Availability Problems in the DNSSEC Deployment

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Motivation: Why Use DNSSEC?

- DNS cache poisoning has been a known attack against DNS since the 1990s [1]
  - Now there is a new variant: the Kaminsky attack
- Patches to existing resolvers and name servers have helped mitigate recent threats
- However, DNSSEC offers a more structured solution to ensure data's origin authenticity and integrity
  - European operational efforts have (arguably) lead the way on the deployment front

Has DNSSEC Overstressed the DNS?

- DNSSEC added a lot to DNS packets
- We added crypto keys (DNSKEYs)
  - Anywhere up to 4,096 bits each
  - Zones should have at least 2 (ZSK + KSK) and maybe more
- We added crypto signatures (RRSIGs)
  - At least one in each RRset and sometimes one for each DNSKEY
  - Varying in size, based on DNSKEY sizes
- Resolvers and name servers need to send and receive these large DNS packets

- In this talk we examine a prominent availability problem in DNSSEC's deployment

Outline

- DNSSEC background
- The network path and large packets
- How SecSpider measures
- Observations
- What can be done

DNSSEC Background

- DNSSEC provides *origin authenticity, data integrity,* and *secure denial of existence* by using public-key cryptography
- Origin authenticity:
  - Resolvers can verify that data has originated from authoritative sources.
- Data integrity
  - Can also verify that responses are not modified in-flight
- Secure denial of existence
  - When there is no data for a query, authoritative servers can provide a response that proves no data exists

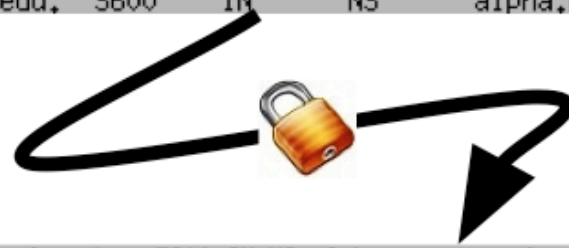
How DNSSEC Works

- DNSSEC zones create public/private keys
  - Public portion goes in DNSSEC record type: DNSKEY
- Zones sign all RRsets and resolvers use DNSKEYs to verify them
  - Each RRset has a signature attached to it: RRSIG
- So, once a resolver has a zone's DNSKEY(s) it can verify that RRsets are intact by verifying their RRSIGs

Signing Example

Using a zone's key on a standard RRset (the NS)

```
secspider.cs.ucla.edu.  3600    IN      NS      zinc.cs.ucla.edu.
secspider.cs.ucla.edu.  3600    IN      NS      alpha.netsec.colostate.edu.
```



Signature (RRSIG) will only verify with the DNSKEY if *no* data was modified

```
secspider.cs.ucla.edu.  3600 IN NS alpha.netsec.colostate.edu.
secspider.cs.ucla.edu.  3600 IN NS zinc.cs.ucla.edu.
secspider.cs.ucla.edu.  3600 IN RRSIG NS 5 4 3600 20080324024800 (
                              20080322024800 44736 secspider.cs.ucla.edu.
                              E4msde1nzVlfGvwDo2X6jLU5d9Xrk37lrYRCZN6yq5ad
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                              SgQWUYm86v8G7ABHHcI+YFD3z3eqSoAoBAE5ysafop1u
                              g7tw1J4xd/IADIVeu1HnVIKRSycILXzvCwcaDWwAd610
                              9oJUBSMgWZjGzYeJO9RzOoUUqIqtn9PgVOzdTm+WnRC3
                              LEz50fdoP743QvPhe7RrF9w1KA3MOptTiQA++W8Gg085
                              NhbJ7MD99nEYaEv3+GuDCTkCy5ZOWoI/2Bcjq1NGBDLo
                              71lo6udu72i1tpyRfTEEQUirpInlZ9+IMw== )
```

Large Message Support in DNSSEC

- Originally, DNS messages were limited to 512 bytes
  - Resolvers use EDNS0 “negotiation” (RFC 2671) to advertise how much DNS buffer space they have for DNS messages
- Name servers try to fit data into buffers of that size
  - If data won’t fit, servers indicate response is “truncated”
  - Resolvers should explore alternate message size, “…considered preferrable to the outright use of TCP…”
- Without exploration, both sides hope the path between them will tolerate UDP packets of that size
  - This can result in *false advertising*
- We will show that this has lead to problems

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The Network Path and PMTU

- A network path is a sequence of links
- Each link can only support packets of a certain size (MTU)
- The smallest MTU for a network path is its bottleneck, or its *Path Maximum Transmission Unit* (PMTU)

Further Complications with DNS' Large Packets

- DNS messages are further limited by "middle boxes" (firewalls, NAT, etc.)
  - Some firewalls drop "suspicious" DNS traffic
  - A recent study found this was quite common in SOHO routers [2]
- Because of middle boxes, network paths that may support large packets may fail to deliver large DNS messages
- We overload the term PMTU to apply in these cases too

How One Can Identify PMTU Problems

- Suppose a resolver advertizes a buffer size to a name server, but that size exceeds the PMTU
  - Result: message is dropped along the network path
- Distinguishing random drops from PMTU failures
  - Retry queries 3 times
- Distinguishing name server failures from PMTU failures
  - Reissue queries with different EDNS0 buffer sizes
  - Query from different network vantages
  - Verify the problem exists over time
  - Check if TCP works

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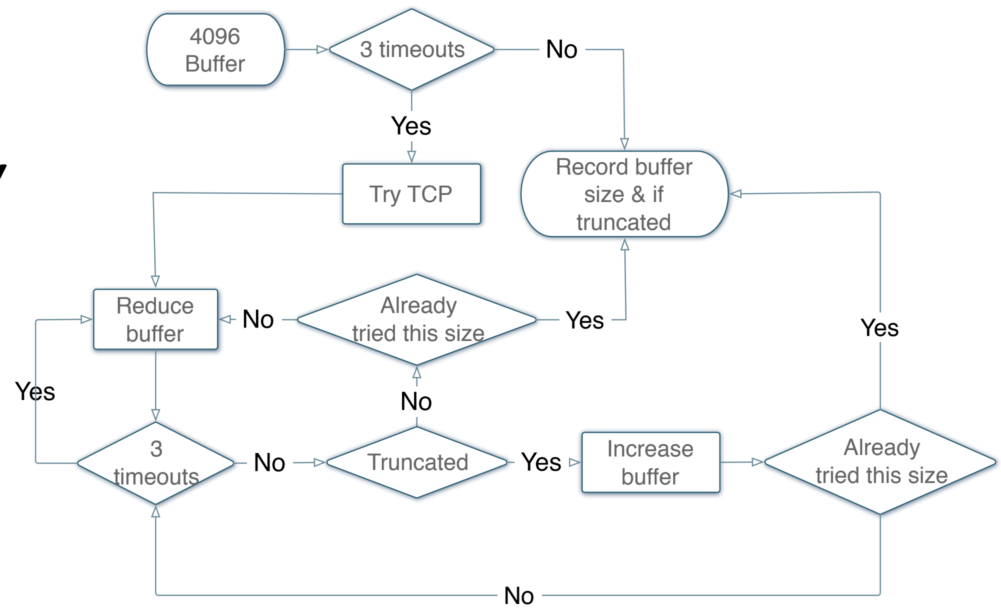
SecSpider's Vantage Points

- We poll all of our DNSSEC zones from 8 vantages in:
  - Europe
  - Asia
  - North America

- We're always looking for more
  - Please consider hosting a lightweight poller for us
  - Please drop me a note if you might be interested eoster@cs.ucla.edu

SecSpider's PMTU Walking

- To trigger a PMTU walk there must be 3 successive DNSKEY query timeouts
- After 3 timeouts, we try TCP
- Then we perform a binary search between 4,096 and 512 to see if any size will work
  - Find out precisely what size works before a failure or truncation



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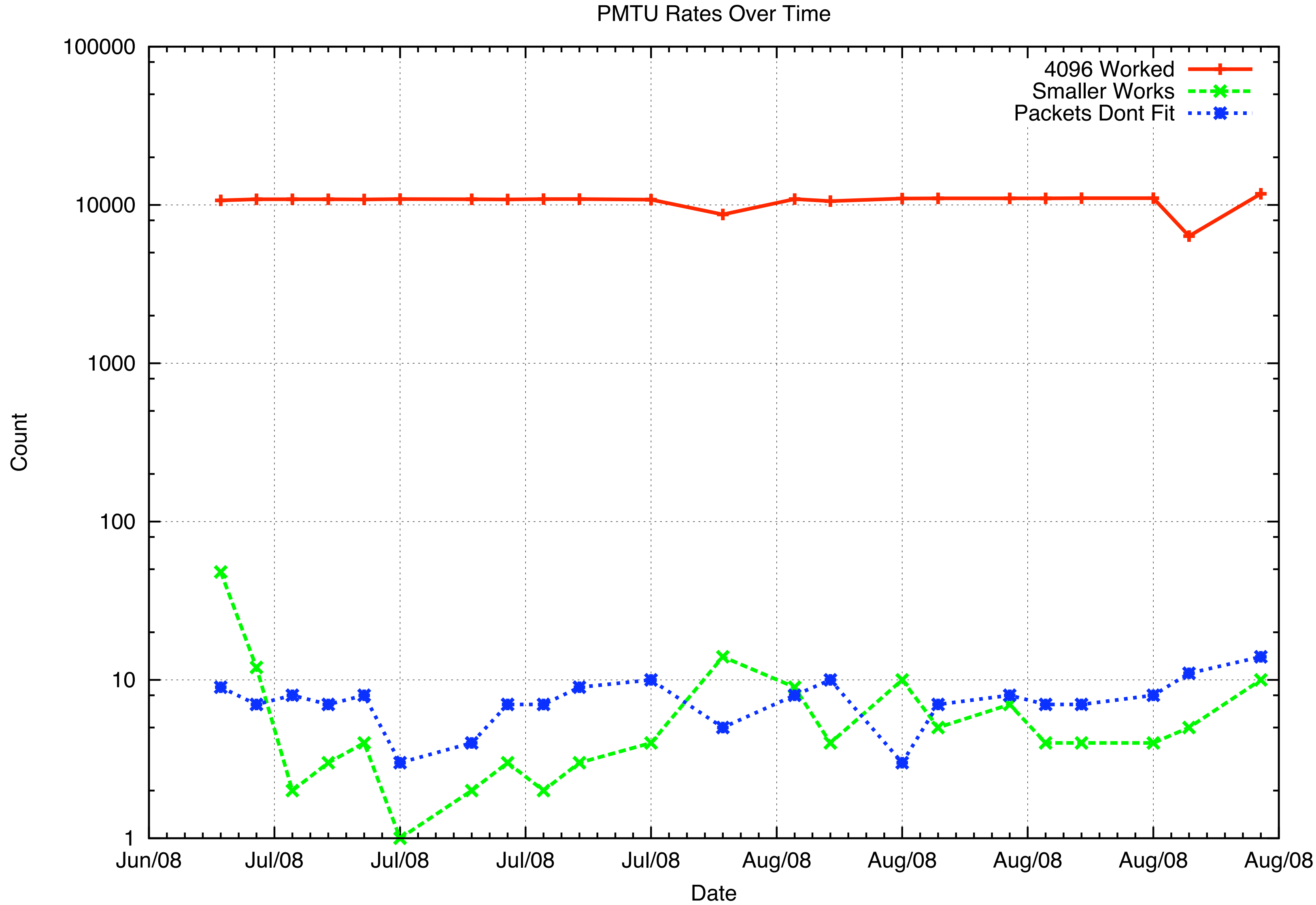
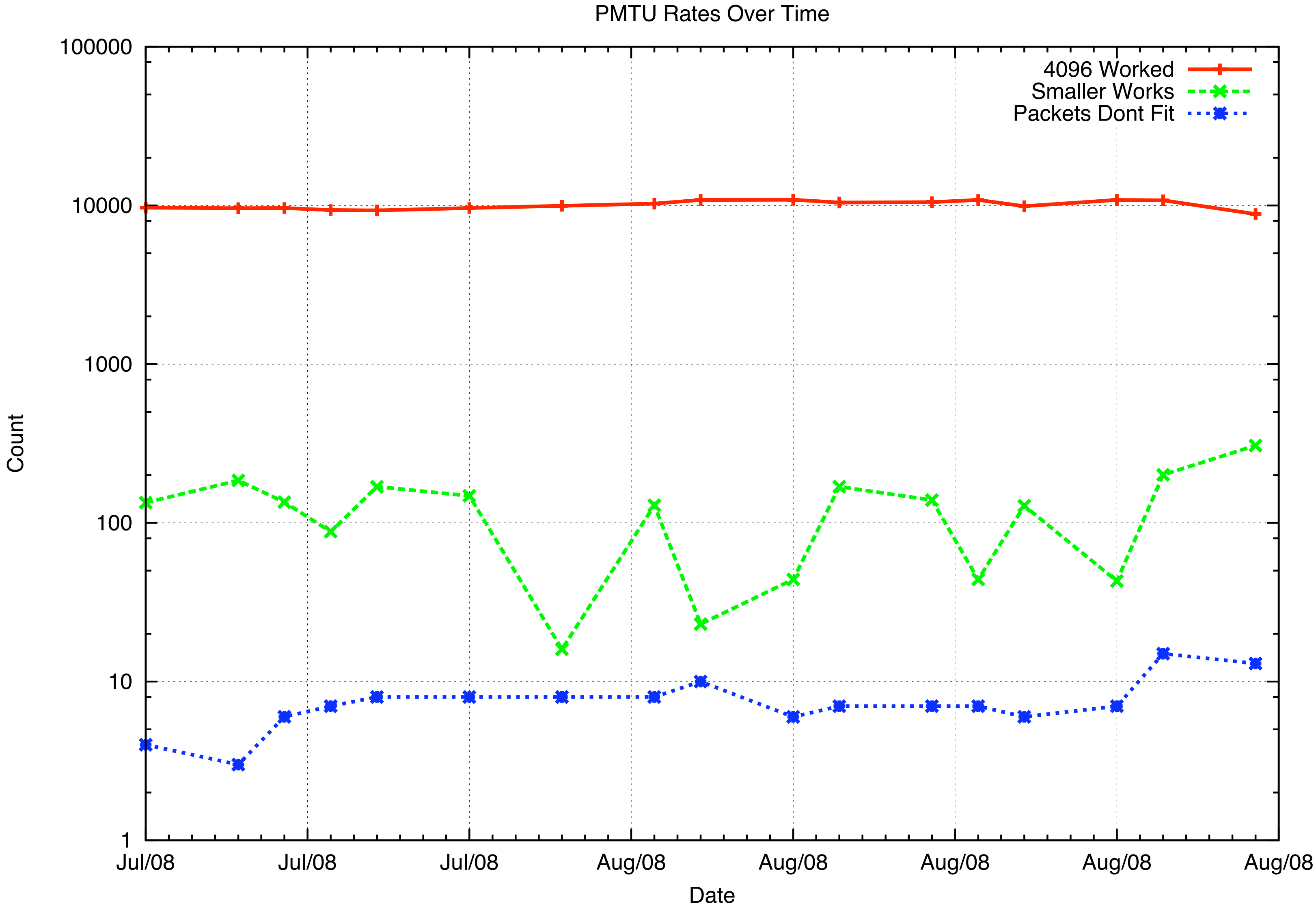
What We Have Observed

- A recent study [4] showed that roughly 60% of queries seen at one root server advertise buffer sizes of 4,096
- In this talk we use our distributed pollers to illustrate:
  - How often does the default behavior of using 4,096 byte buffers work for DNSSEC
  - When it fails, is it possible to advertise smaller buffer sizes that will work
  - How often are key sets just too large to fit over paths
- To illustrate, consider how different 2 pollers results' can be
  - For example, NL NetLabs and a SOHO router (cable modem)

NL NetLabs Poller



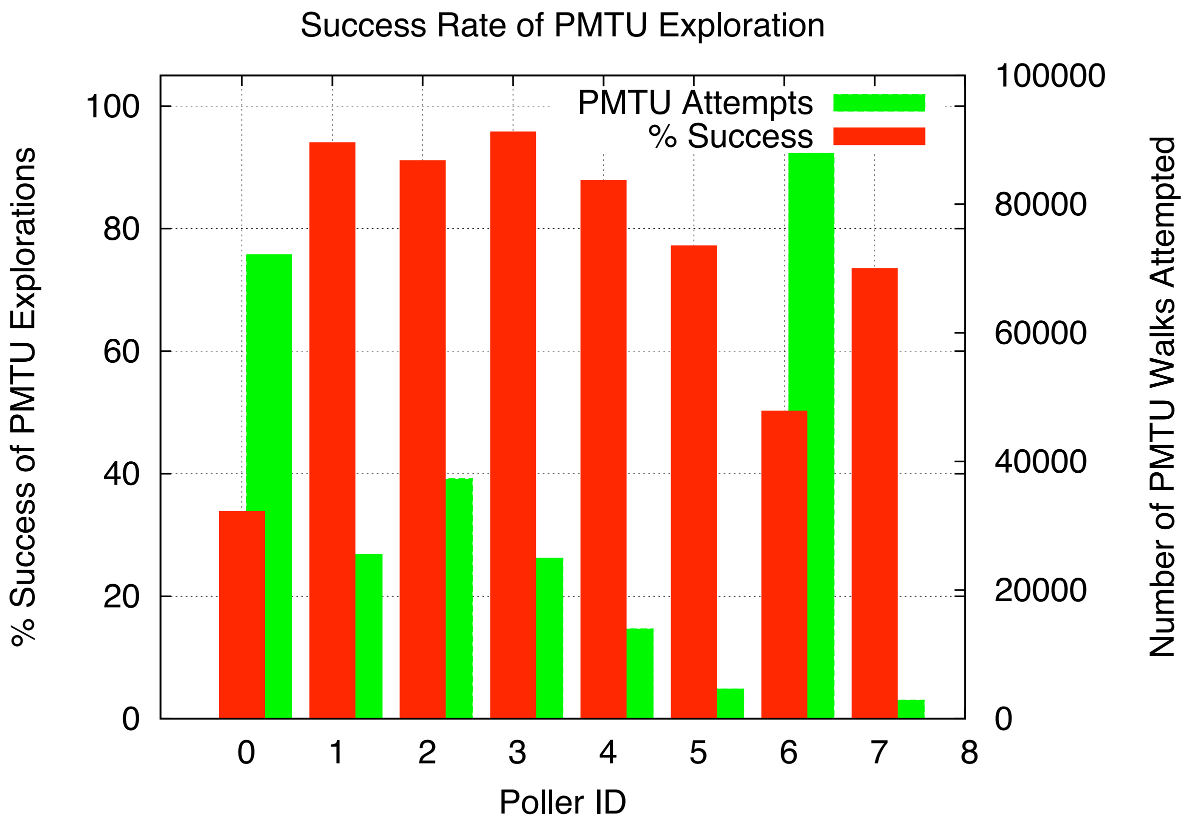
SOHO Router in Los Angeles



It Matters Where You Look From

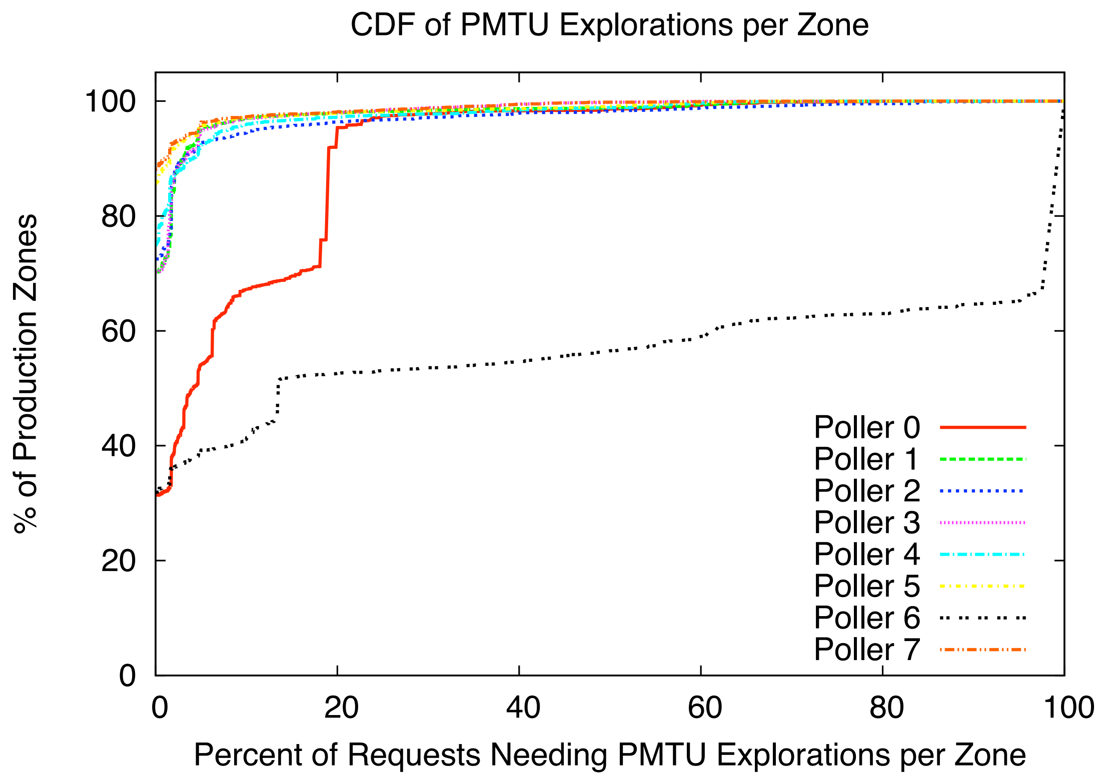
- NL NetLabs only has trouble with roughly 10 zones (for the most part)
- However, at the same time, our SOHO router has PMTU problems with roughly 100 zones

As Seen From All of Our Pollers



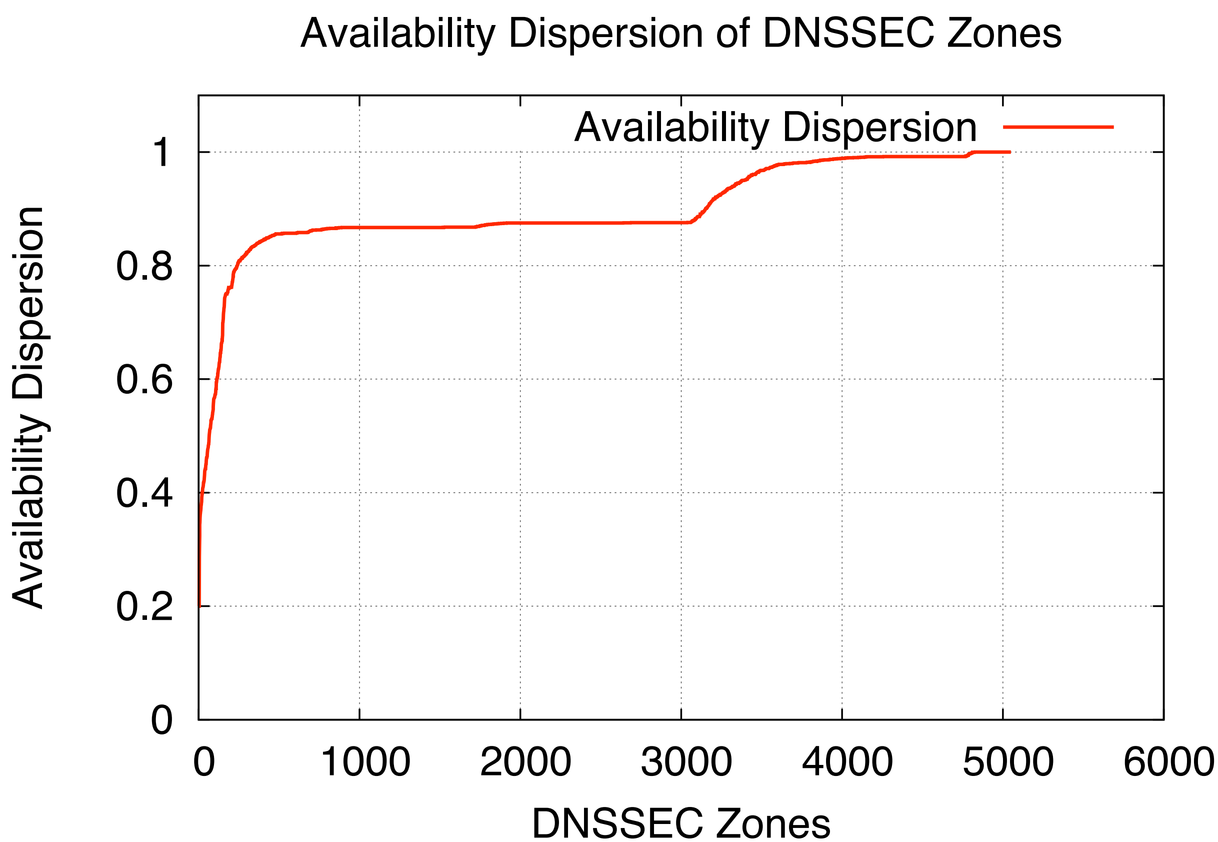
- Green bars indicate the number of times a poller needed to do a PMTU walk
- Red bars indicate the percentage of times a PMTU was was able to find a buffer size the allowed DNSKEYs to be received

How Many Zones Have Trouble?



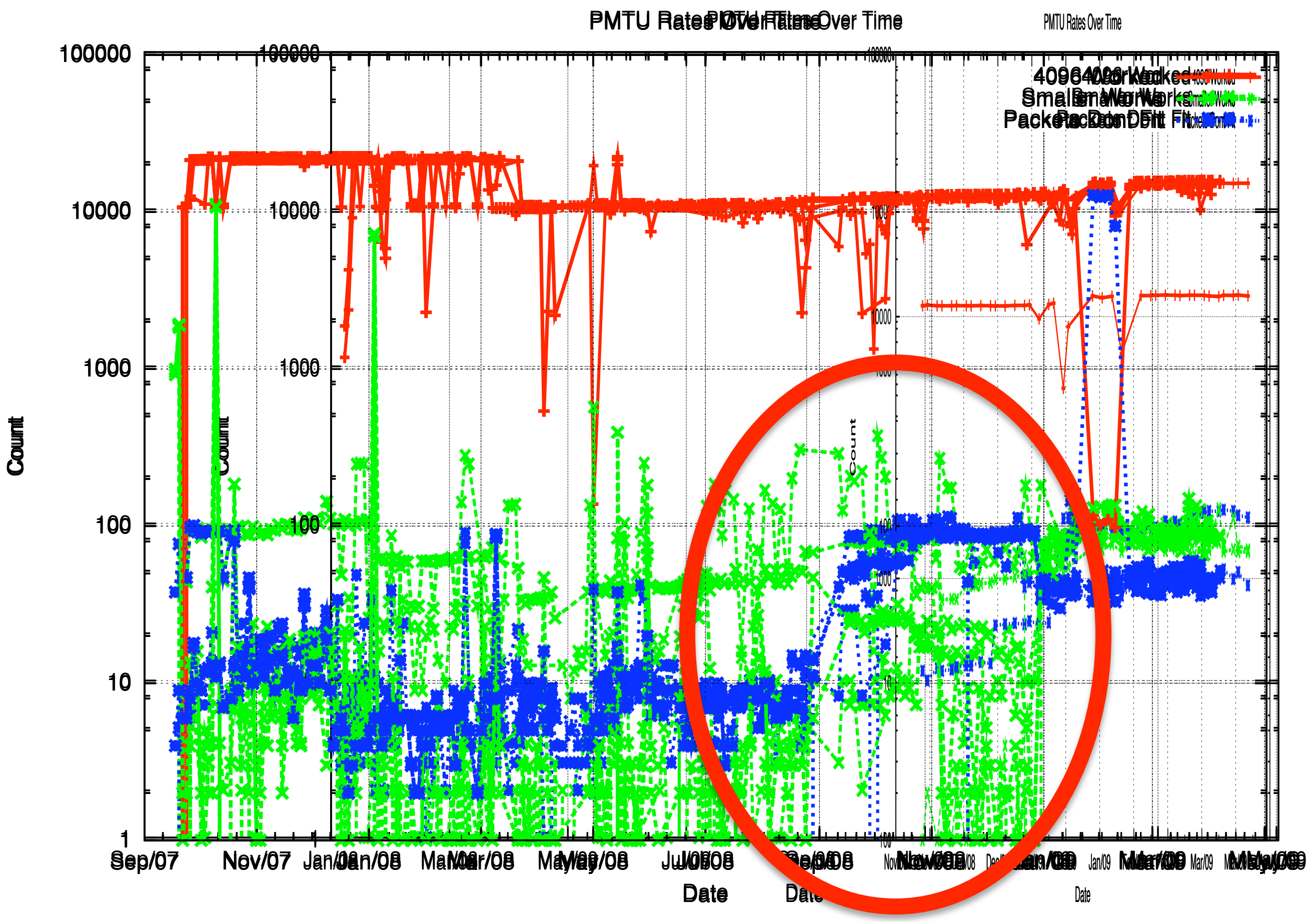
- Fraction of queries (x-axis) that cause PMTU exploration (y-axis)
- For Ex: from poller 0: ~70% of the production zones only need PMTU walks ~20% of the time (or less)
- Poller 6: ~60% of the zones need PMTU walks up to 90% of the time

More Succinct



- We use a metric from [3] to quantify the "availability dispersion" of each zone
  - Captures how different each poller's view of each zone is
- Using a weighted average over time, we see that most zones have suffered dispersion

Something Interesting…



A Correlated Jump in Walks

- In September of 2008, roughly 100 zones began serving DNSKEYs that didn't "fit" their PMTUs
- In November, availability seems restored, but only with PMTU walks
- Still investigating causes, but zones can check their status at
  - http://secspider.cs.ucla.edu/

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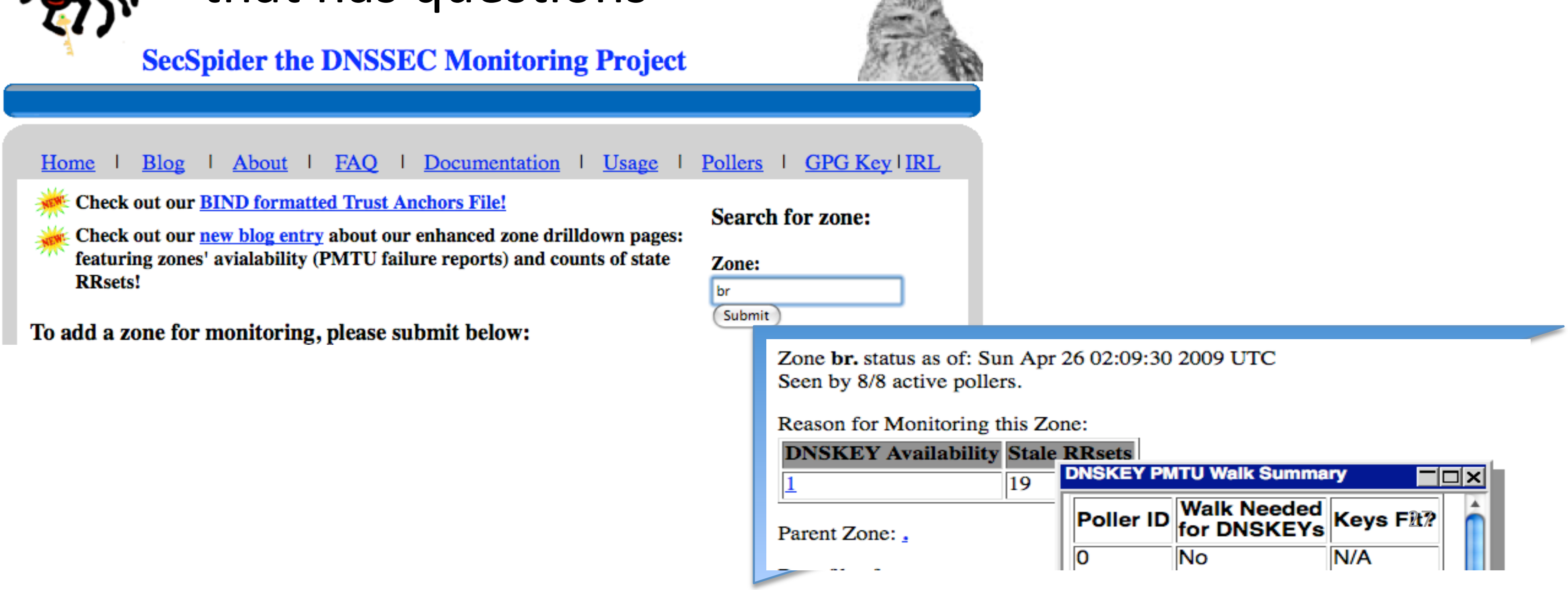
What Can be Done (Tactically)

- Check your zones' availability at: http://secspider.cs.ucla.edu/
  - We are more than happy to work with anyone that has questions



What Can be Done (Strategically)

- Try different DNSKEY configurations then monitor and observe availability through SecSpider
- Use results to collaborate on best-practices documents
- Continue to raise awareness of the problem
- Develop availability dispersion and PMTU recommendations

Summary

- We use Availability dispersion to allow us to expresses how different all of the resolvers' views are
- Distributed monitoring needs to be a service that lets zone operators to assess their zones' availability dispersion
- SecSpider been helping to reveal problems (such as a spike in PMTU walks) before they become insurmountable challenges to the deployment

References

1 Bellovin, S. M. 1995. Using the domain name system for system break-ins. USENIX UNIX Security Symposium 1995

2 http://download.nominet.org.uk/dnssec-cpe/DNSSEC-CPE-Report.pdf

3 Osterweil, E., Ryan, M., Massey, D., and Zhang, L. 2008. Quantifying the operational status of the DNSSEC deployment. ACM SIGCOMM Conference on Internet Measurement. IMC '08

4 https://www.dns-oarc.net/node/146

Thank You

Questions?