DNSSEC and DNSCurve

D. J. Bernstein
University of Illinois at Chicago

The Domain Name System

`ibm.com` wants to see `http://www.mnit.ac.in`.

Browser at `ibm.com`

"The web server `www.mnit.ac.in` has IP address 210.212.97.131."

Administrator at `mnit.ac.in`

Now `ibm.com` retrieves web page from IP address 210.212.97.131.

Same for Internet mail.

`ibm.com` has mail to deliver to `someone@mnit.ac.in`.

Mail client at `ibm.com`

“The mail server for `mnit.ac.in` has IP address 210.212.97.131.”

Administrator at `mnit.ac.in`

Now `ibm.com` delivers mail to IP address 210.212.97.131.

Forging DNS packets

`ibm.com` has mail to deliver to `someone@mnit.ac.in`.

Mail client at `ibm.com`

“The mail server for
`mnit.ac.in`
has IP address
157.22.245.20.”

Attacker anywhere on network

Now `ibm.com`
delivers mail to
IP address 157.22.245.20,
actually the attacker’s machine.

Actually: Client sends query;
attacker has to repeat
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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.

Some general questions

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"The Internet does
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an SSL connection to my bank."

Indeed, many connections
use SSL, Skype, etc.
But *most* connections don't.

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In fact, attackers are forging packets *and* exploiting buffer overflows *and* doing much more. Users want *all* of these problems fixed.

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"It's too easy to write Internet software that exchanges data without any cryptographic protection. Most Internet clients and servers don't know how to make cryptographic connections."

True for most protocols.
But let's focus on HTTP.
Most HTTP servers and browsers (Apache, Internet Explorer, Firefox, etc.) support SSL.

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Indeed, usability is a major issue. Only $\approx$1% of the Apache servers on the Internet have SSL enabled.

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If you connect to
`https://www.google.com`,
Google redirects your browser to
`http://www.google.com`.

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Many companies sell
SSL-acceleration hardware,
but that costs money too.

Why are cryptographic computations so expensive?

Can crypto be faster, without being easy to break?

Can crypto be fast enough to solidly protect all of Google's communications?

Can crypto be fast enough to protect every Internet packet?

Can universal crypto be *usable*?

What cryptography can do

Cryptography can
stop sniffing attackers
by scrambling legitimate packets.

Cryptography is often described
as protecting confidentiality:
attackers can't understand
the scrambled packets.

Can also protect integrity:
attackers can't figure out
a properly scrambled forgery.

Traditional cryptography requires each legitimate client-server pair to share a secret key.

Public-key cryptography has much lower requirements. (1976 Diffie–Hellman; many subsequent refinements)

Each party has one public key. Two parties can communicate securely if each party knows the other party's public key.

1993: IETF begins "DNSSEC" project to add public-key signatures to DNS.

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Surveys by DNSSEC developers, last updated 2009.03.12, have found 253 `*.com` names with DNSSEC signatures. 116 on 2008.08.20; $253 > 116$.

Why is nobody using DNSSEC?

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

DNSSEC tries to minimize server-side costs by *precomputing* signatures of DNS records.

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.

DNSSEC RFCs
say DSA is "10 to 40 times as slow for verification" as RSA;
recommend RSA "as the preferred algorithm" for DNSSEC;
suggest RSA key size
of only 1024 bits
for "leaf nodes in the DNS."

I say:
1024-bit RSA is irresponsible.

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

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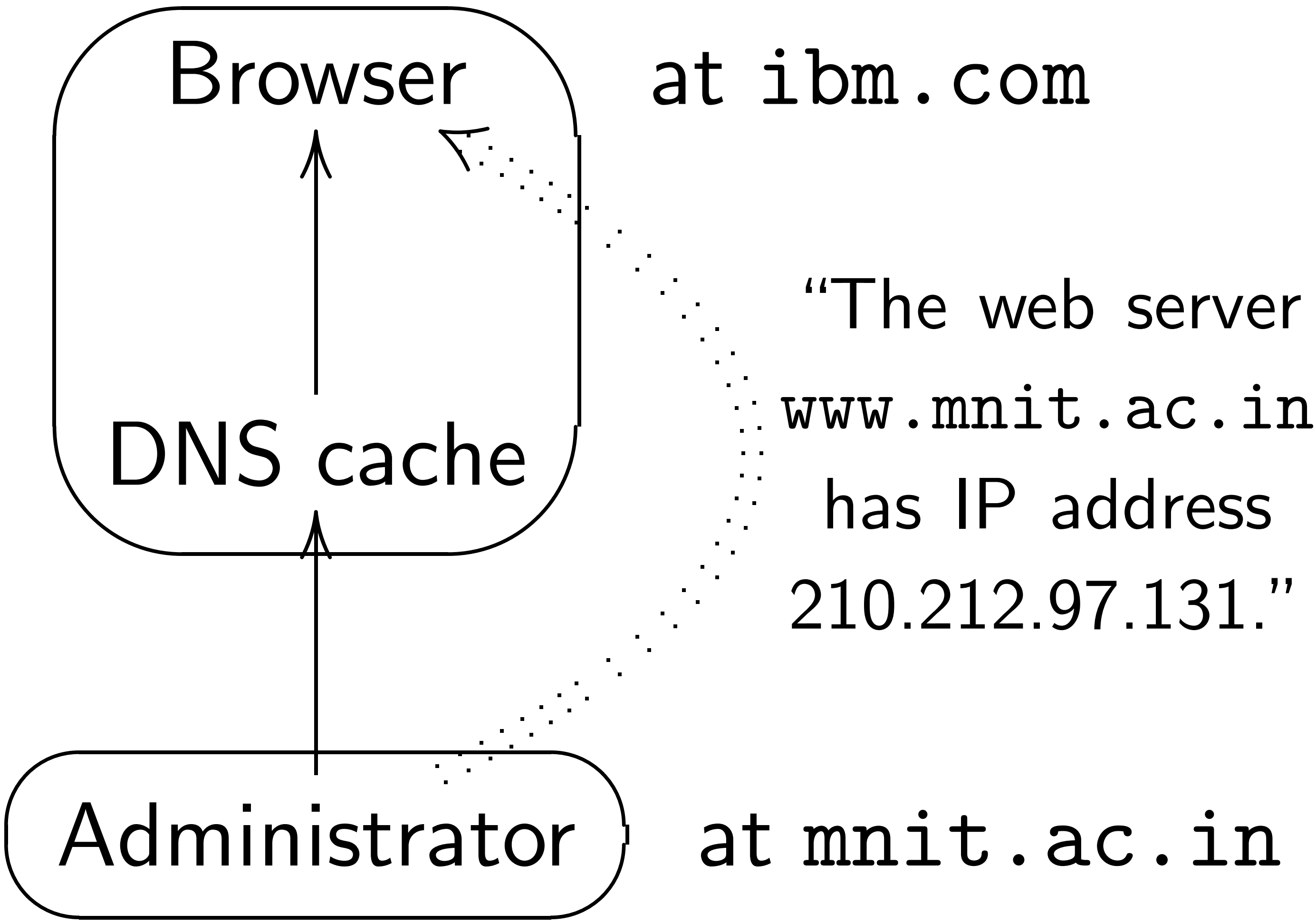
But *most users don't know this*. Why aren't they using DNSSEC?

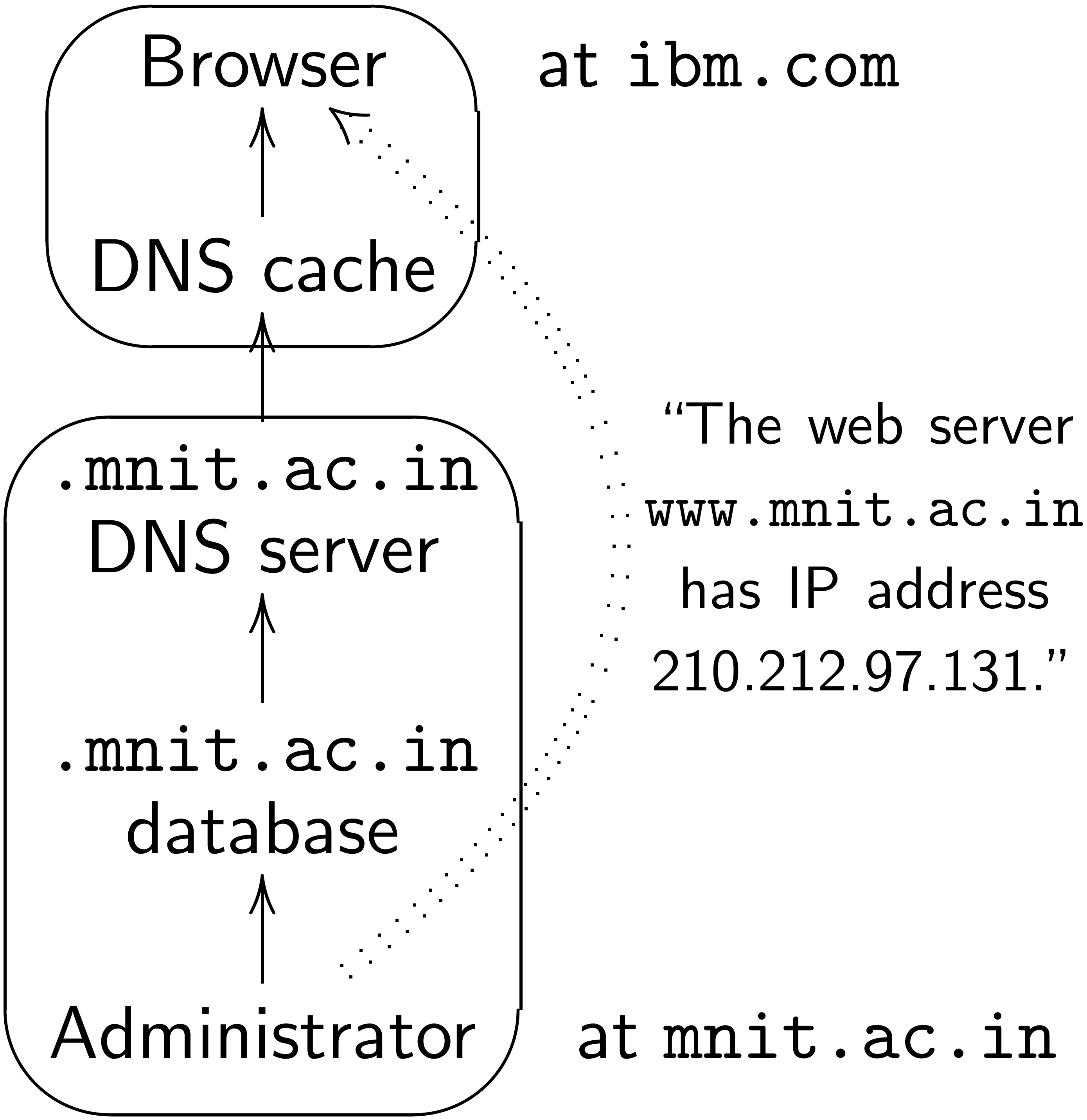
DNS architecture

Browser pulls data from DNS cache at `ibm.com`:

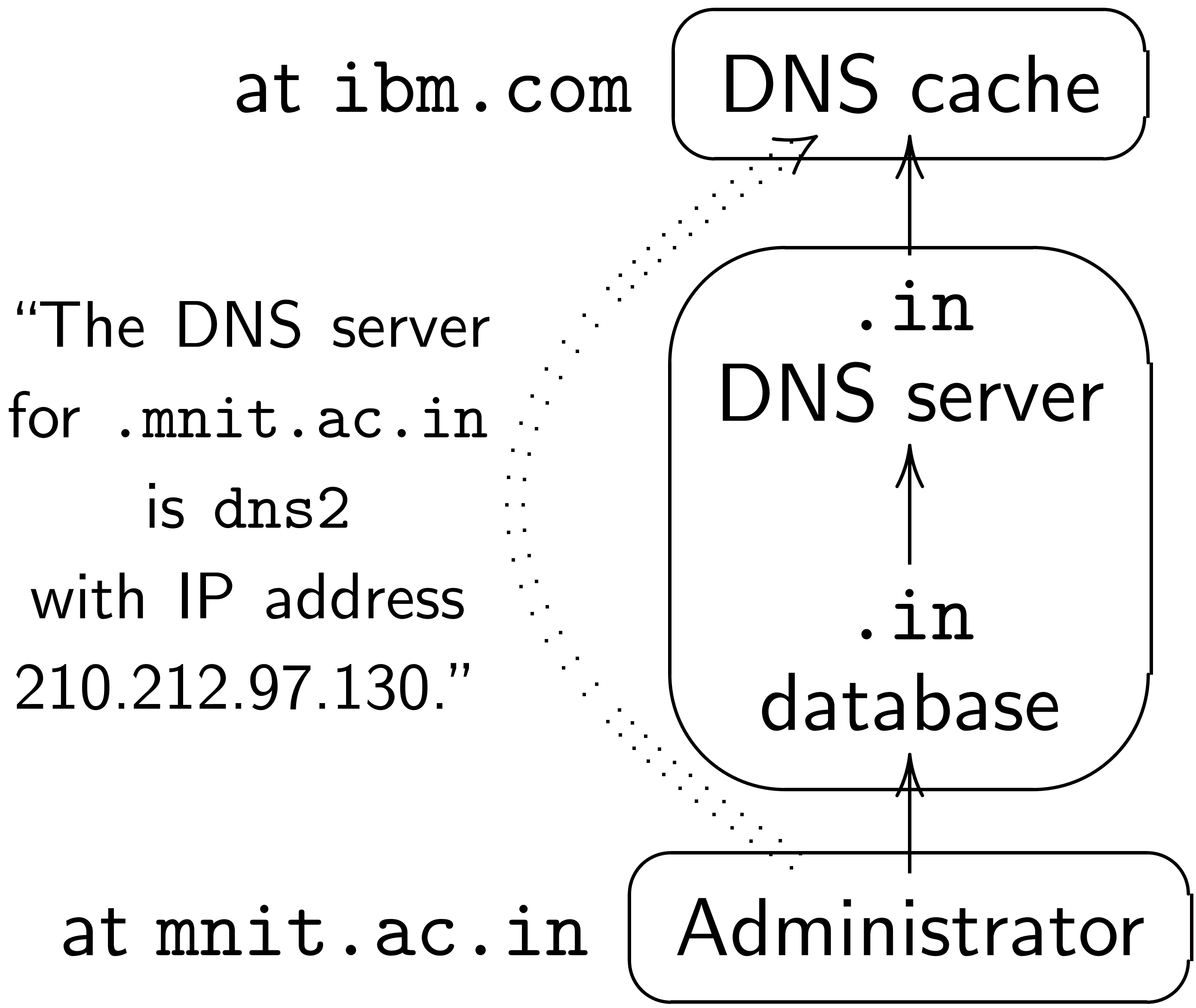


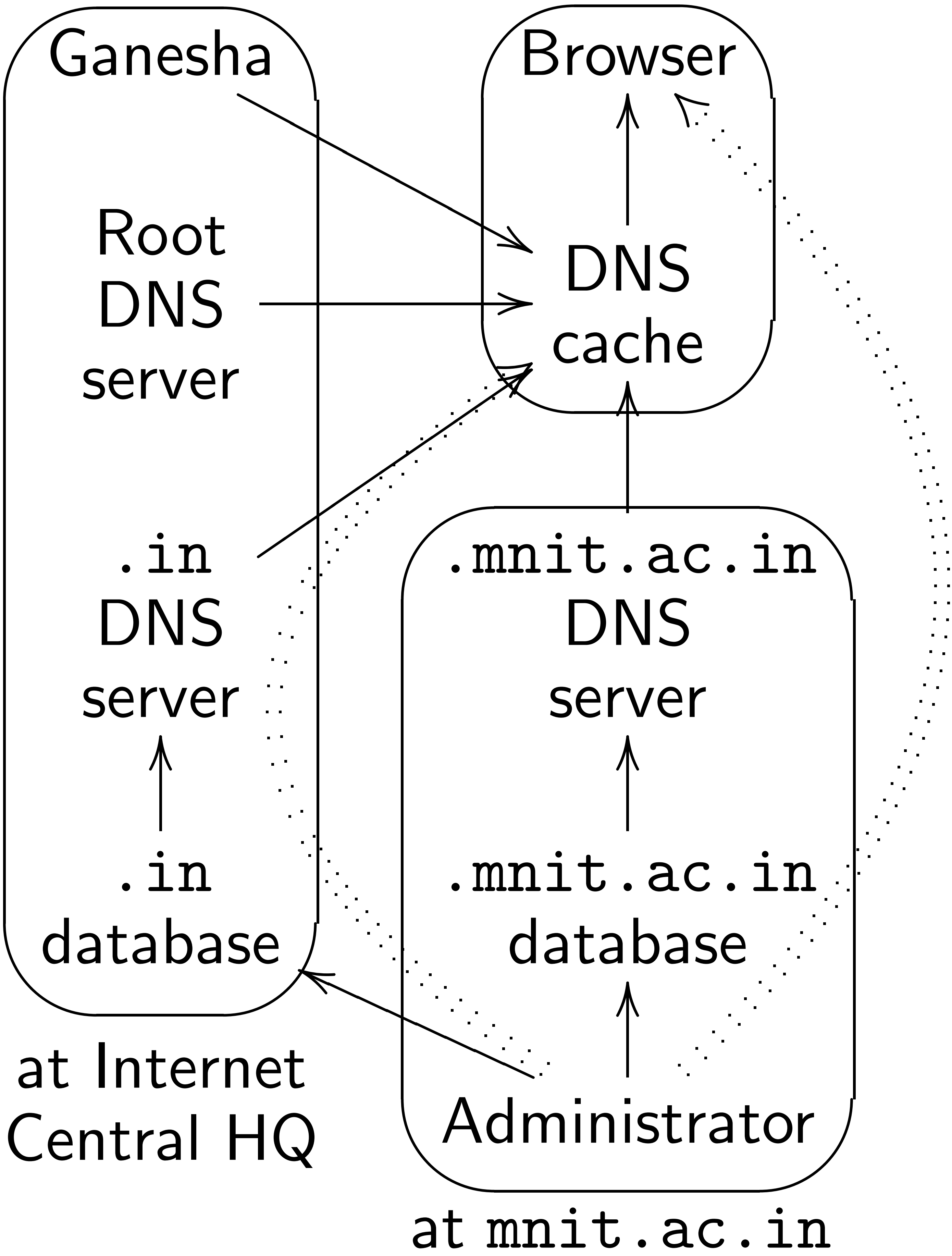
Cache pulls data from administrator if it doesn't already have the data.

Administrator pushes data through local database into `.mnit.ac.in` DNS server:



DNS cache learns location of `.mnit.ac.in` DNS server from `.in` DNS server:




Ganesha
Browser
Root
DNS
server
DNS
cache
.in
DNS
server
.mnit.ac.in
DNS
server
.in
database
.mnit.ac.in
database
at Internet
Central HQ
Administrator
at mnit.ac.in

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 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.

Because of engineering costs and redeployment costs, very few database-management tools have added DNSSEC support.

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2008 slideshow "DNSSEC in six minutes" (79 pages): "Any time you modify a zone … you must re-run `dnssec-signzone`."

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

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

Big zones such as `.com`
refuse to sign complete database.
Full DNSSEC signing would be
much too slow and much too big.

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

Often many more packets than original DNS.
Higher latency for user.
More frequent failures.

Also, much easier for attacker to deny service.
$> 100\times$ amplification!
Official DNSSEC response, RFC 4033: "DNSSEC provides no protection against denial of service attacks."

Replay attack on DNSSEC:

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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!

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normally signing date + 30 days.

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Also a major administrative
hassle: administrator must
generate new signatures
before old signatures expire.

If administrator forgets,
domain is destroyed.
"DNSSEC suicide."

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Replay attacks work for 30 days.
Have to run `httpsec-signpages`
again before 30-day expiration or
your web pages are destroyed.

But wait, there's more!

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When is the signature precomputed? Does Google precompute signatures for *all* possible names? Too many!

DNSSEC solution: Sign multi-NXDOMAIN such as “there are no names between `chrome.google.com` and `code.google.com`.”

DNSSEC server issues this signed data in response to any name between `chrome` and `code`. Tricky definition of “between”; theoretically implementable.

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Consequence: If you deploy DNSSEC then you are exposing *all* of your DNS names!

Newest DNSSEC variant:
"NSEC3" (2008 Laurie),
exposing *hashes* of DNS names.
Hash is 150 SHA-1 iterations.

Hash-enumeration attack:
Attacker guesses many names,
computes their hashes,
compares to the hashes
exposed by DNSSEC+NSEC3.

Small 10-computer cluster:
$\approx 2^{44}$ guesses/year.

Large company or botnet:
$\approx 2^{64}$ guesses/year.

Without DNSSEC,
attacker has to send query
for each guessed name.

Flooding a 4Mbps connection:
$\approx 2^{37}$ guesses/year.

Compared to normal DNS,
DNSSEC+NSEC3
makes guessing *silent* and
makes it *millions of times faster*
for a well-equipped attacker.

DNSSEC+NSEC3 is advertised
as being better than DNSSEC;
but it still loses privacy
compared to normal DNS.

Precomputation impact summary:

DNSSEC is pain for implementors.
Hundreds of DNS programs—
all caches, all servers,
and all management tools—
need to be modified to
precompute and store signatures.

DNSSEC is pain for
administrators, far beyond a
simple upgrade.

DNSSEC hurts privacy.
DNSSEC hurts reliability.
DNSSEC aids denial of service.

Rethinking signatures

Conventional wisdom:
DNSSEC's precomputation,
sacrificing security while
creating severe usability problems,
is necessary for speed.

Can we achieve adequate speed
without precomputation?
Let's change the design.

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Let's change the design.

1. Add encryption.
Want to protect against sabotage
and against espionage.
So use public-key signatures
and public-key encryption.

2. Merge signing with encryption.

"Public-key signcryption" protects against forgery and eavesdropping in one step.

"Public-key authenticated encryption" is even faster.

No need to
partition the algorithms into
an encryption component and
an authentication component.
Combined algorithms are faster.

3. Merge public-key operations across multiple messages.

It's silly for a sender
to authcrypt two messages
to the same recipient.

"Hybrid cryptography"
is much faster.

Example: Sender
generates a random AES key,
authcrypts the AES key,
uses the AES key to encrypt and
authenticate both messages.

4. Choose sensible primitives.

256-bit elliptic-curve cryptography using public-domain software:

489069 Core 2 cycles to handle a new communication partner.

5355 cycles to encrypt and authenticate a 510-byte message.

6786 cycles to verify and decrypt a legitimate 510-byte message.

3465 cycles to reject a forged 510-byte message.

A 2.5GHz Intel Core 2 Quad
Q9300 CPU costs US$225.
Complete computer: $400.

This CPU has 4 cores.
Each core carries out
2.5 billion cycles/second.

On this computer,
the same software takes just
49 seconds to handle 1000000
new communication partners,
and just 12 seconds to handle
10000000 incoming packets *and*
10000000 outgoing packets.

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Verisign says that it wants to be prepared for 4 trillion packets/day. Cryptographic cost of 4 trillion partners/day with this software: < 3000 computers.

What is this software?

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Actually done three months ago. Subsequent time has been QA.

NaCl is now released:
http://nacl.cace-project.eu

The DNSCurve project

DNSCurve uses NaCl
to add heavy-duty integrity
(RSA-1024 has 80-bit security;
DNSCurve has 128-bit security)
and some confidentiality
and availability
to the Domain Name System.

Despite all this security,
DNSCurve is very easy for DNS
software authors to implement
and very easy for
administrators to deploy.

Administrator has to change
the `mnit.ac.in` server
to support DNSCurve,
or install a DNSCurve forwarder
alongside the server.

Administrator does *not* need to
change database software,
does *not* need to store signatures,
does *not* need new procedures
for updating DNS records, and
does *not* risk DNSSEC suicide.

Administrator changes
server name such as `dns2`
to a server name that encodes
the DNSCurve public key.

The `.in` server
and database software
and web interface
already support
`mnit.ac.in` server names
selected by the
`mnit.ac.in` administrator!

Cache has to be upgraded
to support DNSCurve.

Cache naturally sees the
encoded DNSCurve public key.
Cache encrypts and authenticates
DNS packets sent to that server.
Cache verifies and decrypts DNS
packets received from that server.

No extra packets.
Forged packets are
very efficiently discarded.
Denial of service becomes
much more difficult.

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No. DNSSEC can protect against compromise of DNS servers if administrator generates signatures on another machine that has not been compromised.

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Analogy: HTTPSEC, unlike HTTPS, can protect against compromise of HTTP servers if administrator signs web pages on another machine.

But does this justify the pain of DNSSEC+HTTPSEC?

More information on DNSCurve:

See `http://dnscurve.org`.

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Thinking beyond networking:
When people sacrifice security
and usability for the sake of
performance, are they really
improving performance?