The DNS security mess

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The Domain Name System

`fsf.org` wants to see
`http://www.redhat.com`.

Browser at `fsf.org`

“The web server
`www.redhat.com`
has IP address
96.6.144.112.”

Administrator at `redhat.com`

Now `fsf.org`
retrieves web page from
IP address 96.6.144.112.

Same for Internet mail.

`fsf.org` has mail to deliver to `someone@redhat.com`.

Mail client at `fsf.org`

↑

"The mail server for
`redhat.com`
has IP address
66.187.233.32."

Administrator at `redhat.com`

Now `fsf.org`
delivers mail to
IP address 66.187.233.32.

Forging DNS packets

`fsf.org` has mail to deliver to `someone@redhat.com`.

Mail client at `fsf.org`

"The mail server for
`redhat.com`
has IP address
157.22.245.20."

Attacker anywhere on network

Now `fsf.org`
delivers mail to
IP address 157.22.245.20,
actually the attacker's machine.

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"No sniffers on *my* network!" . . . so a blind attacker guesses the bits to repeat, eventually gets lucky. After analysis, optimization: blind forgery is about as easy as downloading a movie.

Amazing news

Tuesday 2 June 2009:
“.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.”

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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!

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… or is it?

Let's find a `.org` server:

```
$ dig +short ns org
d0.org.afilias-nst.org.
b0.org.afilias-nst.org.
a0.org.afilias-nst.info.
c0.org.afilias-nst.info.
b2.org.afilias-nst.org.
a2.org.afilias-nst.info.

$ dig +short \
b0.org.afilias-nst.org
199.19.54.1
```

Look up one of my domains:

```
$ dig \
www.mwisc.org @199.19.54.1
```

Everything looks normal:

```
;; AUTHORITY SECTION:
mwisc.org. 86400
  IN NS d.ns.mwisc.org.
mwisc.org. 86400
  IN NS f.ns.mwisc.org.
;; ADDITIONAL SECTION:
d.ns.mwisc.org. 86400
  IN A 131.193.36.21
f.ns.mwisc.org. 86400
  IN A 131.193.36.24
```

Now ask for signatures:

```
$ dig +dnssec \
www.mwisc.org @199.19.54.1
```

Same answer as before,
plus four new records:

```
h9p7u7tr2u91d0v0ljs9l1gid
np90u3h.org. 86400 IN TYP
E50 \#39 0101000104D399EA
AB148A77C7ACEFCBC55446032
B2D961CC5EB6821 EF2600072
200000000290

h9p7u7tr2u91d0v0ljs9l1gid
np90u3h.org. 86400 IN RRS
```

IG TYPE50 7 2 86400 20090
70721303120090623203031 3
7493 org. lkzaiDXNZExggNf
W3PFLNRP8WPTECXUWH0tktDjX
thkE60pm6LoT0rRq TgfwK7NS
4GjN98rwqKH7iCfRr09CJ1BzC
XIdtWn5W0T0mtgwp413YF2O r
OO6RmDbXzbPcA5NXTsMk6b7fL
AHzRYEPBdBt1x3XJAZAPkrBPN
7dx2W w+g=

1b8fe79t5m6vkn6eo6s0n3gb7
mls aicq.org. 86400 IN TY
PE50 \#38 010100010 4D399E
AAB140ADEA6FED9985FAABFED

FA1D4E4B147C5D83 D2C90006
40000000002

1b8fe79t5m6vkn6eo6s0n3gb7
mlsaicq.org. 86400 IN RRS
IG TYPE50 7 2 86400 20090
701154428200906171444283
7493 org. Yv5+u5gugBuwP7V
r2PE5/LdLIbi5GuWr8j9wl0pI
ExHBrYbL+BkD7Nv6 Lhah0v7i
nS1yhgmLJC8ySj5gMghnZXxzP
v6WvQlcjUj1nukPtU+tqUXE s
KwAdzgizMu14qM36UMMhl8P3U
W4YzAJdoplJk9Ml3Oo7bYMdS3
P5gC3 F0w=

These `.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.

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What about serious attackers
using many more computers?
e.g. botnet operators?

I say:
Using RSA-1024 is irresponsible.

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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.

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` says "`.org` might have data with hashes between `1b39ggevfp3b72r9r901o1osqddn4ben` and `1bfadvmpj1fqlfvdv8eksiokfheo7km9` 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."

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"DNSSEC:
Fifteen years of development.
Millions of dollars of
U.S. government grants
(DISA, NSF, DHS, etc.).
Hundreds of users."

What went wrong?

Some of the Internet's DNS servers are extremely busy: e.g., the root servers, the `.com` servers, the `google.com` servers.

Can they afford crypto? Hmmm. DNSSEC tries to minimize server-side costs by *precomputing* signatures of DNS records. "No per-query crypto."

Signature is computed once; saved; sent to many clients. Hopefully the server can afford to sign each DNS record once.

Clients don't share the work of *verifying* a signature.

DNSSEC tries to reduce client-side costs through choice of crypto primitive.

Many DNSSEC crypto options: 640-bit RSA, original specs; 768-bit RSA, many docs; 1024-bit RSA, current RFCs (for "leaf nodes in the DNS"); DSA, "10 to 40 times as slow for verification" but faster for signatures.

DNSSEC made breakable choices
such as 640-bit RSA
for no reason other than
fear of server overload.

DNSSEC needed more options
to survive the inevitable breaks.

Profusion of options made
DNSSEC crypto complicated,
hard to review for bugs.

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

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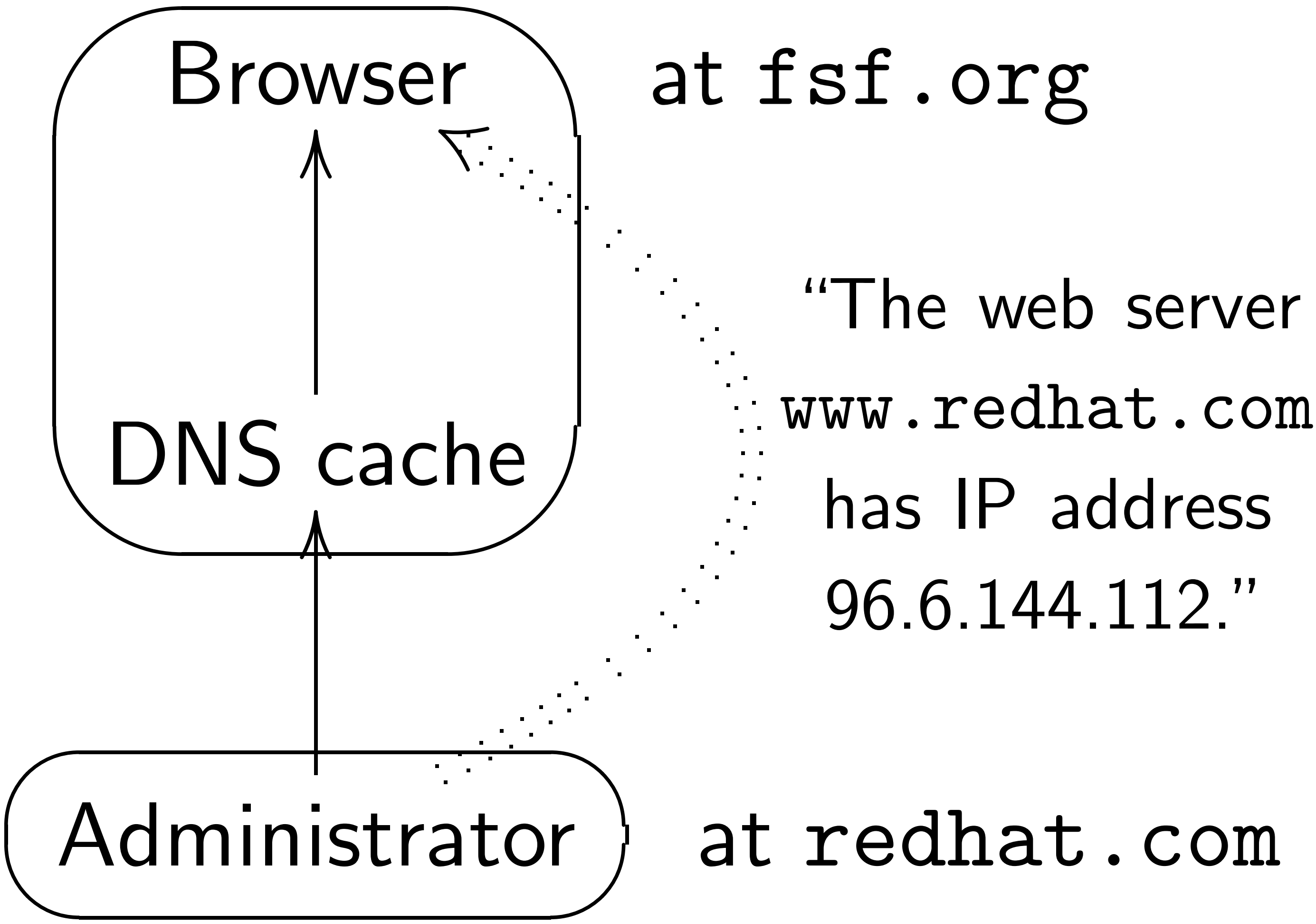
DNSSEC's fear of overload forced DNSSEC down a path of unreliability, insecurity, and unusability. This is why DNSSEC has been a failure.

My main point Saturday:
Per-query crypto leads to a much simpler protocol with much higher reliability,
much higher security,
and much higher usability.
Can still handle the loads using state-of-the-art crypto.

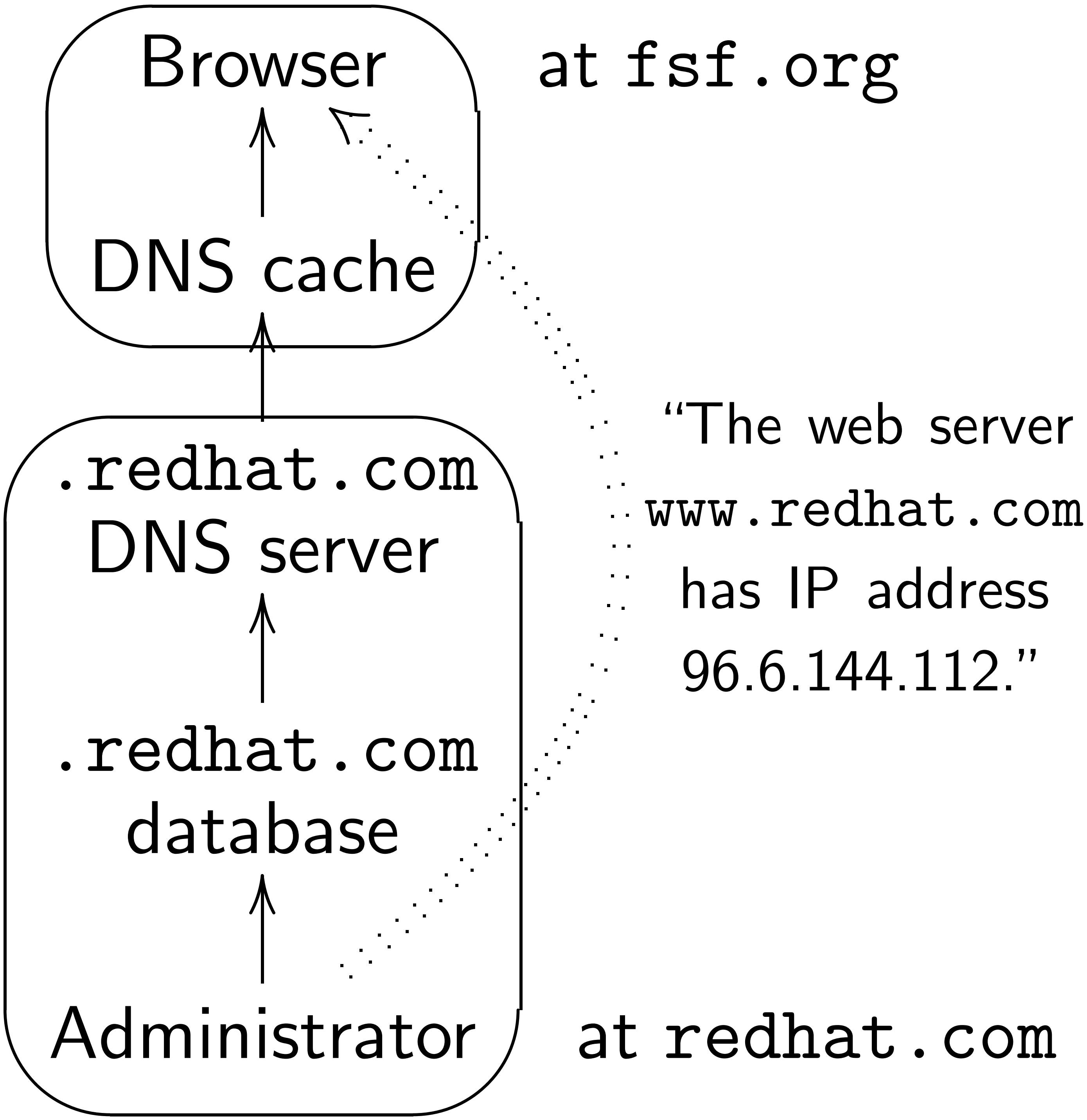
DNS architecture

Browser pulls data from DNS cache at `fsf.org`:

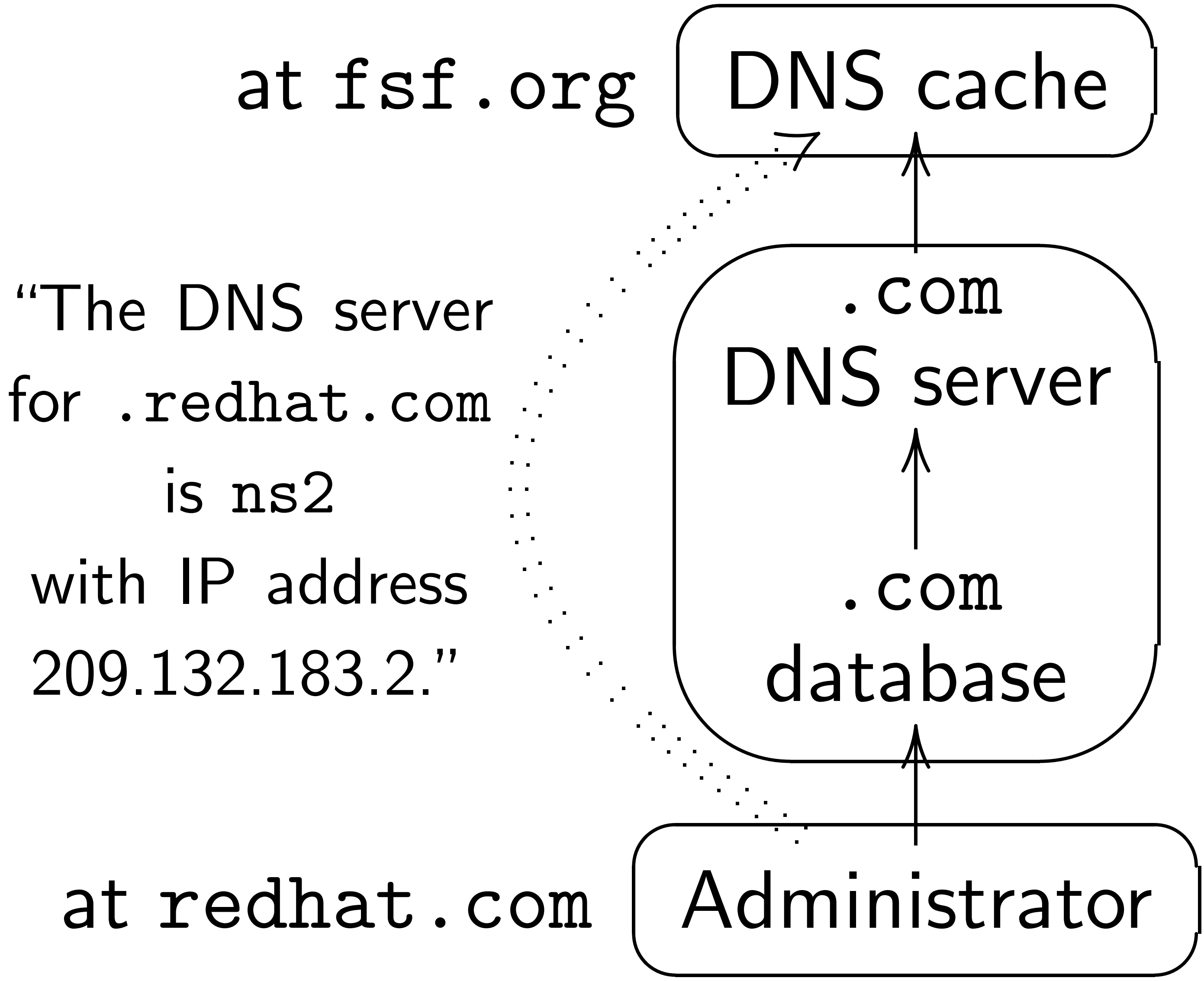


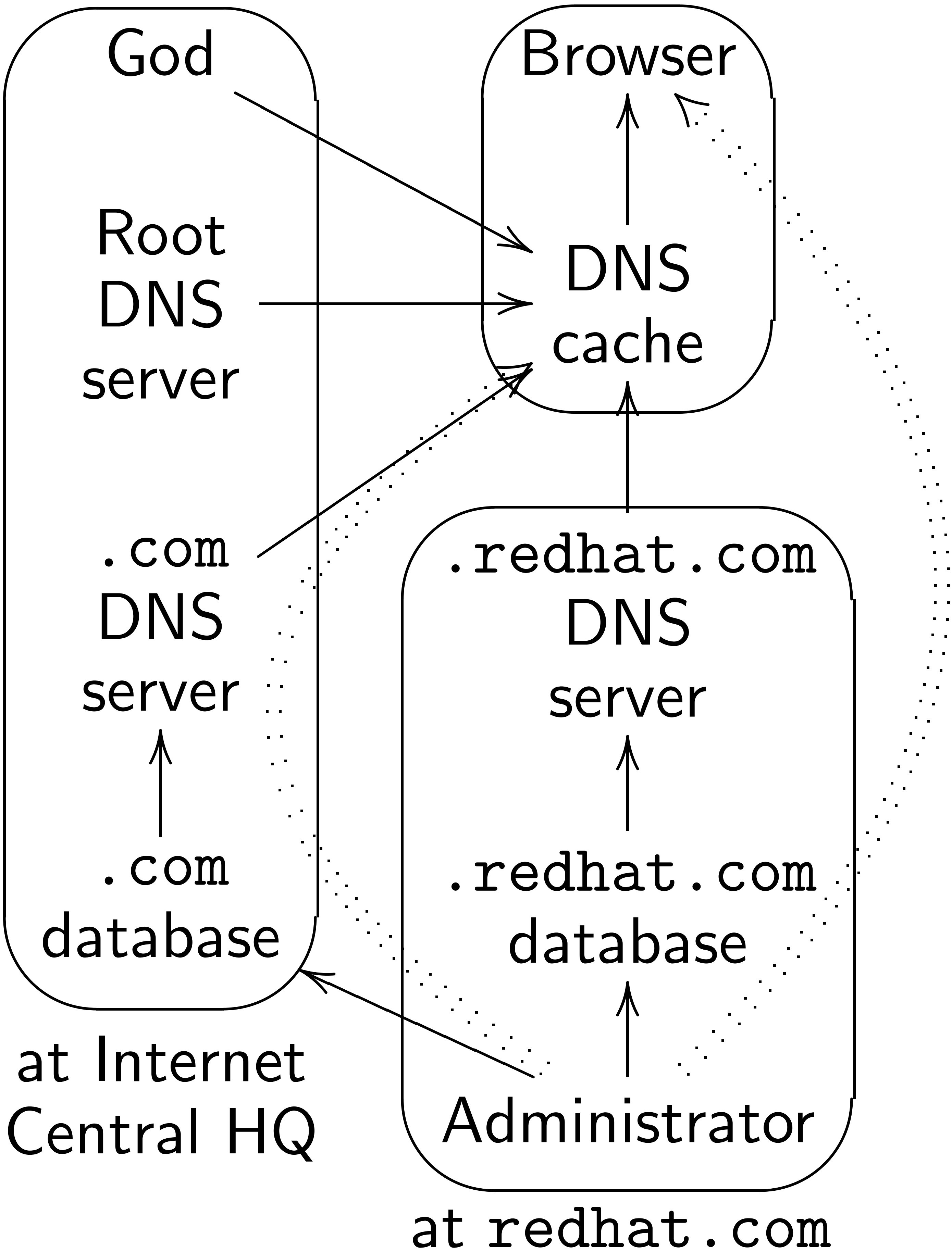
Cache pulls data from administrator if it doesn't already have the data.

Administrator pushes data through local database into `.redhat.com` DNS server:



DNS cache learns location of `.redhat.com` DNS server from `.com` DNS server:




God
Root
DNS
server
.com
DNS
server
.com
database
at Internet
Central HQ
Browser
DNS
cache
.redhat.com
DNS
server
.redhat.com
database
Administrator
at redhat.com

DNS server software listed in Wikipedia: BIND, Microsoft DNS, djbdns, Dnsmasq, Simple DNS Plus, NSD, PowerDNS, MaraDNS, ANS, Posadis, Secure64 DNS.

DNS database-management tools listed by 2008 Salomon: BPP, DNS Boss, DNStool, `gencidrzone`, `h2n`, `makezones`, NSC, `nsupdate`, SENDS, `updatehosts`, Utah Tools, `webdns`, `zsu`. Plus hundreds of homegrown tools written by DNS registrars etc.

DNSSEC changes everything

DNSSEC requires new code in every DNS-management tool.

Whenever a tool adds or changes a DNS record, also has to precompute and store a DNSSEC signature for the new record.

Often considerable effort for the tool programmers.

Example: Signing 2GB database can produce 10GB database (2005 NIST study).
Tool reading database into RAM probably has to be reengineered.

Administrator also has to send public key to `.com`.

The `.com` server
and database software
and web interface
need to be updated
to accept these public keys
and to sign everything.

DNS cache needs new software
to fetch keys, fetch signatures,
and verify signatures.

Tons of pain for implementors.
Still many gaping holes
after fifteen years of work.

Example: `.org` has no way
to receive DNSSEC public keys
from `*.org` users
(via, e.g., `joker.com`).

Example: `.org` software
can't manage signatures
for millions of `.org` records.
Much too slow, much too big.

Replay attacks

Attacker inspects DNSSEC signatures from `redhat.com`.

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

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Attacker buys the old addresses, forges DNS responses with the *old* DNS records and the *old* signatures. Passes signature verification. Successfully steals mail!

DNSSEC has a partial defense.
Signature has an expiration date,
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for up to 30 days.

Plus extra code: re-sign
before old signatures expire.

Any mistakes destroy your domain
("DNSSEC suicide"). 2009:
This happened to all ISC DLV
DNSSEC users. UCLA admin:
"The solution in all cases was to
disable DNSSEC validation."

Another type of replay:

`www.redhat.com` is actually published by Akamai.

Client in Brazil asks for `www.redhat.com`.
Akamai responds with IP address in Sao Paulo.

Attacker replays same response to user in Berlin.
User expected fast, reliable connection to a nearby server; receives slow, unreliable connection across the ocean.

Expiration dates don't help.

Query espionage

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`http://dnscurve.org/espionage.html` has a simple `dnsoutloud` script combining `tcpdump`, `text2wave`, and `play`.

Would any DNSSEC proponent like to run `dnsoutloud` in a busy Internet cafe with the volume turned up?

Database espionage

Privacy-violating speed:

$\approx 2^{29}$ noisy guesses/day:
DNS today.

$> 2^{40}$ silent guesses/day,
many more with large botnet:
Current DNSSEC (NSEC3).

Instantaneous: Old DNSSEC,
or DNS with public AXFR.

DDoS amplification

```
dig +bufsize=4096 +dnssec
any se @a.ns.se
```

To Sweden: 31-byte UDP packet.
From Sweden:
3974-byte UDP packet.

```
dig +bufsize=4096 +dnssec
any br @a.dns.br
```

To Brazil: 31-byte UDP packet.
From Brazil:
1621-byte UDP packet.

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Recompute and store signature
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Dynamic content? Give up.

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Replay attacks work for 30 days.
Filename guessing is much faster.
Nothing is encrypted.
Denial of service is trivial.

Security review

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Availability: Bad today.
With DNSSEC, much worse.