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Quantifying the Impact of DNSSEC Misconfiguration

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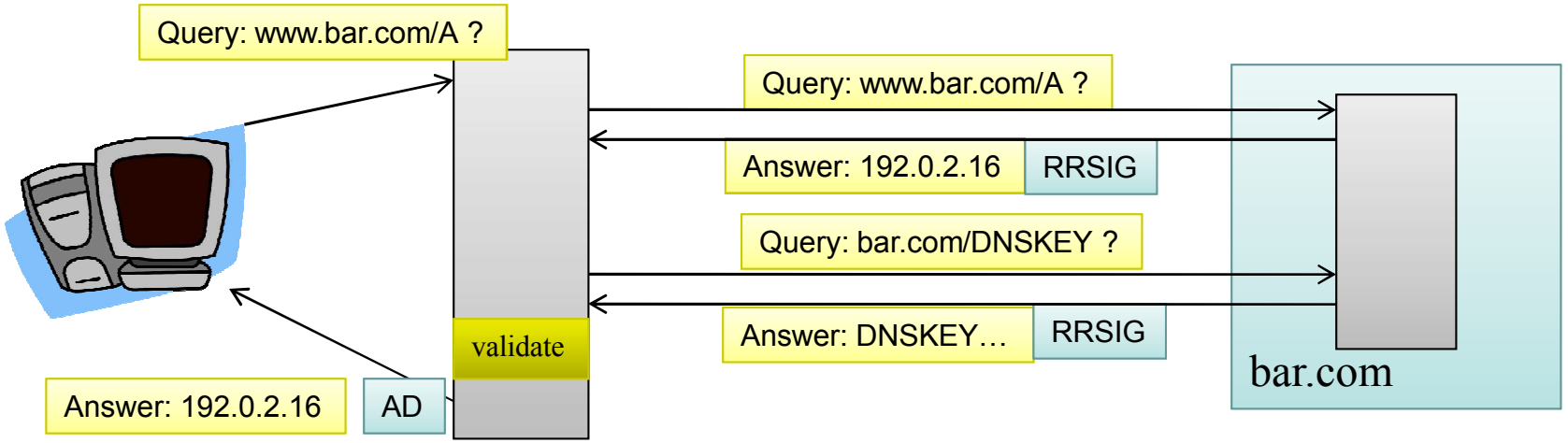
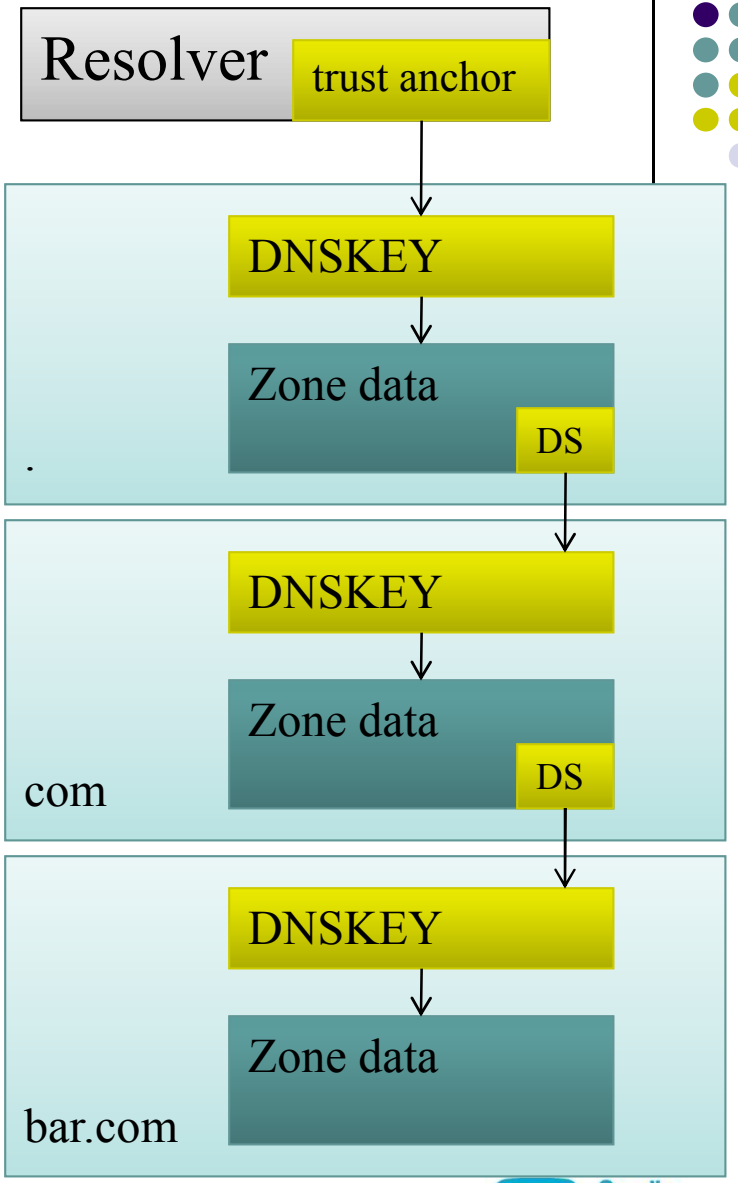
DNS Security Extensions (DNSSEC)

- DNS data signed with private keys for authentication
- Signatures (RRSIGs) and public keys (DNSKEYs) published in zone data
- Resolver validates response
  - If authentic: Authenticated data (AD) bit is set
  - If bogus: SERVFAIL message is returned



Chain of trust

- DNSKEY must be authenticated
- Resolver must have some notion of trust
- Trust extends through ancestry to a trust anchor at resolver
- DS resource record – provides digest of DNSKEY in child zone



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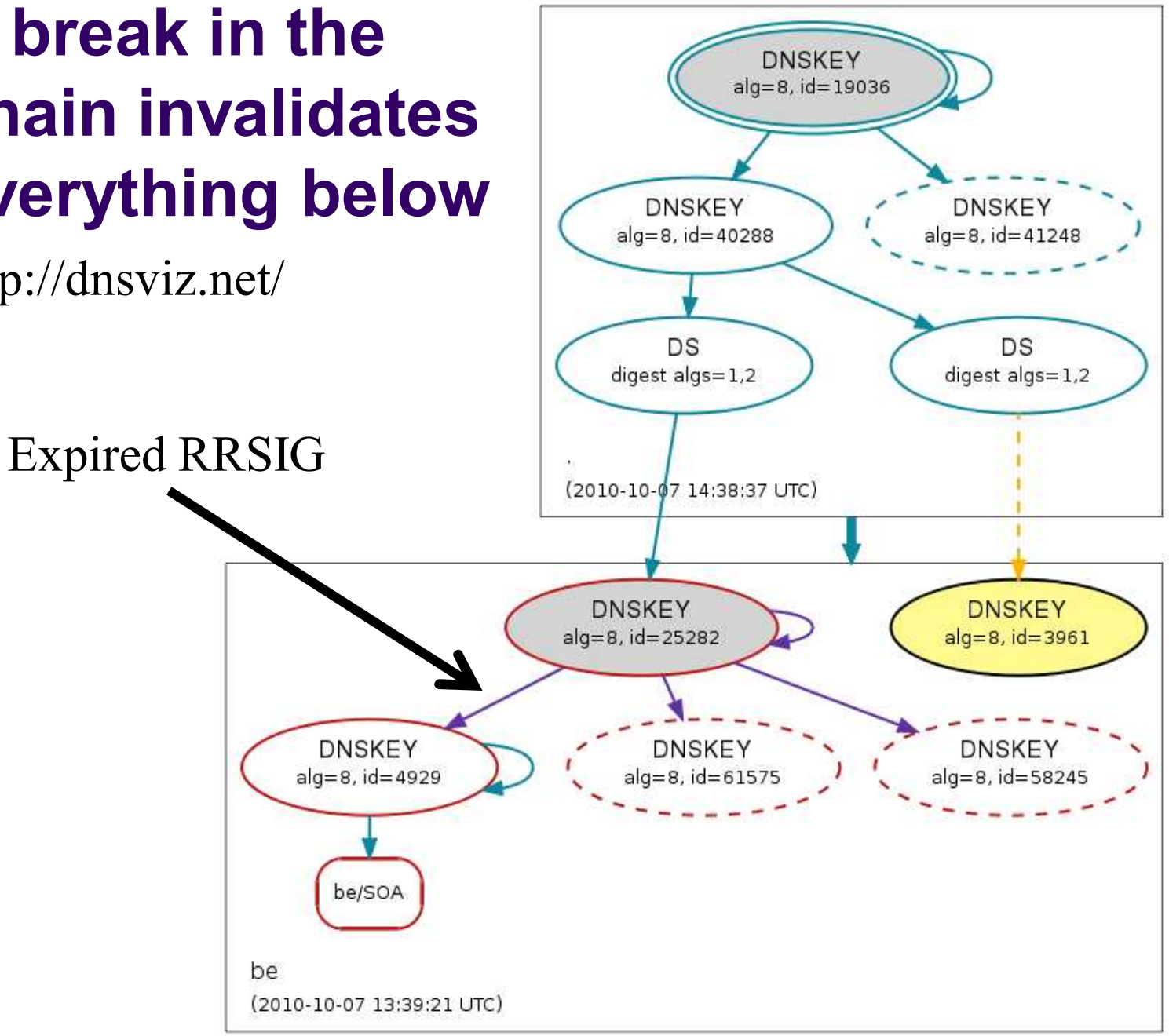
A break in the chain invalidates everything below

http://dnsviz.net/



Bogus responses

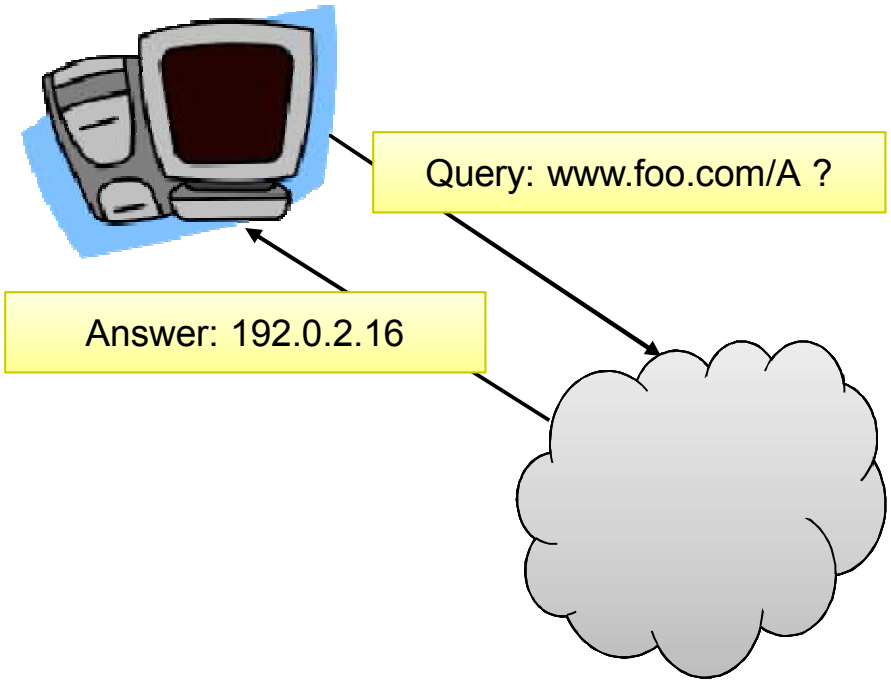
Is a bogus response the result of malicious tampering or misconfiguration?

Availability and security

- DNS must be both ***truthful*** and ***available***
- DNSSEC is a security retrofit
  - DNSSEC increases maintenance complexity
  - Troubleshooting is difficult
- Misconfigurations abound, rendering name resolution unavailable

Objectives

- Establish model and metrics for assessing availability of DNSSEC deployments
- Quantify complexity that may increase potential for DNSSEC misconfiguration
- Introduce techniques to mitigate effects of misconfiguration



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Outline

- DNSSEC misconfigurations
- DNS complexity analysis
- Misconfiguration mitigation
- Summary

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DNSSEC Misconfigurations

- Zone misconfigurations
  - Missing, expired, or bogus RRSIG
  - Missing DNSKEYs
- Delegation misconfigurations
  - No DNSKEY in child matching any DS in parent
  - Missing NSEC RRs for insecure delegation
- Trust anchor misconfiguration
  - Stale trust anchor at resolver

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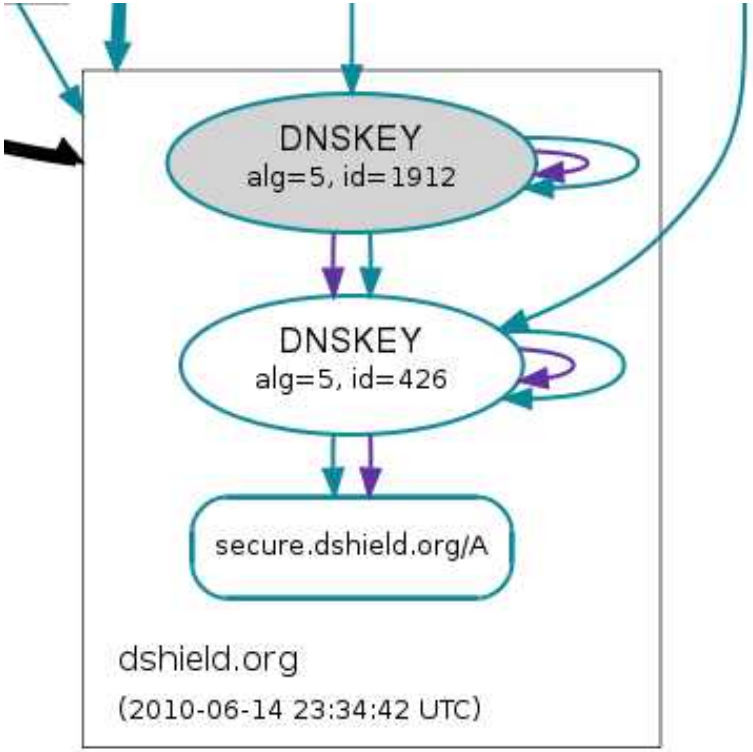
Failure isn't always certain

- Valid path may co-exist with invalid paths
- Concerns:
  - Non-validating upstream caches
  - Reduced redundancy
    - Load balancing
    - Failover
  - Symptoms of larger problem

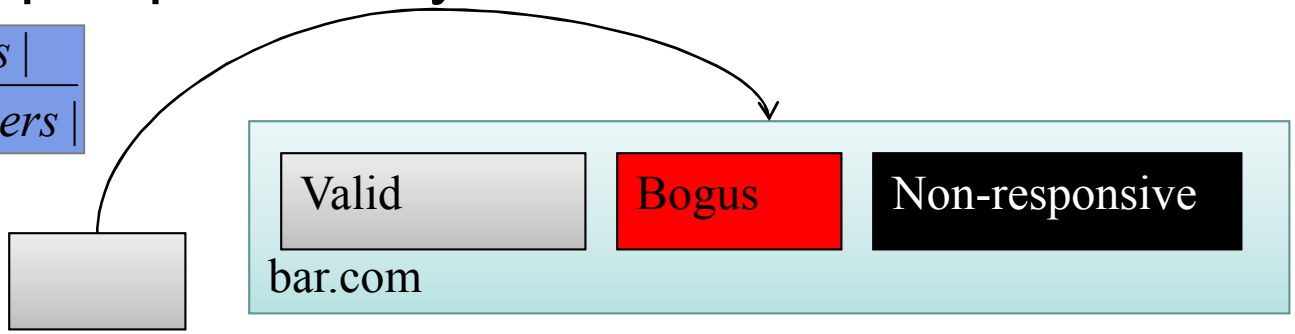


http://dnsviz.net/

Failure potential

- Probability of bogus validation
- Based on fraction of responsive authoritative servers serving bogus or incomplete data
  - Resolvers will retry if server non-responsive
  - Not all servers will retry if server responds with bogus data
- Assumption: resolver queries any authoritative server with equal probability

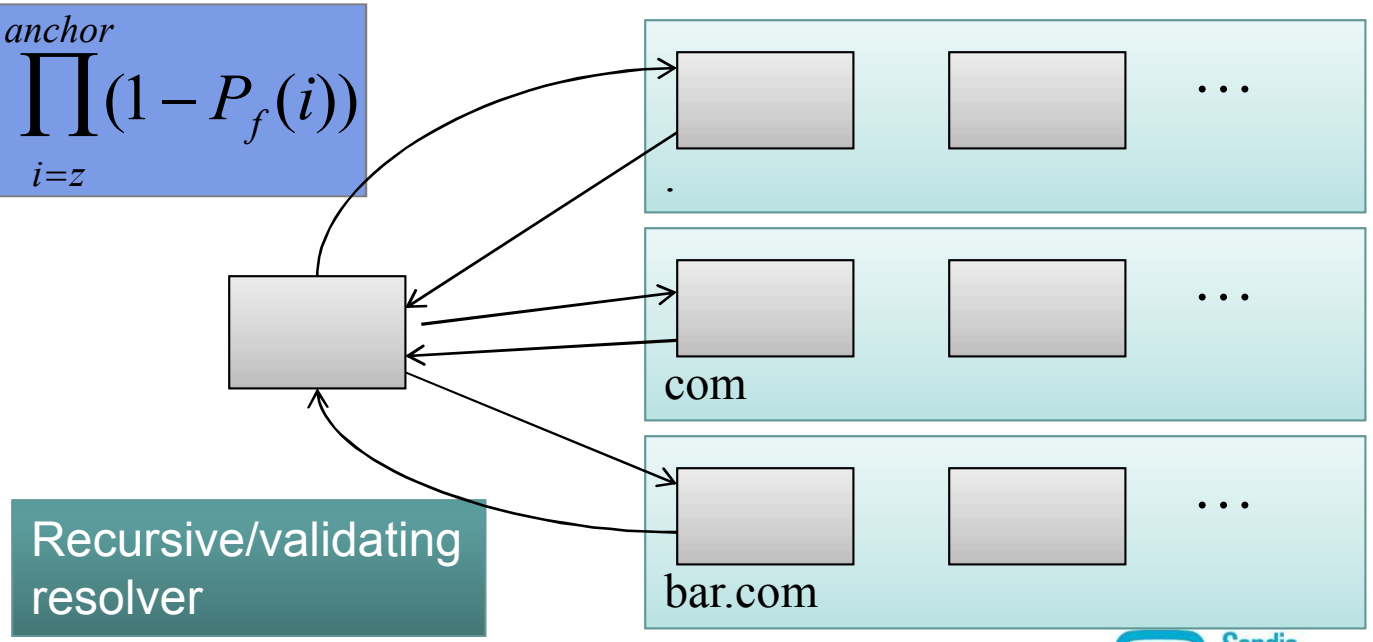
$$P_f(z) = \frac{|bogus\_servers|}{|responsive\_servers|}$$



Failure potential

- Formula extends to chain of trust in ancestor zones
- Failure potential of each zone is combined independently of one another

$$P_f^r(z) = 1 - \prod_{i=z}^{anchor} (1 - P_f(i))$$

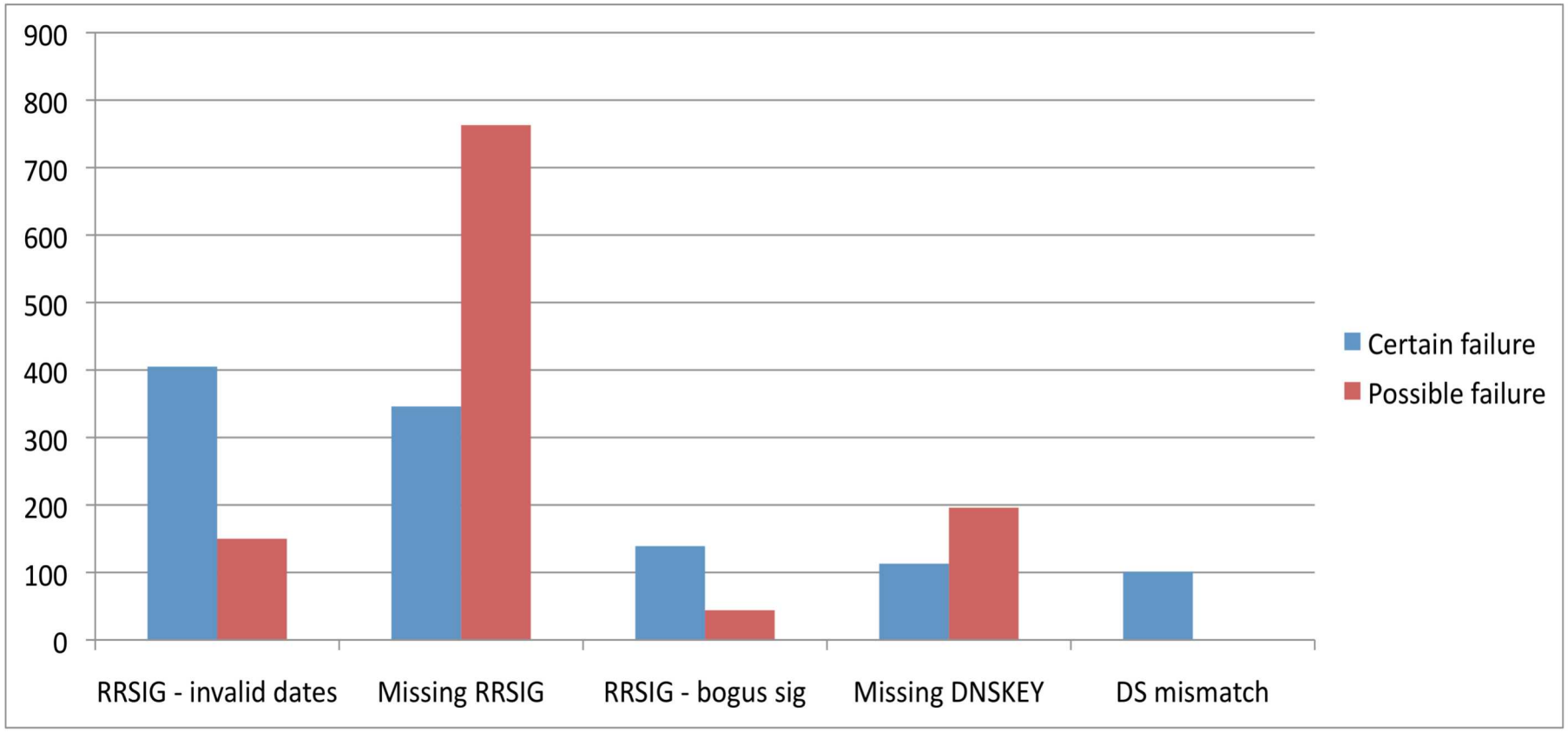


DNSSEC Deployment Survey

- Polled ~2,200 production signed zones over a five month period (June – Nov, 2010)
- Validation of SOA RR analyzed every four hours
- Failure event – a non-zero failure potential lasting two or more consecutive polls

Statistic	Value
Production signed zones polled	2,242
Total failure events	2,634
Events resulting in possible failure (failure potential 0 < n < 1.0)	1,998 (76%)
Events resulting in certain failure (failure potential = 1.0)	636 (24%)
Zone-class misconfigurations resulting in certain failure	460 (72%)
Delegation-class errors resulting in certain failure	176 (28%)
Errors (any class) caused by misconfigured ancestor zones	178 (28%)

Misconfigurations by Type



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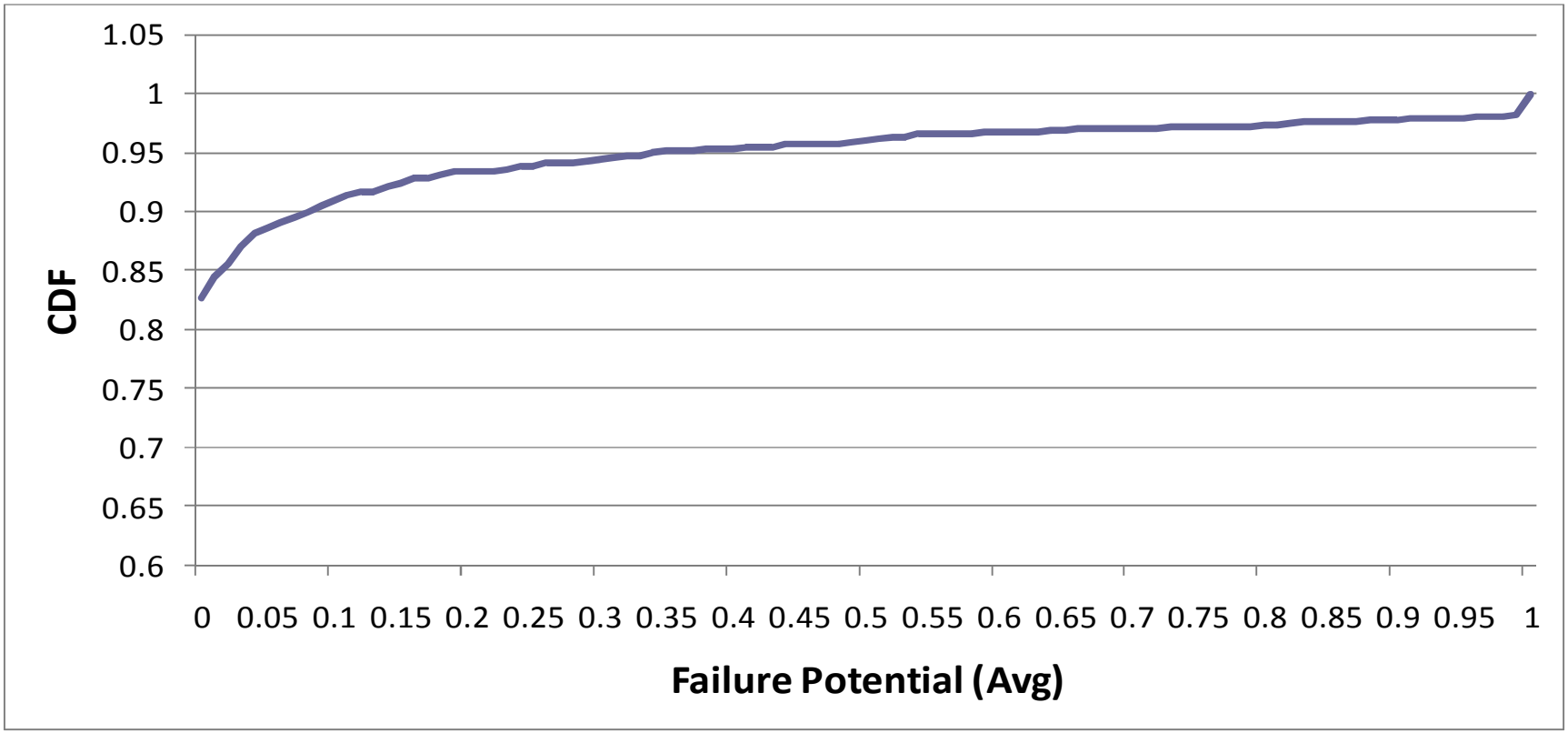
Failure Potential of Zones



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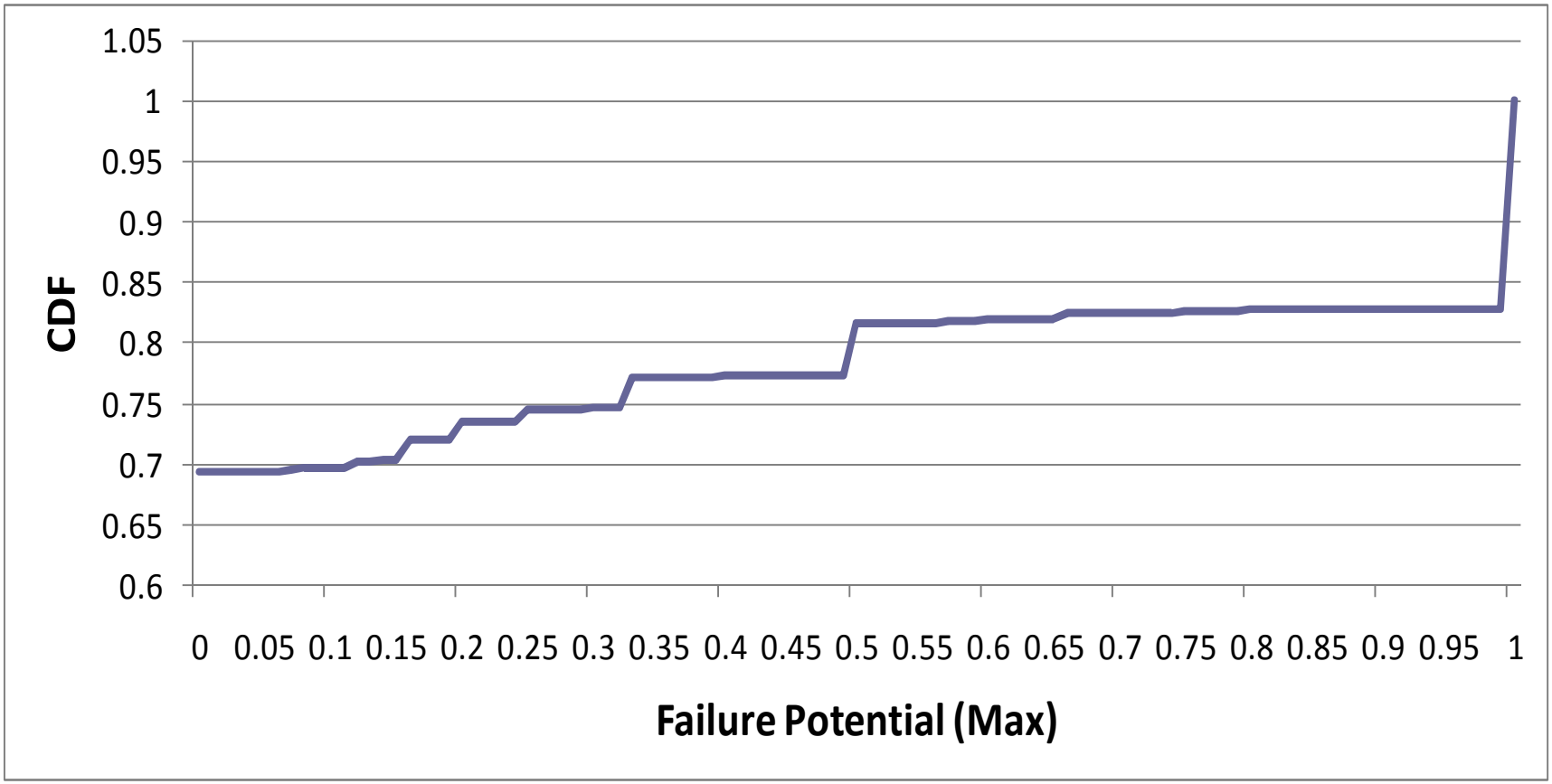
Failure Potential of Zones (Max)



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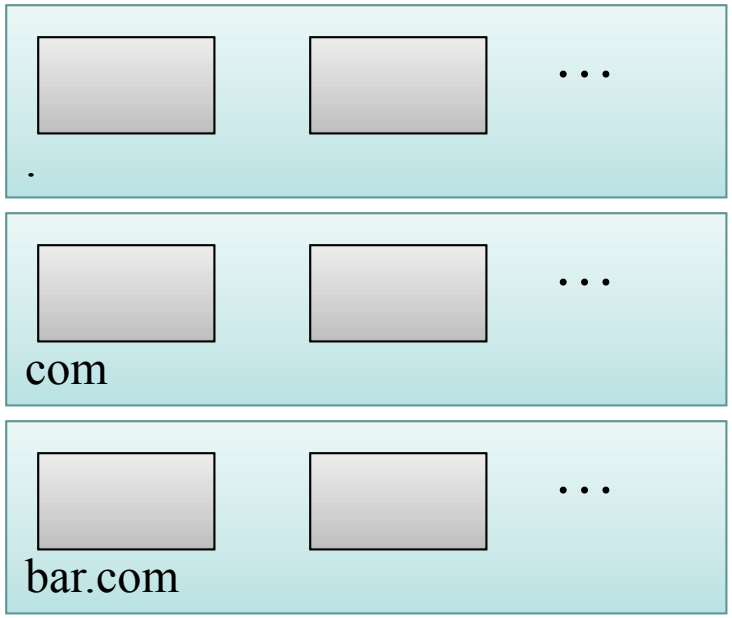
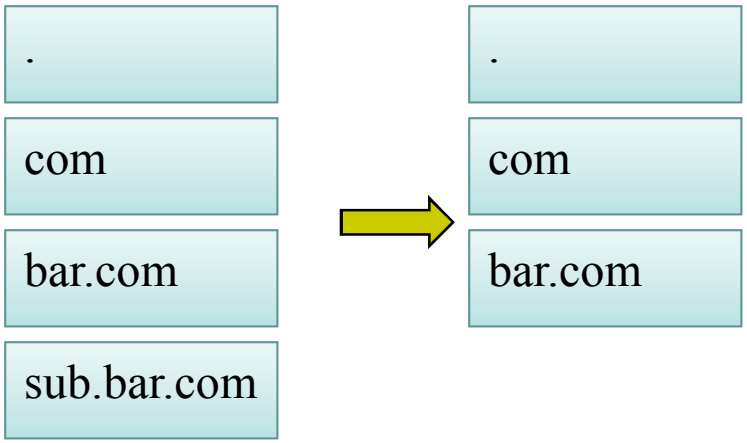
Complexity analysis

- Complexity creates potential for misconfiguration
- Hierarchical complexity:
  - Size of ancestry (zone depth)
- Administrative complexity:
  - Servers administered by distinct organizations



Hierarchical reduction potential

- If ancestry might reasonably be consolidated, what is the reduction?
- Ancestry reduced, but original namespace can be preserved



$$HRP = \frac{|orig\_zones| - |consolidated\_zones|}{|orig\_zones|}$$

$$= 0.25$$

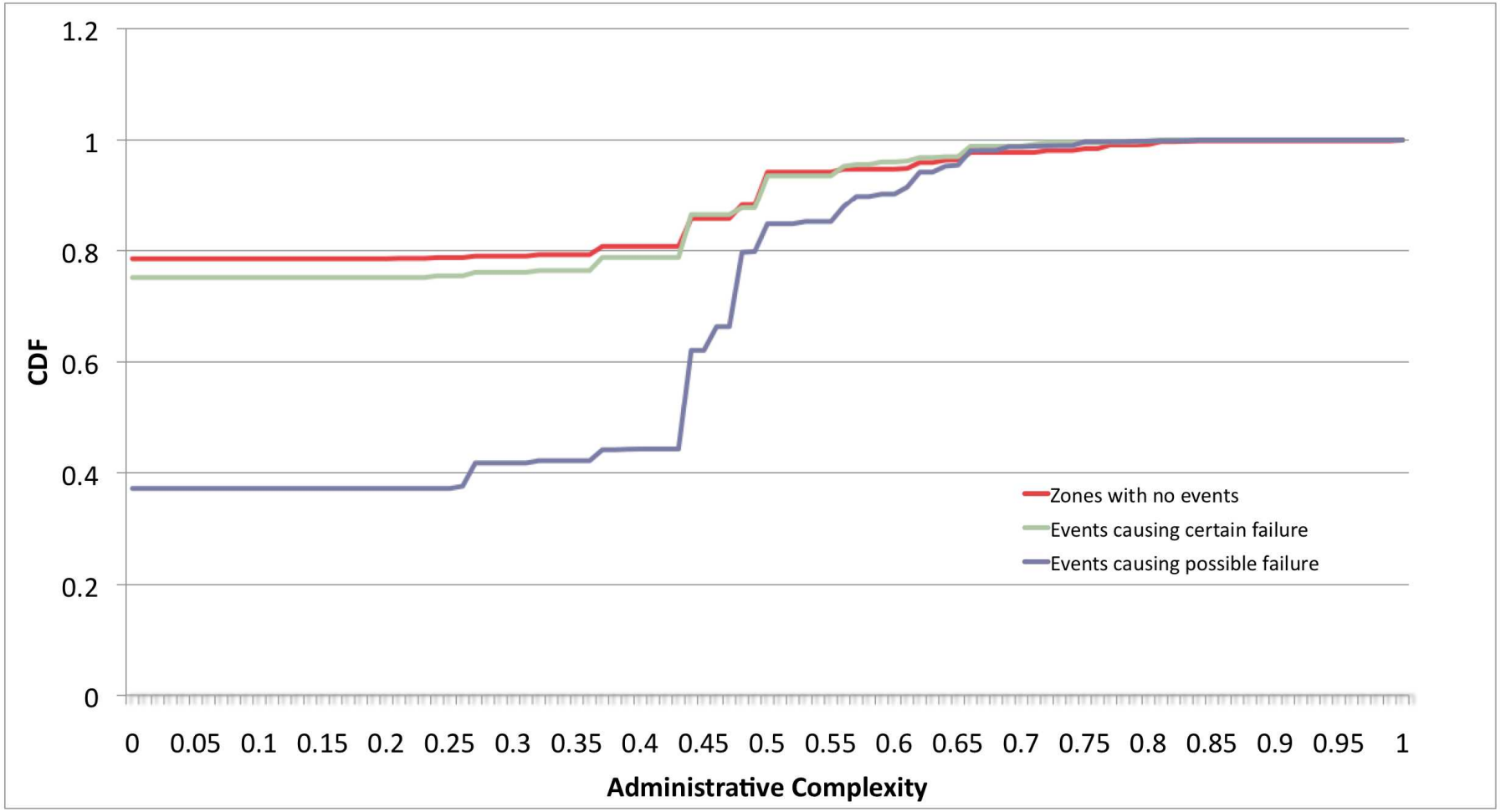
Administrative Complexity

- How diverse is the set of organizations administering a zone?
- Complexity measured by random sampling (with replacement) of authoritative servers to determine the probability that two organizations are selected

$$AC = 1 - \sum_{o \in orgs} \left(\frac{|servers(o)|}{|all\_servers|} \right)^2$$

$$= 0.5$$

Administrative complexity



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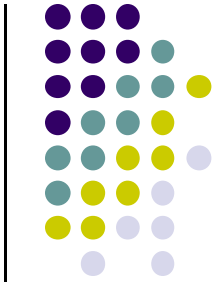
Avoiding and mitigating effects of misconfiguration



- Follow best practice operational standards (RFCs)
  - Key rollover procedures
  - Trust anchor rollover procedures
- Validation diligence
  - Resolver keeps trying alternative authoritative servers to find valid response
  - Optimality can be difficult – where is the break in the chain?
  - Implemented in BIND 9

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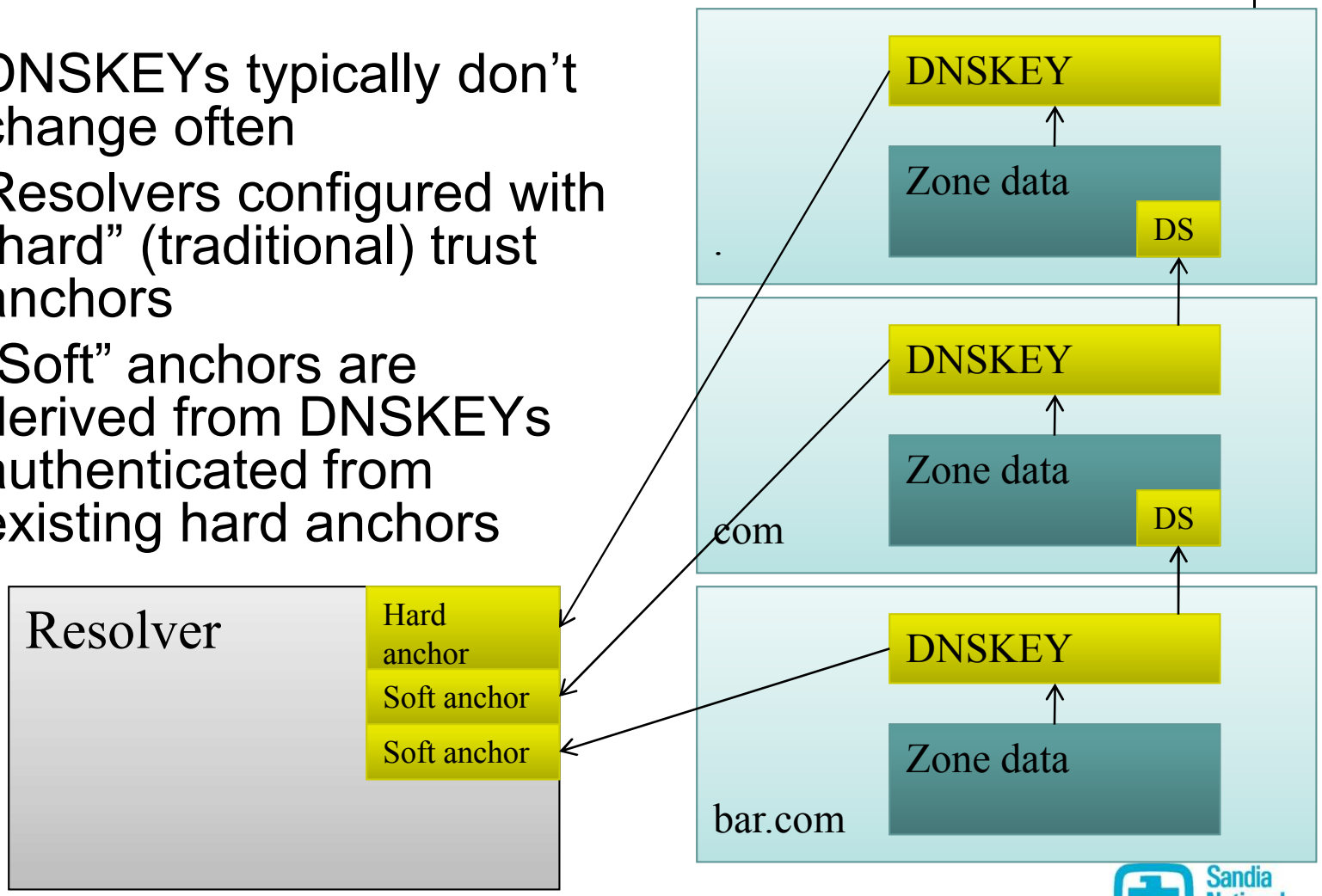
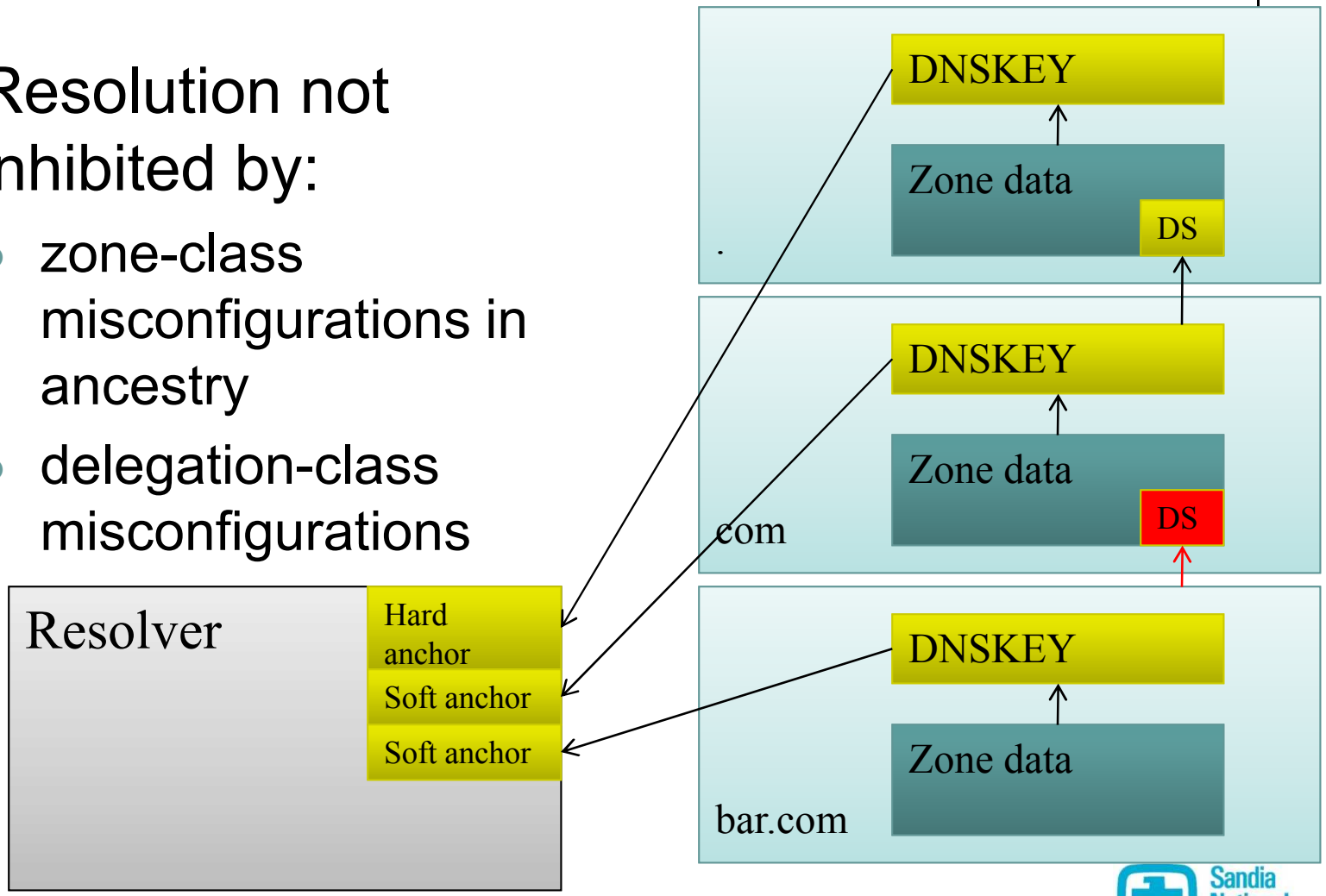
Soft anchoring

- DNSKEYs typically don't change often
- Resolvers configured with "hard" (traditional) trust anchors
- "Soft" anchors are derived from DNSKEYs authenticated from existing hard anchors



Impact of soft anchoring

- Resolution not inhibited by:
  - zone-class misconfigurations in ancestry
  - delegation-class misconfigurations



Maintaining soft anchors

- Resolvers follow procedure similar to that used for rolling hard trust anchors (RFC 5011)
- Resolver periodically polls soft anchor zone
- Soft anchor addition:
  - Newly authenticated DNSKEYs persist for “hold down” period
  - New DNSKEY seen with corresponding DS
- Soft anchor removal:
  - Delegation to soft anchor made insecure
  - DNSKEY is revoked
  - DNSKEY and its DS RR are removed

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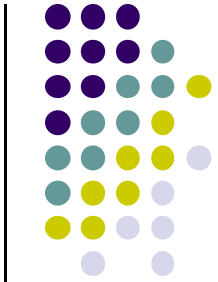
Soft anchoring limitations



- Doesn’t help when misconfigurations are at or below the bottom “link” in the chain of trust
- Resolver must have authenticated soft anchors through valid chain of trust before misconfiguration
- Scalability
  - Maintenance overhead of all trust anchors may be intense
  - Least-recently used policy may help

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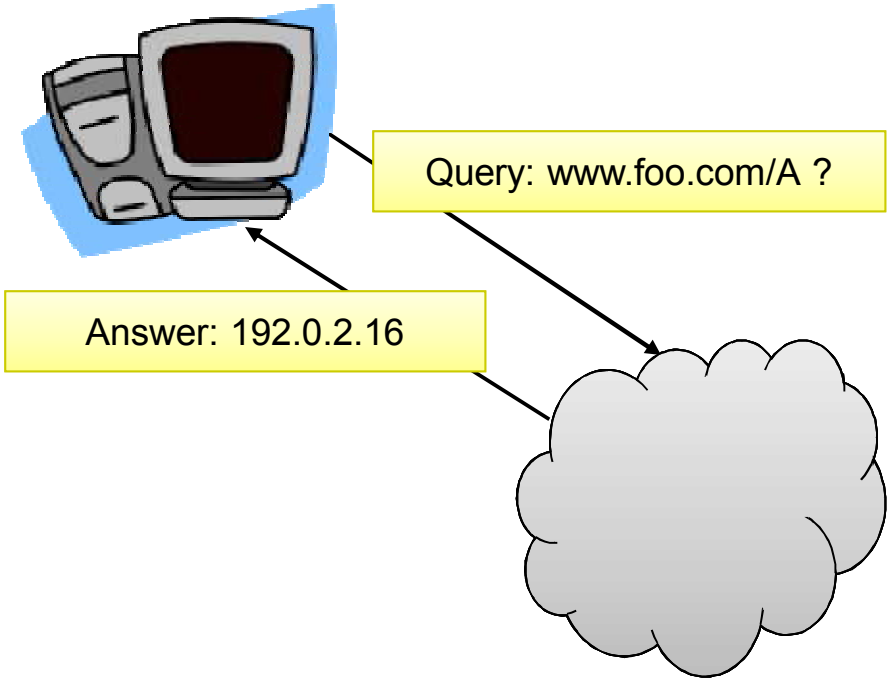
- DNS responses must be both accurate and available
- DNSSEC deployment requires careful deployment and maintenance
- Soft anchoring can mitigate effects of misconfiguration



Acknowledgements

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Questions?

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