for that name
- This graph is often large and includes many vulnerable hosts, making domain hijacks possible

Goals

- Identify vulnerable assets
  - Which domain names have large dependencies and entail high risk?
  - Which domains are affected by servers with known security holes and can be easily taken over?
- Identify valuable assets
  - Which servers control the largest portion of the namespace and are thus likely to be attacked?

Survey Methodology

- Collected 593160 domain names
  - Visible names people care about from Yahoo & DMOZ
  - Separately examined the Alexa Top-500
- Traversed 166771 name servers
  - Large set of important nameservers
- Examined the dependence graphs for 535036 domains, 196 top-level-domains

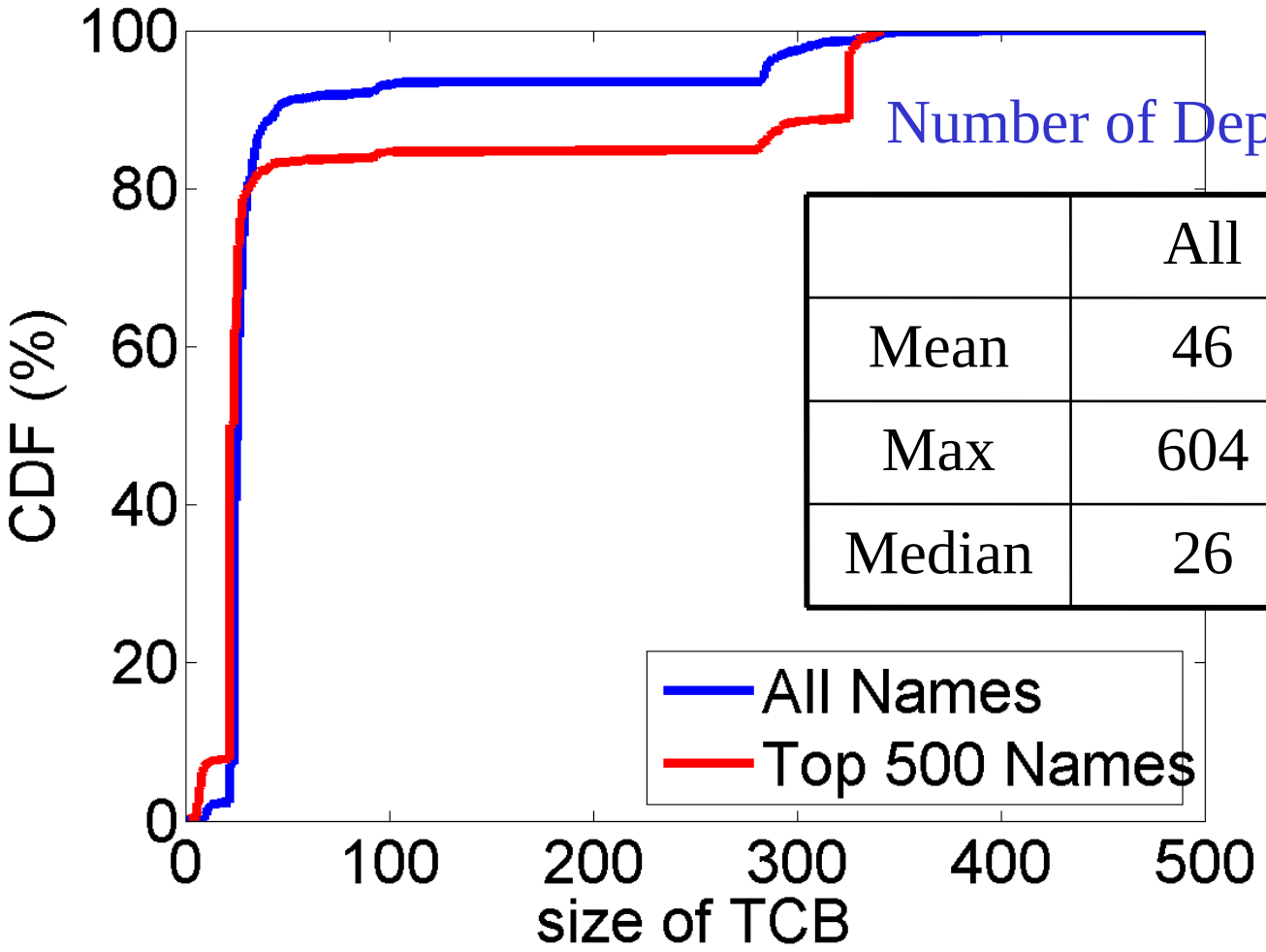
How vulnerable is a typical name?

How big is the average TCB?

Which domains have the largest TCBs?

What are the chances of a successful domain hijack?

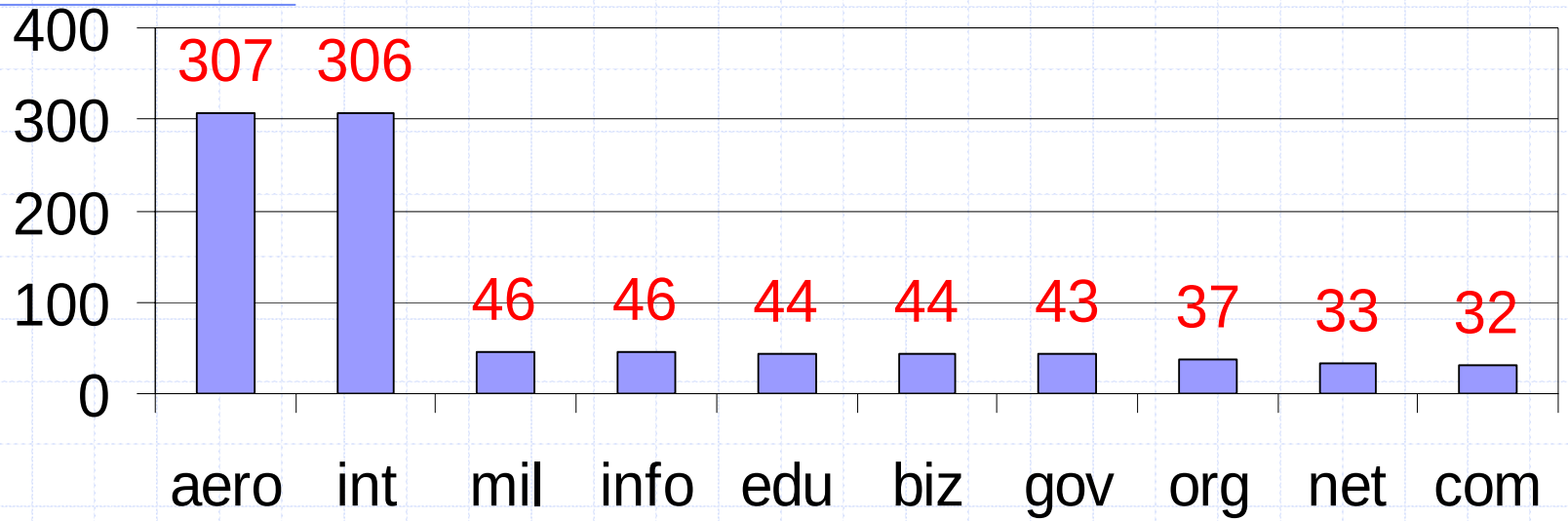
TCB Size

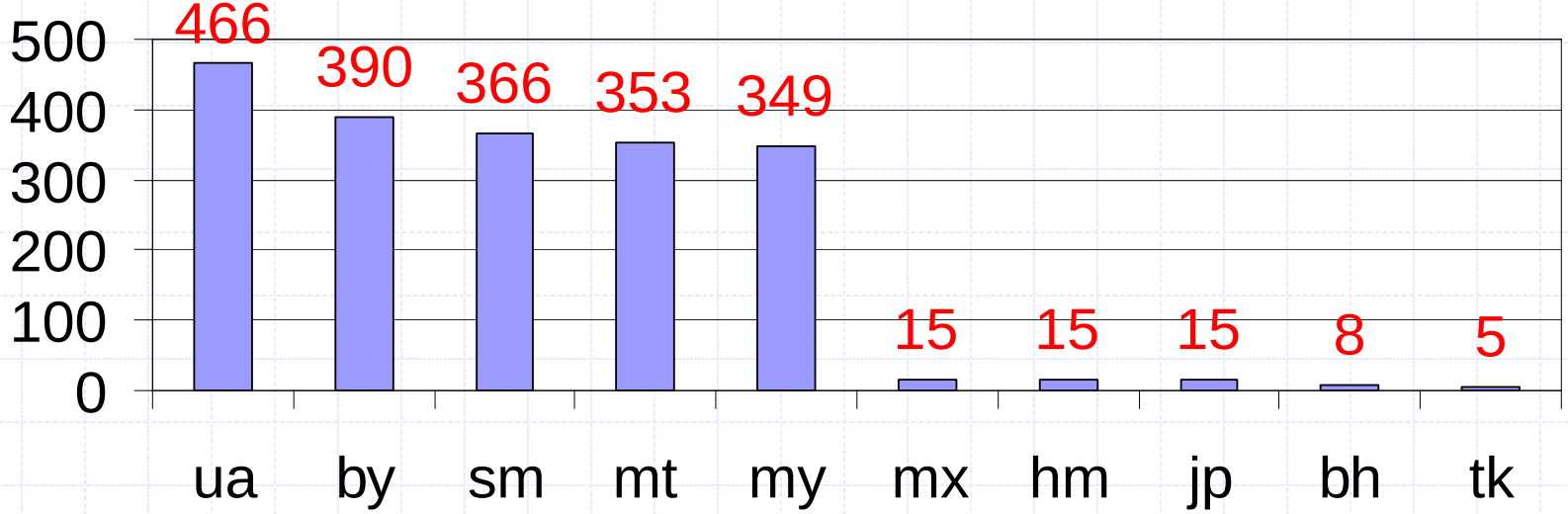


Number of Dependencies

	All	Top 500
Mean	46	68
Max	604	342
Median	26	22

Dependencies by TLD





Most Vulnerable Name

- Roman Catholic Church website in the Ukraine depends on nameservers in
  - Berkeley, NYU, UCLA, Russia, Poland, Sweden, Norway, Germany, Austria, France, England, Canada, Israel, Australia
- An attacker in Monash, Australia could redirect the IP binding for a website in Ukraine
- It's a small world after all...

Lessons for TLD Operators

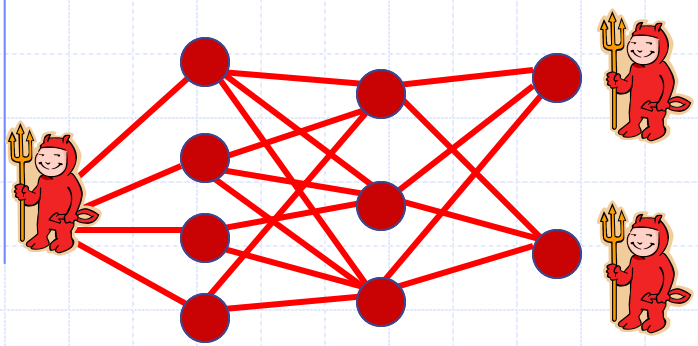
- Some TLDs are set up such that all names in them are dependent on many nameservers
  - AERO, Ukraine, Malaysia, Poland, Italy...
- Some TLDs have few dependencies
  - Japan
- Possible to achieve high failure resilience without depending on lots of hosts

Vulnerable Names

- Surveyed BIND version numbers
  - Queried public version numbers
  - 40% response rate
- Compared against database of known vulnerabilities from ISC
  - Many have well-known exploit scripts available
- Examined the dependency graphs to determine how vulnerable names are

Chances of domain hijacks

- Not all vulnerabilities are equal



- An attacker can compromise a name completely (0wn it) if it can acquire a graph cut

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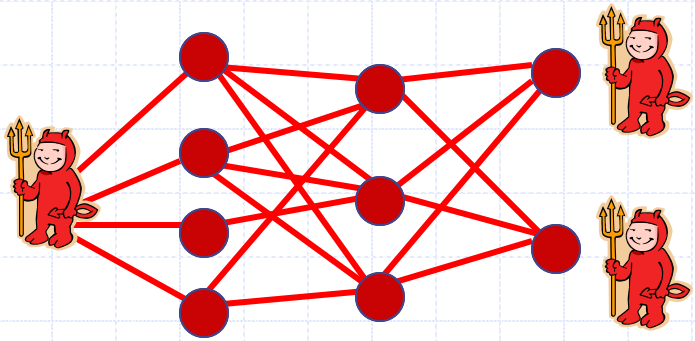

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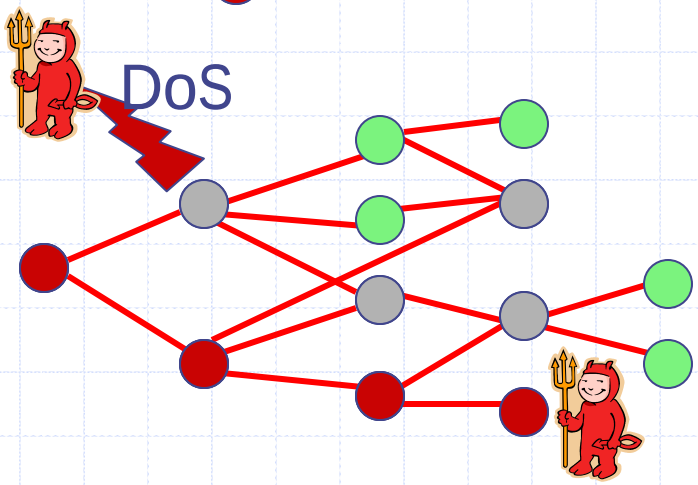
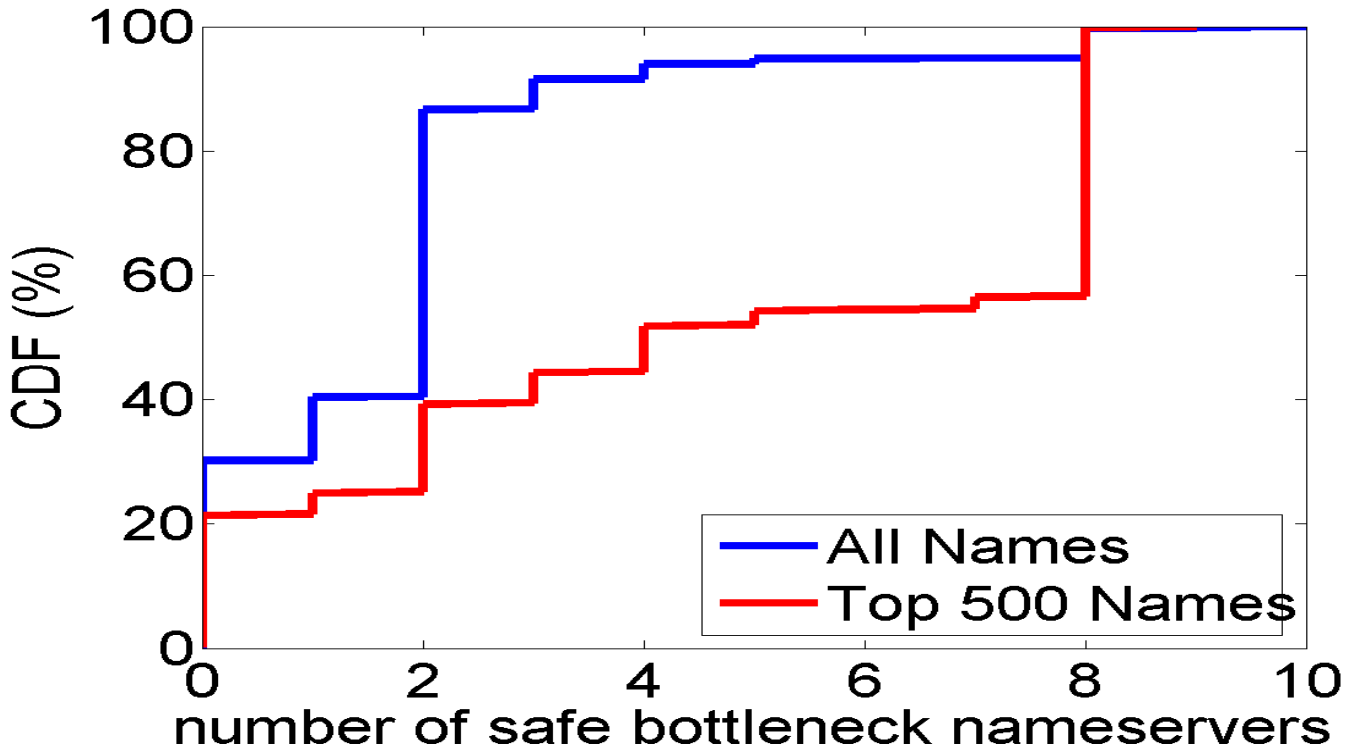


- If a full cut is not vulnerable, attacker must combine compromise with DoS

Vulnerability to Security Flaws



- Due to large TCBs for names, an attacker can use vulnerable servers and small DoS attacks to 0wn many names

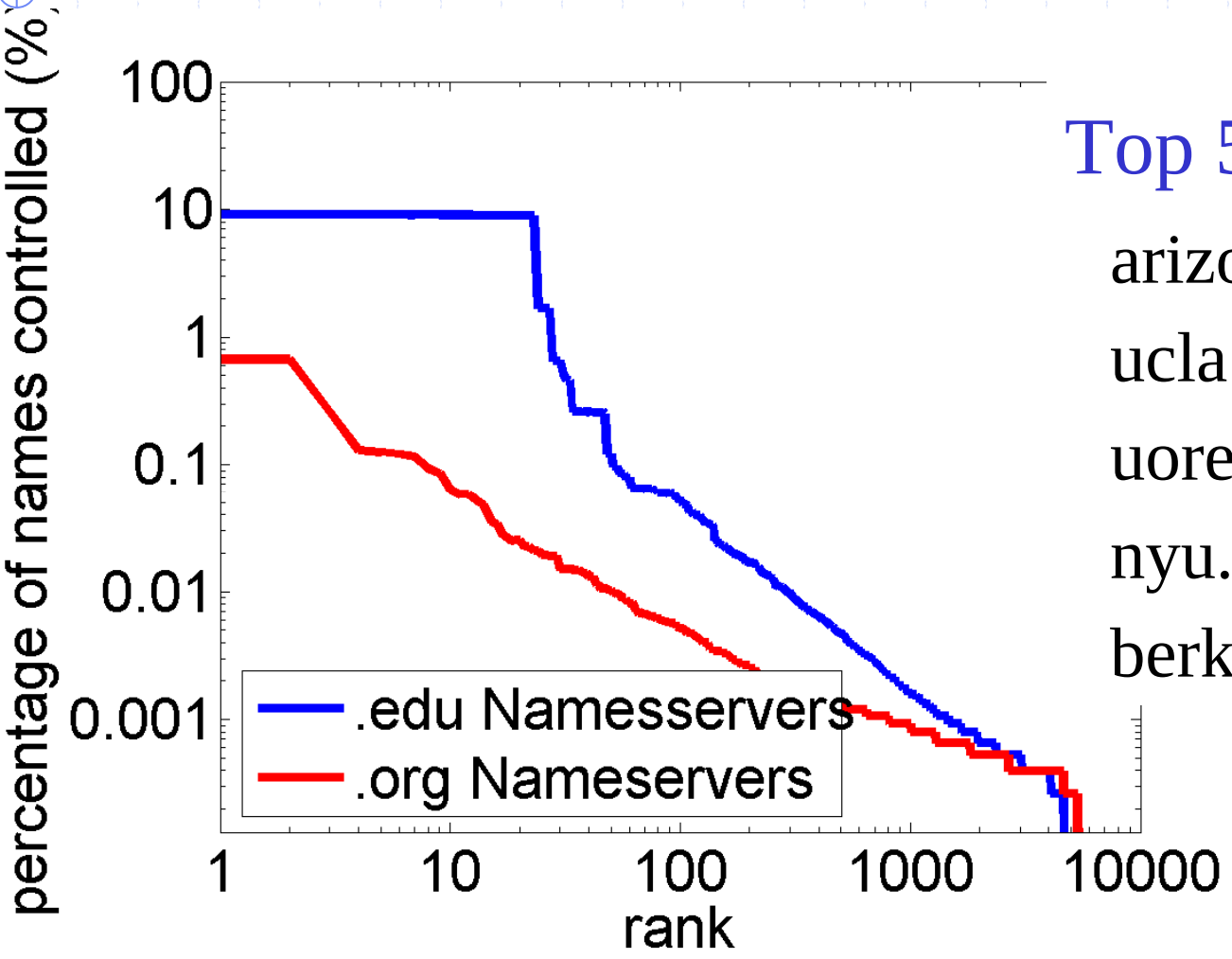
Vulnerable Names

- 17% of servers have known loopholes
- 30% of names are directly vulnerable
- 84% are vulnerable with 2-host DoS
- An attacker that can DoS 8 hosts can 0wn almost any name
- DNS dependencies expand the impact of vulnerabilities

Where are the valuable nameservers?

“Ok, I want to take over the Internet. Where do I start?”

Most Valuable Nameservers



Top 5 Domains

arizona.edu

ucla.edu

uoregon.edu

nyu.edu

berkeley.edu

Valuable Nameservers

- Many nameservers in the .EDU domain appear in dependency graphs
- Operators have no fiduciary responsibility to name owners
- Name owners as well as operators most likely do not realize the dependencies
  - Potential security risks and legal liabilities!

Conclusions

- Domain names have subtle dependencies
  - Due to name-based delegations inherent to DNS
- High risk of domain hijacks
  - Conventional wisdom is wrong, name owners should delegate carefully
- DNS is overdue for a redesign, for security
  - More data available at: http://www.cs.cornell.edu/people/egs/beehive/