The DNS security mess

D. J. Bernstein

University of Illinois at Chicago;
Technische Universiteit Eindhoven

The Domain Name System

`tue.nl` wants to see `http://www.ru.nl`.

Browser at `tue.nl`

↑ "The web server `www.ru.nl` has IP address 131.174.78.60."

Administrator at `ru.nl`

Now `tue.nl` retrieves web page from IP address 131.174.78.60.

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are signing with DNSSEC,
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for attackers to forge
data from those servers!

... or is it?

Decemb

Let's fin

```
$ dig
d0.org
a0.org
c0.org
b2.org
a2.org
b0.org

$ dig
  b0.
199.19
```

an that the
ned'?
s the first part
est phase.
ographically
itative data
zone file.
new records to
lows verification
enticity and

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!

... or is it?

December 2015: n

Let's find a `.org` s

```
$ dig +short n
d0.org.afilias
a0.org.afilias
c0.org.afilias
b2.org.afilias
a2.org.afilias
b0.org.afilias

$ dig +short \
  b0.org.afili
199.19.54.1
```

e

part

ly

a

ds to

cation

d

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!

... or is it?

December 2015: reality

Let's find a `.org` server:

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

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

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!

… or is it?

December 2015: reality

Let's find a `.org` server:

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

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

raphy! Authority!
tion! Authenticity!
r! Sounds great!

mply configure
.org public key
DNS software.
the .org servers
ng with DNSSEC,
onger possible
ckers to forge
m those servers!

it?

December 2015: reality

Let's find a .org server:

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

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

Look up

```
$ dig
  www
  @199
```

Everythi

```
;; AUT
greenp
  864
  ns-
;; ADD
ns-em
  864
  37.
```

thority!
enticity!
great!

igure
lic key
vare.
servers
DNSSEC,
sible
rge
ervers!

December 2015: reality

Let's find a `.org` server:

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

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

Look up greenpea

```
$ dig \
  www.greenpea
  @199.19.54.1
```

Everything looks r

```
;; AUTHORITY S
greenpeace.org
  86400 IN NS
  ns-emea.gree
;; ADDITIONAL
ns-emea.greenp
  86400 IN A
  37.48.104.54
```

December 2015: reality

Let's find a `.org` server:

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

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

Look up `greenpeace.org`:

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

Everything looks normal:

```
;; AUTHORITY SECTION:
greenpeace.org.
  86400 IN NS
  ns-emea.greenpeace.or
;; ADDITIONAL SECTION:
ns-emea.greenpeace.org.
  86400 IN A
  37.48.104.54
```

December 2015: reality

Let's find a `.org` server:

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

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

Look up `greenpeace.org`:

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

Everything looks normal:

```
;; AUTHORITY SECTION:
greenpeace.org.
  86400 IN NS
  ns-emea.greenpeace.org.
;; ADDITIONAL SECTION:
ns-emea.greenpeace.org.
  86400 IN A
  37.48.104.54
```

er 2015: reality

d a .org server:

```
 +short ns org
g.afilias-nst.org.
g.afilias-nst.info.
g.afilias-nst.info.
g.afilias-nst.org.
g.afilias-nst.info.
g.afilias-nst.org.

 +short \
org.afilias-nst.org
9.54.1
```

Look up greenpeace.org:

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

Everything looks normal:

```
;; AUTHORITY SECTION:
greenpeace.org.
  86400 IN NS
  ns-emea.greenpeace.org.
;; ADDITIONAL SECTION:
ns-emea.greenpeace.org.
  86400 IN A
  37.48.104.54
```

Where's

Have to

```
$ dig
  www
  @19
```

Old ans

```
h9p7u
np90u
C3 1
69T6U
 NS S
3PARA

h9p7u
```

reality

server:

```
s org
-nst.org.
-nst.info.
-nst.info.
-nst.org.
-nst.info.
-nst.org.

as-nst.org
```

Look up greenpeace.org:

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

Everything looks normal:

```
;; AUTHORITY SECTION:
greenpeace.org.
  86400 IN NS
  ns-emea.greenpeace.org.
;; ADDITIONAL SECTION:
ns-emea.greenpeace.org.
  86400 IN A
  37.48.104.54
```

Where's the crypto

Have to ask for sig

```
$ dig +dnssec
  www.greenpea
  @199.19.54.1
```

Old answer + four

```
h9p7u7tr2u91d0
np90u3h.org. 8
C3 1 1 1 D399E
69T6U801GSG9E1
 NS SOA RRSIG
3PARAM

h9p7u7tr2u91d0
```

.
.
.
g

Look up greenpeace.org:

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

Everything looks normal:

```
;; AUTHORITY SECTION:
greenpeace.org.
  86400 IN NS
  ns-emea.greenpeace.org.
;; ADDITIONAL SECTION:
ns-emea.greenpeace.org.
  86400 IN A
  37.48.104.54
```

Where's the crypto?

Have to ask for signatures:

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

Old answer + four new lines

```
h9p7u7tr2u91d0v0ljs9l1g
np90u3h.org. 86400 IN N
C3 1 1 1 D399EAAB H9PAR
69T6U801GSG9E1LMITK4DEM
 NS SOA RRSIG DNSKEY NS
3PARAM


h9p7u7tr2u91d0v0ljs9l1g
```

Look up `greenpeace.org`:

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

Everything looks normal:

```
;; AUTHORITY SECTION:
greenpeace.org.
  86400 IN NS
  ns-emea.greenpeace.org.
;; ADDITIONAL SECTION:
ns-emea.greenpeace.org.
  86400 IN A
  37.48.104.54
```

Where's the crypto?

Have to ask for signatures:

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

Old answer + four new lines:

```
h9p7u7tr2u91d0v0ljs9l1gid
np90u3h.org. 86400 IN NSE
C3 1 1 1 D399EAAB H9PARR6
69T6U8O1GSG9E1LMITK4DEMOT
 NS SOA RRSIG DNSKEY NSEC
3PARAM


h9p7u7tr2u91d0v0ljs9l1gid
```

greenpeace.org:

```
\
.greenpeace.org \
9.19.54.1
```

ng looks normal:

```
THORITY SECTION:
peace.org.
00 IN NS
emea.greenpeace.org.
DITIONAL SECTION:
ea.greenpeace.org.
00 IN A
48.104.54
```

Where's the crypto?

Have to ask for signatures:

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

Old answer + four new lines:

```
h9p7u7tr2u91d0v0ljs9l1gid
np90u3h.org. 86400 IN NSE
C3 1 1 1 D399EAAB H9PARR6
69T6U801GSG9E1LMITK4DEMOT
 NS SOA RRSIG DNSKEY NSEC
3PARAM

h9p7u7tr2u91d0v0ljs9l1gid
```

```
np90u
IG NS
06023
448 o
EZ1/m
UJRUA
Tcziy
ALtRD
80Jdf
YBNTu
Cota

bgca0
qng3p
C3 1
```

ace.org:

ce.org \

normal:

ECTION:

.

npeace.org.

SECTION:

eace.org.

Where's the crypto?

Have to ask for signatures:

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

Old answer + four new lines:

```
h9p7u7tr2u91d0v0ljs9l1gid
np90u3h.org. 86400 IN NSE
C3 1 1 1 D399EAAB H9PARR6
69T6U801GSG9E1LMITK4DEMOT
 NS SOA RRSIG DNSKEY NSEC
3PARAM

h9p7u7tr2u91d0v0ljs9l1gid
```

```
np90u3h.org. 8
IG NSEC3 7 2 8
06023715 20151
448 org. OGLya
EZ1/mnvAG8NJ2z
UJRUAfKVCzaWJj
TcziyRmM8iYvBN
ALtRDom1rdpsVD
80Jdf2sbfXmZd1
YBNTujz2NPadBA
Cota iBk=

bgca0g0ug0p6o7
qng3p2f.org. 8
C3 1 1 1 D399E
```

rg.

Where's the crypto?

Have to ask for signatures:

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

Old answer + four new lines:

```
h9p7u7tr2u91d0v0ljs9l1gid
np90u3h.org. 86400 IN NSE
C3 1 1 1 D399EAAB H9PARR6
69T6U801GSG9E1LMITK4DEM0T
 NS SOA RRSIG DNSKEY NSEC
3PARAM

h9p7u7tr2u91d0v0ljs9l1gid
```

```
np90u3h.org. 86400 IN R
IG NSEC3 7 2 86400 2016
06023715 20151216013715
448 org. OGLyaFRtHdR6UB
EZ1/mnvAG8NJ2z5nBi5ALpY
UJRUAfKVCzaWJjZ rpgB6Wg
TcziyRmM8iYvBNwzmUxoPzg
ALtRDom1rdpsVDxGveMJu6
80Jdf2sbfXmZd1viiz+RXRv
YBNTujz2NPadBATPlUNr0sb
Cota iBk=

bgca0g0ug0p6o7425emkt9u
qng3p2f.org. 86400 IN N
C3 1 1 1 D399EAAB BGDM7
```

Where's the crypto?

Have to ask for signatures:

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

Old answer + four new lines:

```
h9p7u7tr2u91d0v0ljs9l1gid
np90u3h.org. 86400 IN NSE
C3 1 1 1 D399EAAB H9PARR6
69T6U8O1GSG9E1LMITK4DEM0T
 NS SOA RRSIG DNSKEY NSEC
3PARAM

h9p7u7tr2u91d0v0ljs9l1gid
np90u3h.org. 86400 IN RRS
IG NSEC3 7 2 86400 201601
06023715 20151216013715 1
448 org. OGLyaFRtHdR6UBeq
EZ1/mnvAG8NJ2z5nBi5ALpYtE
UJRUAfKVCzaWJjZ rpgB6WgcF
TcziyRmM8iYvBNwzmUxoPzgkv
ALtRDom1rdpsVDxGveMJu6 pE
80Jdf2sbfXmZd1viiz+RXRvNI
YBNTujz2NPadBATPlUNr0sbQj
Cota iBk=

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN NSE
C3 1 1 1 D399EAAB BGDM7MS
```

the crypto?

ask for signatures:

```
+dnssec \
.greenpeace.org \
9.19.54.1
```

wer + four new lines:

```
7tr2u91d0v0ljs9l1gid
3h.org. 86400 IN NSE
1 1 D399EAAB H9PARR6
8O1GSG9E1LMITK4DEMOT
OA RRSIG DNSKEY NSEC
M

7tr2u91d0v0ljs9l1gid
```

```
np90u3h.org. 86400 IN RRS
IG NSEC3 7 2 86400 201601
06023715 20151216013715 1
448 org. OGLyaFRtHdR6UBeq
EZ1/mnvAG8NJ2z5nBi5ALpYtE
UJRUAfKVCzaWJjZ rpgB6WgcF
TcziyRmM8iYvBNwzmUxoPzgkv
ALtRDom1rdpsVDxGveMJu6 pE
80Jdf2sbfXmZd1viiz+RXRvNI
YBNTujz2NPadBATPlUNr0sbQj
Cota iBk=

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN NSE
C3 1 1 1 D399EAAB BGDM7MS
```

```
F9V1T
 A RR

bgca0
qng3p
IG NS
30150
448 o
P7sk0
Vn/Q4
0rk7b
fevV8
StsWz
sK+PU
ggs9
```

o?

gnatures:

\
ce.org \

r new lines:

```
v0ljs9l1gid
6400 IN NSE
AAB H9PARR6
LMITK4DEMOT
DNSKEY NSEC


v0ljs9l1gid
```

```
np90u3h.org. 86400 IN RRS
IG NSEC3 7 2 86400 201601
06023715 20151216013715 1
448 org. OGLyaFRtHdR6UBeq
EZ1/mnvAG8NJ2z5nBi5ALpYtE
UJRUAfKVCzaWJjZ rpgB6WgcF
TcziyRmM8iYvBNwzmUxoPzgkv
ALtRDom1rdpsVDxGveMJu6 pE
80Jdf2sbfXmZd1viiz+RXRvNI
YBNTujz2NPadBATPlUNr0sbQj
Cota iBk=

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN NSE
C3 1 1 1 D399EAAB BGDM7MS
```

```
F9V1T1JFVI8FA2
 A RRSIG

bgca0g0ug0p6o7
qng3p2f.org. 8
IG NSEC3 7 2 8
30150037 20151
448 org. Wg2ha
P7sk04Y/nSp+sR
Vn/Q4DEXqftVYe
0rk7bZ/K+v0+5m
fevV8t4ZmWrS+N
StsWztJ50oxdmZ
sK+PUKaB6dx2Bo
ggs9 MB0=
```

s:

gid
NSE
R6
NOT
SEC

gid

np90u3h.org. 86400 IN RRS
IG NSEC3 7 2 86400 201601
06023715 20151216013715 1
448 org. OGLyaFRtHdR6UBeq
EZ1/mnvAG8NJ2z5nBi5ALpYtE
UJRUAfKVCzaWJjZ rpgB6WgcF
TcziyRmM8iYvBNwzmUxoPzgkv
ALtRDom1rdpsVDxGveMJu6 pE
80Jdf2sbfXmZd1viiz+RXRvNI
YBNTujz2NPadBATPlUNr0sbQj
Cota iBk=

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN NSE
C3 1 1 1 D399EAAB BGDM7MS

F9V1T1JFVI8FA211MH4JD7U
A RRSIG

bgca0g0ug0p6o7425emkt9u
qng3p2f.org. 86400 IN R
IG NSEC3 7 2 86400 2015
30150037 20151209140037
448 org. Wg2ha2mg0DnjiV
P7sk04Y/nSp+sR5uhChRWyz
Vn/Q4DEXqftVYeh v/x7Cmz
0rk7bZ/K+v0+5mOMyao6Fod
fevV8t4ZmWrS+NLjNfx/yl
StsWztJ50oxdmZw1EwOALH/
sK+PUKaB6dx2BoEOiFn1plP
ggs9 MBO=

np90u3h.org. 86400 IN RRS
IG NSEC3 7 2 86400 201601
06023715 20151216013715 1
448 org. OGLyaFRtHdR6UBeq
EZ1/mnvAG8NJ2z5nBi5ALpYtE
UJRUAfKVCzaWJjZ rpgB6WgcF
TcziyRmM8iYvBNwzmUxoPzgkv
ALtRDom1rdpsVDxGveMJu6 pE
80Jdf2sbfXmZd1viiz+RXRvNI
YBNTujz2NPadBATPlUNr0sbQj
Cota iBk=

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN NSE
C3 1 1 1 D399EAAB BGDM7MS
F9V1T1JFVI8FA211MH4JD7UJ7
 A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201512
30150037 20151209140037 1
448 org. Wg2ha2mg0DnjiVNl
P7sk04Y/nSp+sR5uhChRWyzqH
Vn/Q4DEXqftVYeh v/x7Cmz2Q
0rk7bZ/K+v0+5mOMyao6Fod8+
fevV8t4ZmWrS+NLjNfx/yl So
StsWztJ50oxdmZw1Ew0ALH/5g
sK+PUKaB6dx2BoE0iFn1plPSf
ggs9 MB0=

```
3h.org. 86400 IN RRS
EC3 7 2 86400 201601
715 20151216013715 1
rg. OGLyaFRtHdR6UBeq
nvAG8NJ2z5nBi5ALpYtE
fKVCzaWJjZ rpgB6WgcF
RmM8iYvBNwzmUxoPzgkv
om1rdpsVDxGveMJu6 pE
2sbfXmZd1viiz+RXRvNI
jz2NPadBATPlUNr0sbQj
iBk=

g0ug0p6o7425emkt9ue4
2f.org. 86400 IN NSE
1 1 D399EAAB BGDM7MS
```

```
F9V1T1JFVI8FA211MH4JD7UJ7
 A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201512
30150037 20151209140037 1
448 org. Wg2ha2mg0DnjiVNl
P7sk04Y/nSp+sR5uhChRWyzqH
Vn/Q4DEXqftVYeh v/x7Cmz2Q
0rk7bZ/K+v0+5m0Myao6Fod8+
fevV8t4ZmWrS+NLjNfx/yl So
StsWztJ50oxdmZw1Ew0ALH/5g
sK+PUKaB6dx2BoE0iFn1plPSf
ggs9 MB0=
```

Wow, th
Must be

```
$ tcpdu
  host
```

shows pa
dig send
to the .
receives

See mor

```
$ dig +
  org @
```

Sends 8
receives
totalling

```
6400 IN RRS
6400 201601
216013715 1
FRtHdR6UBeq
5nBi5ALpYtE
Z rpgB6WgcF
wzmUxoPzgkv
xGveMJu6 pE
viiz+RXRvNI
TPlUNr0sbQj


425emkt9ue4
6400 IN NSE
AAB BGDM7MS
```

```
F9V1T1JFVI8FA211MH4JD7UJ7
 A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201512
30150037 20151209140037 1
448 org. Wg2ha2mg0DnjiVNl
P7sk04Y/nSp+sR5uhChRWyzqH
Vn/Q4DEXqftVYeh v/x7Cmz2Q
0rk7bZ/K+v0+5mOMyao6Fod8+
fevV8t4ZmWrS+NLjNfx/yl So
StsWztJ50oxdmZw1EwOALH/5g
sK+PUKaB6dx2BoE0iFn1plPSf
ggs9 MB0=
```

Wow, that's a lot
Must be strong cr

```
$ tcpdump -n -e
  host 199.19.54
```

shows packet sizes
dig sends 89-byte
to the `.org` DNS
receives 696-byte

See more DNSSEC

```
$ dig +dnssec an
  org @199.19.54
```

Sends 89-byte IP
receives two IP fra
totalling 2362 byte

```
RS
301
5 1
3eq
YtE
gcF
gkv
pE
+NI
5Qj


1e4
NSE
VMS
```

```
F9V1T1JFVI8FA211MH4JD7UJ7
 A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201512
30150037 20151209140037 1
448 org. Wg2ha2mg0DnjiVNl
P7sk04Y/nSp+sR5uhChRWyzqH
Vn/Q4DEXqftVYeh v/x7Cmz2Q
0rk7bZ/K+v0+5m0Myao6Fod8+
fevV8t4ZmWrS+NLjNfx/yl So
StsWztJ50oxdmZw1Ew0ALH/5g
sK+PUKaB6dx2BoE0iFn1plPSf
ggs9 MB0=
```

Wow, that's a lot of data.
Must be strong cryptograph

```
$ tcpdump -n -e \
  host 199.19.54.1 &
```

shows packet sizes:
dig sends 89-byte IP packet
to the `.org` DNS server,
receives 696-byte IP packet.

See more DNSSEC data:

```
$ dig +dnssec any \
  org @199.19.54.1
```

Sends 89-byte IP packet,
receives two IP fragments
totalling 2362 bytes.

```
F9V1T1JFVI8FA211MH4JD7UJ7
 A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201512
30150037 20151209140037 1
448 org. Wg2ha2mg0DnjiVNl
P7sk04Y/nSp+sR5uhChRWyzqH
Vn/Q4DEXqftVYeh v/x7Cmz2Q
0rk7bZ/K+v0+5m0Myao6Fod8+
fevV8t4ZmWrS+NLjNfx/yl So
StsWztJ50oxdmZw1Ew0ALH/5g
sK+PUKaB6dx2BoE0iFn1plPSf
ggs9 MB0=
```

Wow, that's a lot of data.
Must be strong cryptography!

```
$ tcpdump -n -e \
  host 199.19.54.1 &
```

shows packet sizes:
`dig` sends 89-byte IP packet to the `.org` DNS server, receives 696-byte IP packet.

See more DNSSEC data:

```
$ dig +dnssec any \
  org @199.19.54.1
```

Sends 89-byte IP packet, receives two IP fragments totalling 2362 bytes.

1JFVI8FA211MH4JD7UJ7
SIG

g0ug0p6o7425emkt9ue4
2f.org. 86400 IN RRS
EC3 7 2 86400 201512
037 20151209140037 1
rg. Wg2ha2mg0DnjiVNl
4Y/nSp+sR5uhChRWyzqH
DEXqftVYeh v/x7Cmz2Q
Z/K+v0+5mOMyao6Fod8+
t4ZmWrS+NLjNfx/yl So
tJ50oxdmZw1Ew0ALH/5g
KaB6dx2BoE0iFn1plPSf
MB0=

Wow, that's a lot of data.
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```
$ tcpdump -n -e \
  host 199.19.54.1 &
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See more DNSSEC data:

```
$ dig +dnssec any \
  org @199.19.54.1
```

Sends 89-byte IP packet, receives two IP fragments totalling 2362 bytes.

Interlude

What ha
this data

11MH4JD7UJ7

425emkt9ue4
6400 IN RRS
6400 201512
209140037 1
2mgODnjiVNl
5uhChRWyzqH
h v/x7Cmz2Q
OMyao6Fod8+
LjNfx/yl So
w1EwOALH/5g
EOiFn1plPSf

Wow, that's a lot of data.
Must be strong cryptography!

```
$ tcpdump -n -e \
  host 199.19.54.1 &
```

shows packet sizes:
`dig` sends 89-byte IP packet to the `.org` DNS server, receives 696-byte IP packet.

See more DNSSEC data:

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$ dig +dnssec any \
  org @199.19.54.1
```

Sends 89-byte IP packet, receives two IP fragments totalling 2362 bytes.

Interlude: the atta

What happens if w
this data at somec

J7
e4
RS
12
1
Nl
qH
2Q
8+
So
5g
Sf

Wow, that's a lot of data.
Must be strong cryptography!

```
$ tcpdump -n -e \
  host 199.19.54.1 &
```

shows packet sizes:
`dig` sends 89-byte IP packet to the `.org` DNS server, receives 696-byte IP packet.

See more DNSSEC data:

```
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  org @199.19.54.1
```

Sends 89-byte IP packet, receives two IP fragments totalling 2362 bytes.

Interlude: the attacker's vie

What happens if we aim this data at someone else?

Wow, that's a lot of data.
Must be strong cryptography!

```
$ tcpdump -n -e \
  host 199.19.54.1 &
```

shows packet sizes:
`dig` sends 89-byte IP packet
to the `.org` DNS server,
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See more DNSSEC data:

```
$ dig +dnssec any \
  org @199.19.54.1
```

Sends 89-byte IP packet,
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Interlude: the attacker's view

What happens if we aim
this data at someone else?

Wow, that's a lot of data.
Must be strong cryptography!

```
$ tcpdump -n -e \
  host 199.19.54.1 &
```

shows packet sizes:
`dig` sends 89-byte IP packet
to the `.org` DNS server,
receives 696-byte IP packet.

See more DNSSEC data:

```
$ dig +dnssec any \
  org @199.19.54.1
```

Sends 89-byte IP packet,
receives two IP fragments
totalling 2362 bytes.

Interlude: the attacker's view

What happens if we aim
this data at someone else?

Wow, that's a lot of data.
Must be strong cryptography!

```
$ tcpdump -n -e \
  host 199.19.54.1 &
```

shows packet sizes:
`dig` sends 89-byte IP packet to the `.org` DNS server, receives 696-byte IP packet.

See more DNSSEC data:

```
$ dig +dnssec any \
  org @199.19.54.1
```

Sends 89-byte IP packet, receives two IP fragments totalling 2362 bytes.

Interlude: the attacker's view

What happens if we aim this data at someone else?

Let's see what DNSSEC can do as an amplification tool for denial-of-service attacks.

hat's a lot of data.
strong cryptography!

```
mp -n -e \
199.19.54.1 &
```

acket sizes:
ds 89-byte IP packet
org DNS server,
696-byte IP packet.

e DNSSEC data:

```
dnssec any \
199.19.54.1
```

9-byte IP packet,
two IP fragments
2362 bytes.

Interlude: the attacker's view

What happens if we aim this data at someone else?

Let's see what DNSSEC can do as an amplification tool for denial-of-service attacks.

Downloa

```
wget -m
  secsp
cd secs
awk '
  /GREE
    spl
    sub
    pri
  }
' ./*--
| sort
```

of data.

yptography!

```
\
.1 &
```

s:

IP packet

server,

IP packet.

C data:

```
y \
.1
```

packet,

gments

es.

Interlude: the attacker's view

What happens if we aim this data at someone else?

Let's see what DNSSEC can do as an amplification tool for denial-of-service attacks.

Download DNSSE

```
wget -m -k -I /
  secspider.cs.u
cd secspider.cs.
awk '
  /GREEN.*GREEN.
    split($0,x,/
    sub(/<\/TD>/
    print x[5]
  }
' ./*--zone.html
| sort -u | wc -
```

y!

t

Interlude: the attacker's view

What happens if we aim
this data at someone else?

Let's see what DNSSEC can do
as an amplification tool for
denial-of-service attacks.

Download DNSSEC zone lis

```
wget -m -k -I / \
  secspider.cs.ucla.edu
cd secspider.cs.ucla.edu
awk '
  /GREEN.*GREEN.*GREEN.*Y
    split($0,x,/<TD>/)
    sub(/<\/TD>/,"",x[5])
    print x[5]
  }
' ./*--zone.html \
| sort -u | wc -l
```

Interlude: the attacker's view

What happens if we aim this data at someone else?

Let's see what DNSSEC can do as an amplification tool for denial-of-service attacks.

Download DNSSEC zone list:

```
wget -m -k -I / \
  secspider.cs.ucla.edu
cd secspider.cs.ucla.edu
awk '
  /GREEN.*GREEN.*GREEN.*Yes/ {
    split($0,x,/<TD>/)
    sub(/<\/TD>/,"",x[5])
    print x[5]
  }
' ./*--zone.html \
| sort -u | wc -l
```

e: the attacker's view

appens if we aim
a at someone else?

e what DNSSEC can do
nplification tool for
f-service attacks.

Download DNSSEC zone list:

```
wget -m -k -I / \
  secspider.cs.ucla.edu
cd secspider.cs.ucla.edu
awk '
  /GREEN.*GREEN.*GREEN.*Yes/ {
    split($0,x,/<TD>/)
    sub(/<\/TD>/,"",x[5])
    print x[5]
  }
' ./*--zone.html \
| sort -u | wc -l
```

Make lis

```
( cd sec
  echo
  | xarg
    /^Zo
      su
      su
    }
    /GRE
      sp
      su
      pr
    }'
) | sort
| awk '-
```

acker's view

ve aim
one else?

ISSEC can do
n tool for
ttacks.

Download DNSSEC zone list:

```
wget -m -k -I / \
  secspider.cs.ucla.edu
cd secspider.cs.ucla.edu
awk '
  /GREEN.*GREEN.*GREEN.*Yes/ {
    split($0,x,/<TD>/)
    sub(/<\/TD>/,"",x[5])
    print x[5]
  }
' ./*--zone.html \
| sort -u | wc -l
```

Make list of DNSS

```
( cd secspider.c
  echo ./*--zone
  | xargs awk '
    /^Zone <STRO
      sub(/<STRO
      sub(/<\/ST
    }
    /GREEN.*GREE
      split($0,x
      sub(/<\/TD
      print x[5]
    }'
) | sort -k3n \
| awk '{print $1
```

w

n do

Download DNSSEC zone list:

```
wget -m -k -I / \
  secspider.cs.ucla.edu
cd secspider.cs.ucla.edu
awk '
  /GREEN.*GREEN.*GREEN.*Yes/ {
    split($0,x,/<TD>/)
    sub(/<\/TD>/,"",x[5])
    print x[5]
  }
' ./*--zone.html \
| sort -u | wc -l
```

Make list of DNSSEC names

```
( cd secspider.cs.ucla.ed
  echo ./*--zone.html \
  | xargs awk '
    /^Zone <STRONG>/ { z
      sub(/<STRONG>/,"",z
      sub(/<\/STRONG>/,""
    }
    /GREEN.*GREEN.*GREEN.
      split($0,x,/<TD>/)
      sub(/<\/TD>/,"",x[5
      print x[5],z,rand()
    }'
) | sort -k3n \
| awk '{print $1,$2}' > S
```

Download DNSSEC zone list:

```
wget -m -k -I / \
  secspider.cs.ucla.edu
cd secspider.cs.ucla.edu
awk '
  /GREEN.*GREEN.*GREEN.*Yes/ {
    split($0,x,/<TD>/)
    sub(/<\/TD>/,"",x[5])
    print x[5]
  }
' ./*--zone.html \
| sort -u | wc -l
```

Make list of DNSSEC names:

```
( cd secspider.cs.ucla.edu
  echo ./*--zone.html \
  | xargs awk '
    /^Zone <STRONG>/ { z = $2
      sub(/<STRONG>/,"",z)
      sub(/<\/STRONG>/,"",z)
    }
    /GREEN.*GREEN.*GREEN.*Yes/ {
      split($0,x,/<TD>/)
      sub(/<\/TD>/,"",x[5])
      print x[5],z,rand()
    }'
) | sort -k3n \
| awk '{print $1,$2}' > SERVERS
```

ad DNSSEC zone list:

```
 -k -I / \
ider.cs.ucla.edu
pider.cs.ucla.edu

N.*GREEN.*GREEN.*Yes/ {
it($0,x,/<TD>/)
(/<\/TD>/,"",x[5])
nt x[5]

zone.html \
-u | wc -l
```

Make list of DNSSEC names:

```
( cd secspider.cs.ucla.edu
  echo ./*--zone.html \
  | xargs awk '
    /^Zone <STRONG>/ { z = $2
      sub(/<STRONG>/,"",z)
      sub(/<\/STRONG>/,"",z)
    }
    /GREEN.*GREEN.*GREEN.*Yes/ {
      split($0,x,/<TD>/)
      sub(/<\/TD>/,"",x[5])
      print x[5],z,rand()
    }'
) | sort -k3n \
| awk '{print $1,$2}' > SERVERS
```

For each

estimate

```
while re
do
  dig +c
  +time=
  awk -v
    if
    if
    if
    if
    est
    prin
  }'
done < S
```

C zone list:

```
\
cla.edu
ucla.edu

*GREEN.*Yes/ {
<TD>/)
,"",x[5])



 \
l
```

Make list of DNSSEC names:

```
( cd secspider.cs.ucla.edu
  echo ./*--zone.html \
  | xargs awk '
    /^Zone <STRONG>/ { z = $2
      sub(/<STRONG>/,"",z)
      sub(/<\/STRONG>/,"",z)
    }
    /GREEN.*GREEN.*GREEN.*Yes/ {
      split($0,x,/<TD>/)
      sub(/<\/TD>/,"",x[5])
      print x[5],z,rand()
    }'
) | sort -k3n \
| awk '{print $1,$2}' > SERVERS
```

For each domain:
estimate DNSSEC

```
while read ip z
do
  dig +dnssec +i
  +time=1 any "$
  awk -v "z=$z"
    if ($1 != ";
    if ($2 != "M
    if ($3 != "S
    if ($4 != "r
    est = (22+$5
    print est,ip
  }'
done < SERVERS >
```

t:

es/ {

Make list of DNSSEC names:

```
( cd secspider.cs.ucla.edu
  echo ./*--zone.html \
  | xargs awk '
    /^Zone <STRONG>/ { z = $2
      sub(/<STRONG>/,"",z)
      sub(/<\/STRONG>/,"",z)
    }
    /GREEN.*GREEN.*GREEN.*Yes/ {
      split($0,x,/<TD>/)
      sub(/<\/TD>/,"",x[5])
      print x[5],z,rand()
    }'
) | sort -k3n \
| awk '{print $1,$2}' > SERVERS
```

For each domain: Try query

estimate DNSSEC amplifica

```
while read ip z
do
  dig +dnssec +ignore +tr
  +time=1 any "$z" "@$ip"
  awk -v "z=$z" -v "ip=$i
    if ($1 != ";;") next
    if ($2 != "MSG") next
    if ($3 != "SIZE") nex
    if ($4 != "rcvd:") ne
    est = (22+$5)/(40+len
    print est,ip,z
  }'
done < SERVERS > AMP
```

Make list of DNSSEC names:

```
( cd secspider.cs.ucla.edu
  echo ./*--zone.html \
  | xargs awk '
    /^Zone <STRONG>/ { z = $2
      sub(/<STRONG>/,"",z)
      sub(/<\/STRONG>/,"",z)
    }
    /GREEN.*GREEN.*GREEN.*Yes/ {
      split($0,x,/<TD>/)
      sub(/<\/TD>/,"",x[5])
      print x[5],z,rand()
    }'
) | sort -k3n \
| awk '{print $1,$2}' > SERVERS
```

For each domain: Try query, estimate DNSSEC amplification.

```
while read ip z
do
  dig +dnssec +ignore +tries=1 \
  +time=1 any "$z" "@$ip" | \
  awk -v "z=$z" -v "ip=$ip" '{
    if ($1 != ";;") next
    if ($2 != "MSG") next
    if ($3 != "SIZE") next
    if ($4 != "rcvd:") next
    est = (22+$5)/(40+length(z))
    print est,ip,z
  }'
done < SERVERS > AMP
```

t of DNSSEC names:

```
cspider.cs.ucla.edu
./*--zone.html \
gs awk '
one <STRONG>/ { z = $2
ub(/<STRONG>/,"",z)
ub(/<\/STRONG>/,"",z)

EEN.*GREEN.*GREEN.*Yes/ {
plit($0,x,/<TD>/)
ub(/<\/TD>/,"",x[5])
rint x[5],z,rand()

t -k3n \
{print $1,$2}' > SERVERS
```

For each domain: Try query, estimate DNSSEC amplification.

```
while read ip z
do
  dig +dnssec +ignore +tries=1 \
  +time=1 any "$z" "@$ip" | \
  awk -v "z=$z" -v "ip=$ip" '{
    if ($1 != ";;") next
    if ($2 != "MSG") next
    if ($3 != "SIZE") next
    if ($4 != "rcvd:") next
    est = (22+$5)/(40+length(z))
    print est,ip,z
  }'
done < SERVERS > AMP
```

For each
find dom
maximu

```
sort -n
  if (s
  if ($
  print
  seen[
}' > MA
head -1
wc -l M
```

Output

```
95.6279
2326 MA
```

SEC names:

```
s.ucla.edu
.html \

NG>/ { z = $2
NG>/,"",z)
RONG>/,"",z)

N.*GREEN.*Yes/ {
,/<TD>/)
>/,"",x[5])
,z,rand()

,$2}' > SERVERS
```

For each domain: Try query, estimate DNSSEC amplification.

```
while read ip z
do
  dig +dnssec +ignore +tries=1 \
  +time=1 any "$z" "@$ip" | \
  awk -v "z=$z" -v "ip=$ip" '{
    if ($1 != ";;") next
    if ($2 != "MSG") next
    if ($3 != "SIZE") next
    if ($4 != "rcvd:") next
    est = (22+$5)/(40+length(z))
    print est,ip,z
  }'
done < SERVERS > AMP
```

For each DNSSEC
find domain estim
maximum DNSSE

```
sort -nr AMP | a
  if (seen[$2])
  if ($1 < 30) n
  print $1,$2,$3
  seen[$2] = 1
}' > MAXAMP
head -1 MAXAMP
wc -l MAXAMP
```

Output (last time

```
95.6279 156.154.
2326 MAXAMP
```

s:

```
u

= $2
)
,z)

*Yes/ {

])

ERVERS
```

For each domain: Try query, estimate DNSSEC amplification.

```
while read ip z
do
  dig +dnssec +ignore +tries=1 \
  +time=1 any "$z" "@$ip" | \
  awk -v "z=$z" -v "ip=$ip" '{
    if ($1 != ";;") next
    if ($2 != "MSG") next
    if ($3 != "SIZE") next
    if ($4 != "rcvd:") next
    est = (22+$5)/(40+length(z))
    print est,ip,z
  }'
done < SERVERS > AMP
```

For each DNSSEC server, find domain estimated to ha maximum DNSSEC amplific

```
sort -nr AMP | awk '{
  if (seen[$2]) next
  if ($1 < 30) next
  print $1,$2,$3
  seen[$2] = 1
}' > MAXAMP
head -1 MAXAMP
wc -l MAXAMP
```

Output (last time I tried it):

```
95.6279 156.154.102.26 fi
2326 MAXAMP
```

For each domain: Try query, estimate DNSSEC amplification.

```
while read ip z
do
  dig +dnssec +ignore +tries=1 \
  +time=1 any "$z" "@$ip" | \
  awk -v "z=$z" -v "ip=$ip" '{
    if ($1 != ";;") next
    if ($2 != "MSG") next
    if ($3 != "SIZE") next
    if ($4 != "rcvd:") next
    est = (22+$5)/(40+length(z))
    print est,ip,z
  }'
done < SERVERS > AMP
```

For each DNSSEC server, find domain estimated to have maximum DNSSEC amplification:

```
sort -nr AMP | awk '{
  if (seen[$2]) next
  if ($1 < 30) next
  print $1,$2,$3
  seen[$2] = 1
}' > MAXAMP
head -1 MAXAMP
wc -l MAXAMP
```

Output (last time I tried it):

```
95.6279 156.154.102.26 fi.
2326 MAXAMP
```

n domain: Try query,
e DNSSEC amplification.

```
ead ip z

dnssec +ignore +tries=1 \
=1 any "$z" "@$ip" | \
v "z=$z" -v "ip=$ip" '{
($1 != ";;") next
($2 != "MSG") next
($3 != "SIZE") next
($4 != "rcvd:") next
 = (22+$5)/(40+length(z))
nt est,ip,z

SERVERS > AMP
```

For each DNSSEC server,
find domain estimated to have
maximum DNSSEC amplification:

```
sort -nr AMP | awk '{
  if (seen[$2]) next
  if ($1 < 30) next
  print $1,$2,$3
  seen[$2] = 1
}' > MAXAMP
head -1 MAXAMP
wc -l MAXAMP
```

Output (last time I tried it):

```
95.6279 156.154.102.26 fi.
2326 MAXAMP
```

Can tha
>2000 D
around t
providin
of incom

Try query,
amplification.

```
gnore +tries=1 \
z" "@$ip" | \
-v "ip=$ip" '{
;") next
SG") next
IZE") next
cvd:") next
)/(40+length(z))
,z

 AMP
```

For each DNSSEC server, find domain estimated to have maximum DNSSEC amplification:

```
sort -nr AMP | awk '{
  if (seen[$2]) next
  if ($1 < 30) next
  print $1,$2,$3
  seen[$2] = 1
}' > MAXAMP
head -1 MAXAMP
wc -l MAXAMP
```

Output (last time I tried it):

```
95.6279 156.154.102.26 fi.
2326 MAXAMP
```

Can that really be
>2000 DNSSEC s
around the Interne
providing >30× a
of incoming UDP

,
tion.

```
ries=1 \
 | \
p" '{
.
t
xt
gth(z))
```

For each DNSSEC server,
find domain estimated to have
maximum DNSSEC amplification:

```
sort -nr AMP | awk '{
  if (seen[$2]) next
  if ($1 < 30) next
  print $1,$2,$3
  seen[$2] = 1
}' > MAXAMP
head -1 MAXAMP
wc -l MAXAMP
```

Output (last time I tried it):

```
95.6279 156.154.102.26 fi.
2326 MAXAMP
```

Can that really be true?
>2000 DNSSEC servers
around the Internet, each
providing >30× amplificatio
of incoming UDP packets?

For each DNSSEC server,
find domain estimated to have
maximum DNSSEC amplification:

```
sort -nr AMP | awk '{
  if (seen[$2]) next
  if ($1 < 30) next
  print $1,$2,$3
  seen[$2] = 1
}' > MAXAMP
head -1 MAXAMP
wc -l MAXAMP
```

Output (last time I tried it):

```
95.6279 156.154.102.26 fi.
2326 MAXAMP
```

Can that really be true?
$>$2000 DNSSEC servers
around the Internet, each
providing $>30\times$ amplification
of incoming UDP packets?

For each DNSSEC server,
find domain estimated to have
maximum DNSSEC amplification:

```
sort -nr AMP | awk '{
  if (seen[$2]) next
  if ($1 < 30) next
  print $1,$2,$3
  seen[$2] = 1
}' > MAXAMP
head -1 MAXAMP
wc -l MAXAMP
```

Output (last time I tried it):

```
95.6279 156.154.102.26 fi.
2326 MAXAMP
```

Can that really be true?
>2000 DNSSEC servers
around the Internet, each
providing >30× amplification
of incoming UDP packets?

Let's verify this.

Choose quiet test machines
on two different networks
(without egress filters).

e.g. Sender: 1.2.3.4.
Receiver: 5.6.7.8.

n DNSSEC server,
nain estimated to have
m DNSSEC amplification:

```
r AMP | awk '{
een[$2]) next
1 < 30) next
 $1,$2,$3
$2] = 1
XAMP
 MAXAMP
AXAMP
```

(last time I tried it):

```
 156.154.102.26 fi.
XAMP
```

Can that really be true?
>2000 DNSSEC servers
around the Internet, each
providing >30× amplification
of incoming UDP packets?

Let's verify this.

Choose quiet test machines
on two different networks
(without egress filters).

e.g. Sender: 1.2.3.4.
Receiver: 5.6.7.8.

Run netw
on 1.2.3

On 1.2.3
address
and send

```
ifconfi
  5.6.7
  netma
while r
do
  dig -
  +dnss
  +time
done <
```

C server,
ated to have
C amplification:

```
wk '{
next
ext
```

I tried it):

```
102.26 fi.
```

Can that really be true? >2000 DNSSEC servers around the Internet, each providing >30× amplification of incoming UDP packets?

Let's verify this.

Choose quiet test machines on two different networks (without egress filters).

e.g. Sender: 1.2.3.4.
Receiver: 5.6.7.8.

Run network-traffi
on 1.2.3.4 and 5.6

On 1.2.3.4, set res
address to 5.6.7.8,
and send 1 query/

```
ifconfig eth0:1
  5.6.7.8 \
  netmask 255.25
while read est i
do
  dig -b 5.6.7.8
  +dnssec +ignor
  +time=1 any "$
done < MAXAMP >/
```

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Can that really be true?
>2000 DNSSEC servers
around the Internet, each
providing >30× amplification
of incoming UDP packets?

Let's verify this.

Choose quiet test machines
on two different networks
(without egress filters).

e.g. Sender: 1.2.3.4.
Receiver: 5.6.7.8.

Run network-traffic monitors
on 1.2.3.4 and 5.6.7.8.

On 1.2.3.4, set response
address to 5.6.7.8,
and send 1 query/second:

```
ifconfig eth0:1 \
  5.6.7.8 \
  netmask 255.255.255.255
while read est ip z
do
  dig -b 5.6.7.8 \
  +dnssec +ignore +tries=
  +time=1 any "$z" "@$ip"
done < MAXAMP >/dev/null
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How much server CPU time
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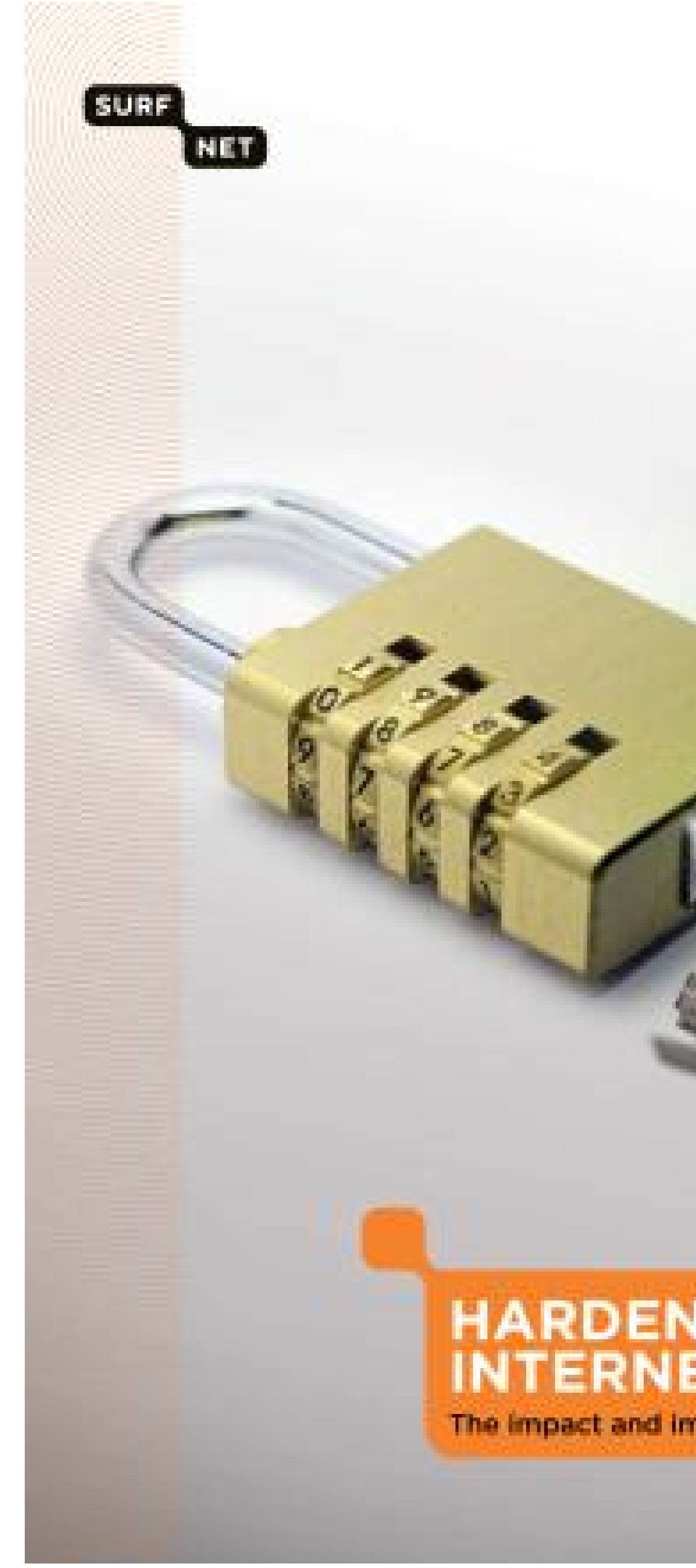

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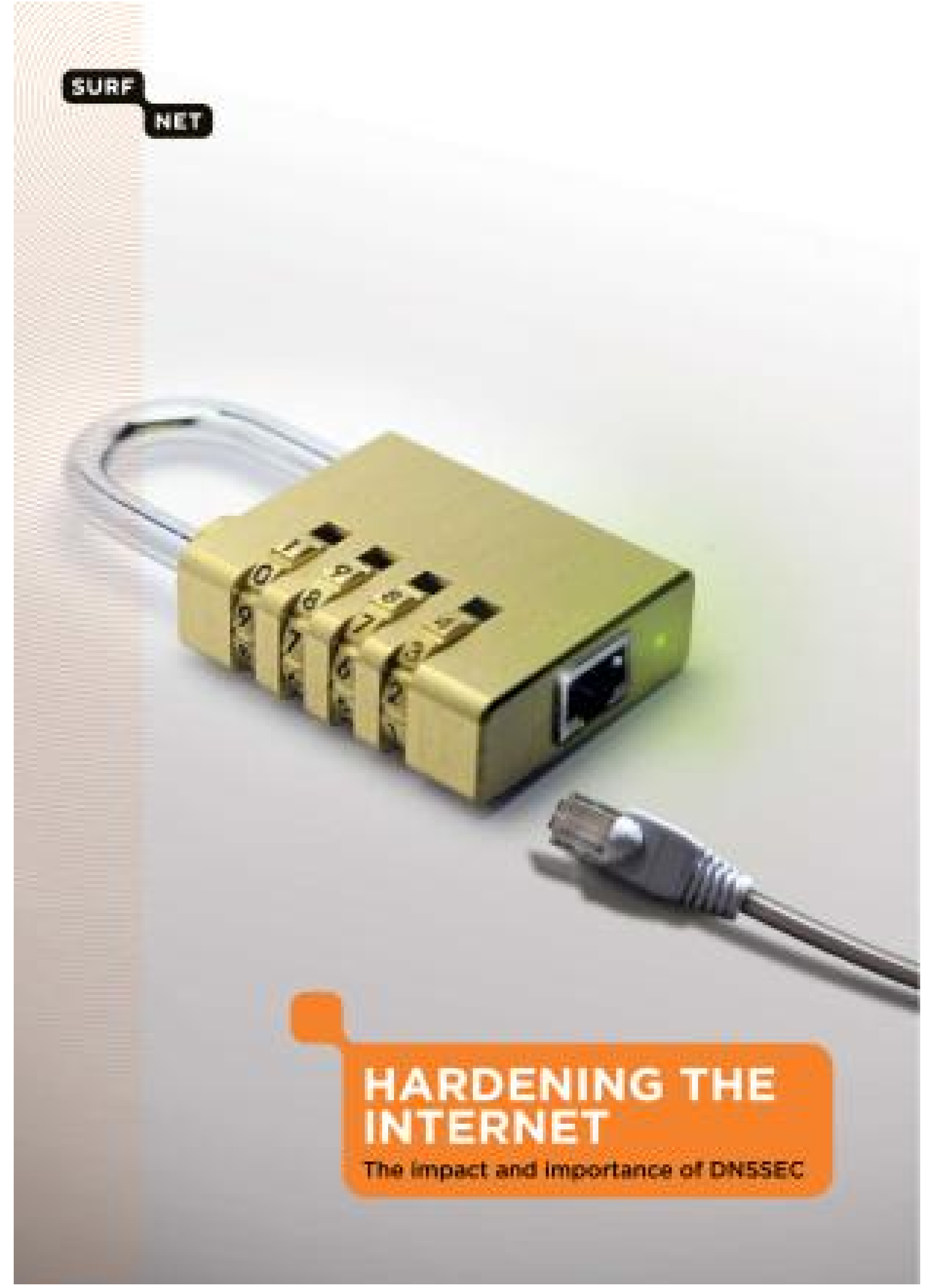

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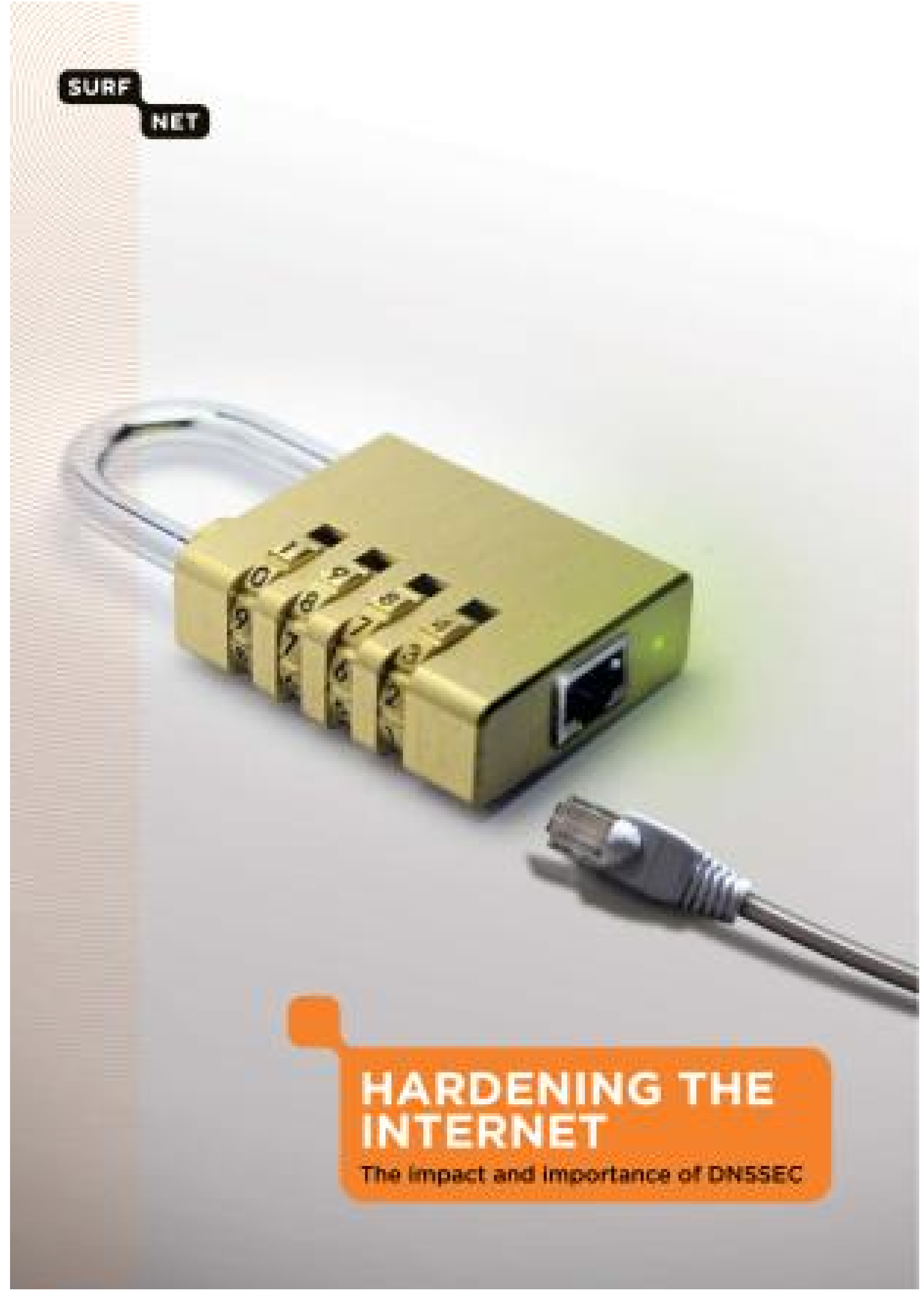

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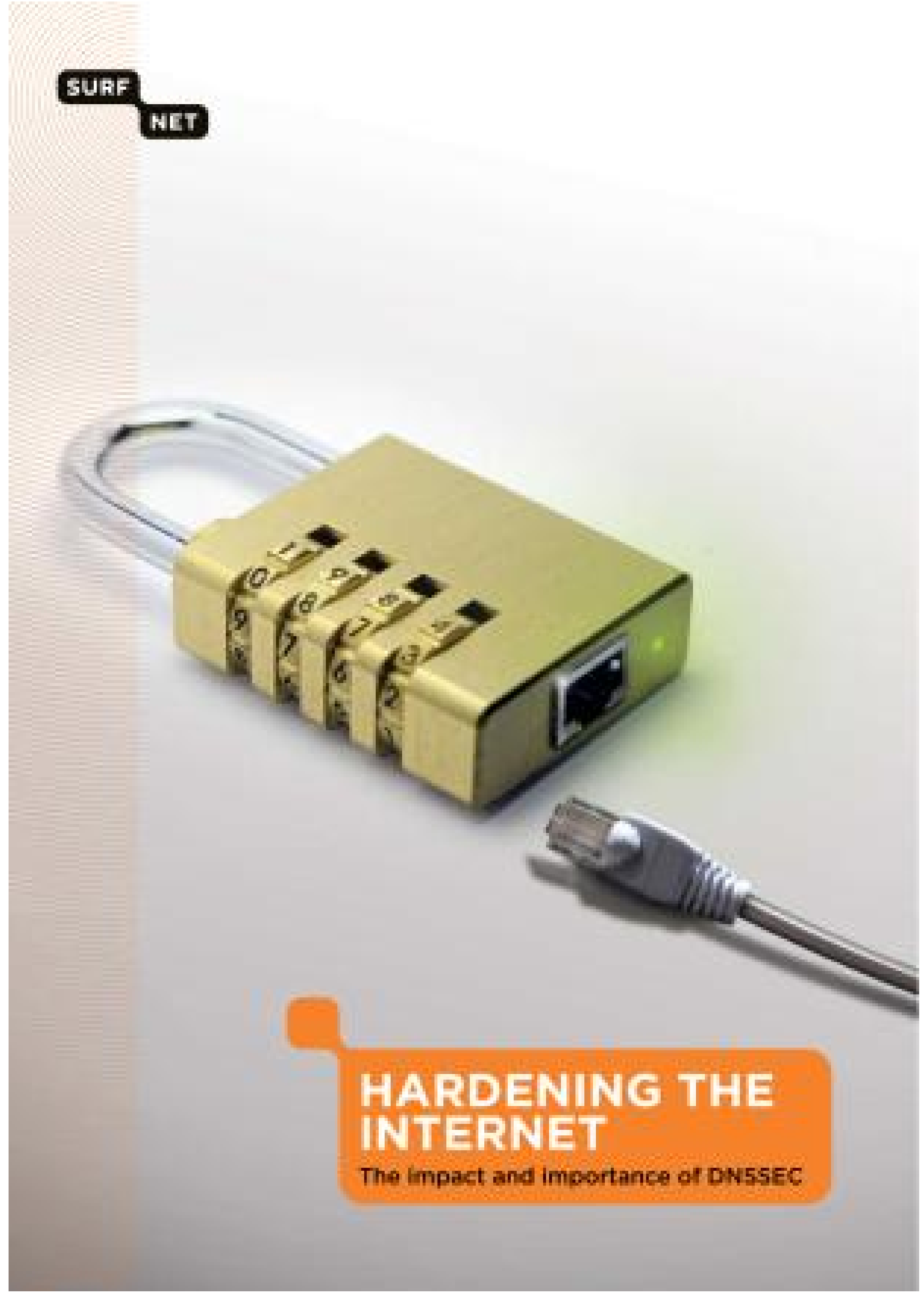

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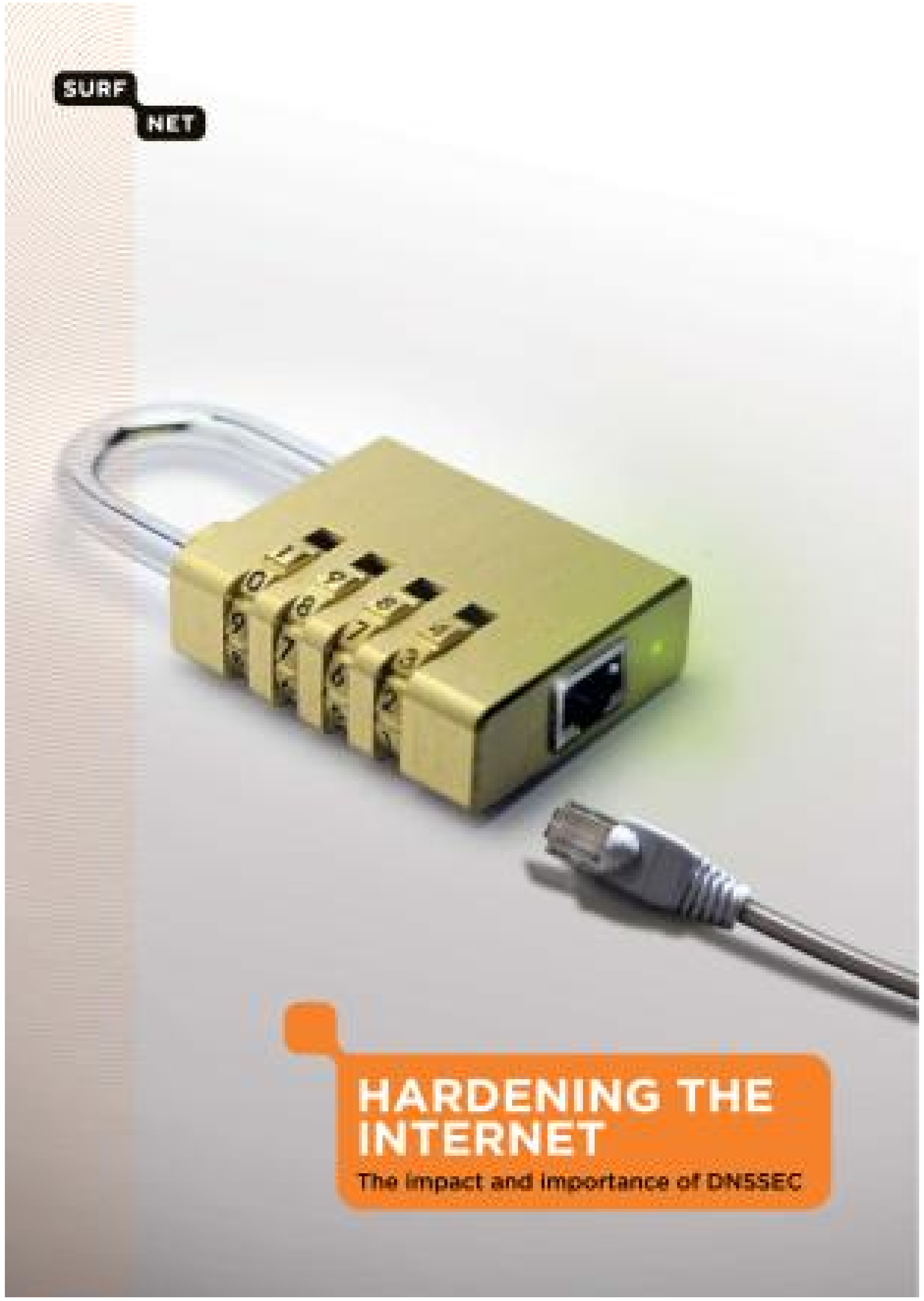

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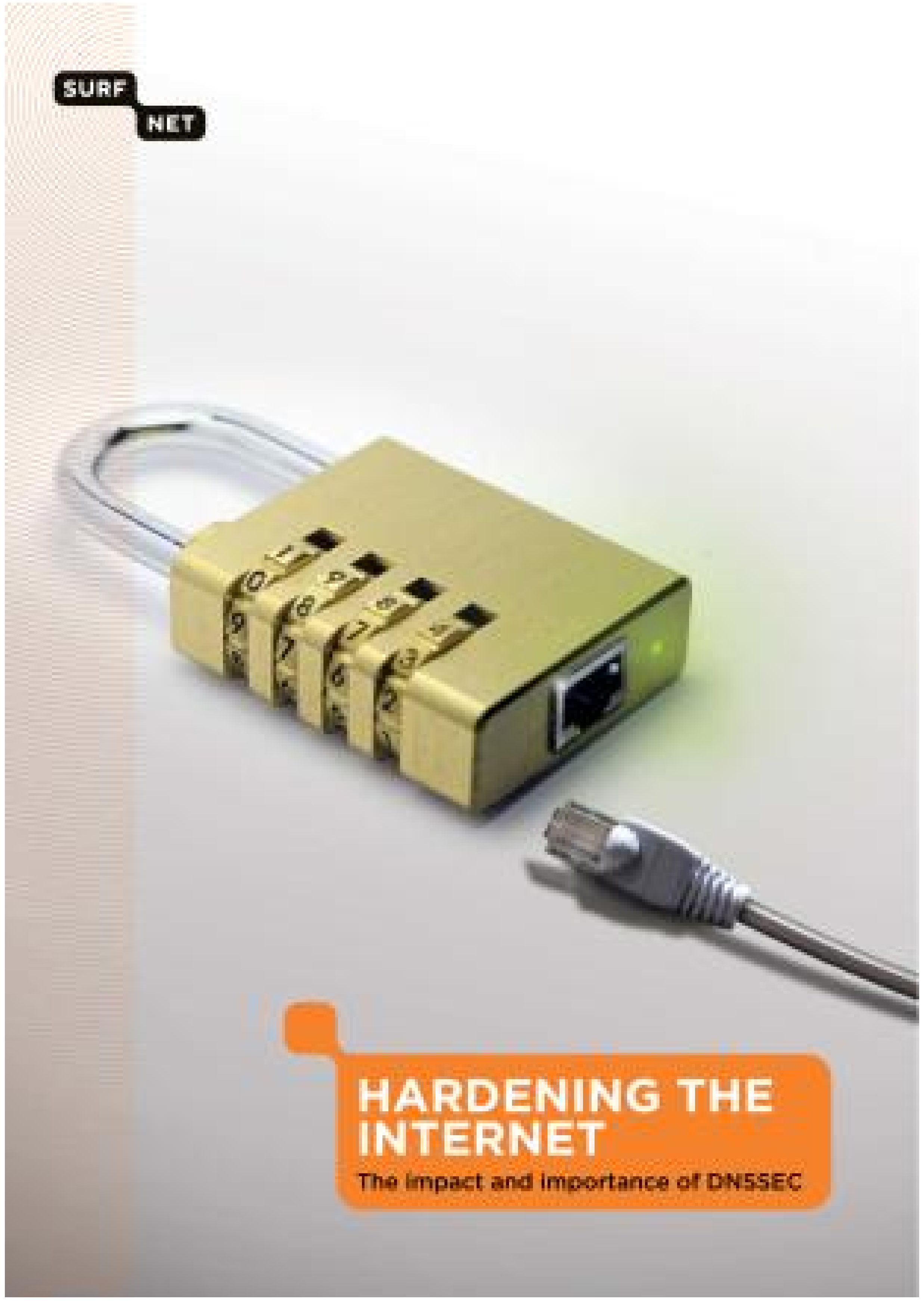

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Still no public announcements
of breaks of 1024-bit RSA.

"RSA-1024: still secure
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What about serious attackers
using many more computers?
e.g. botnet operators?

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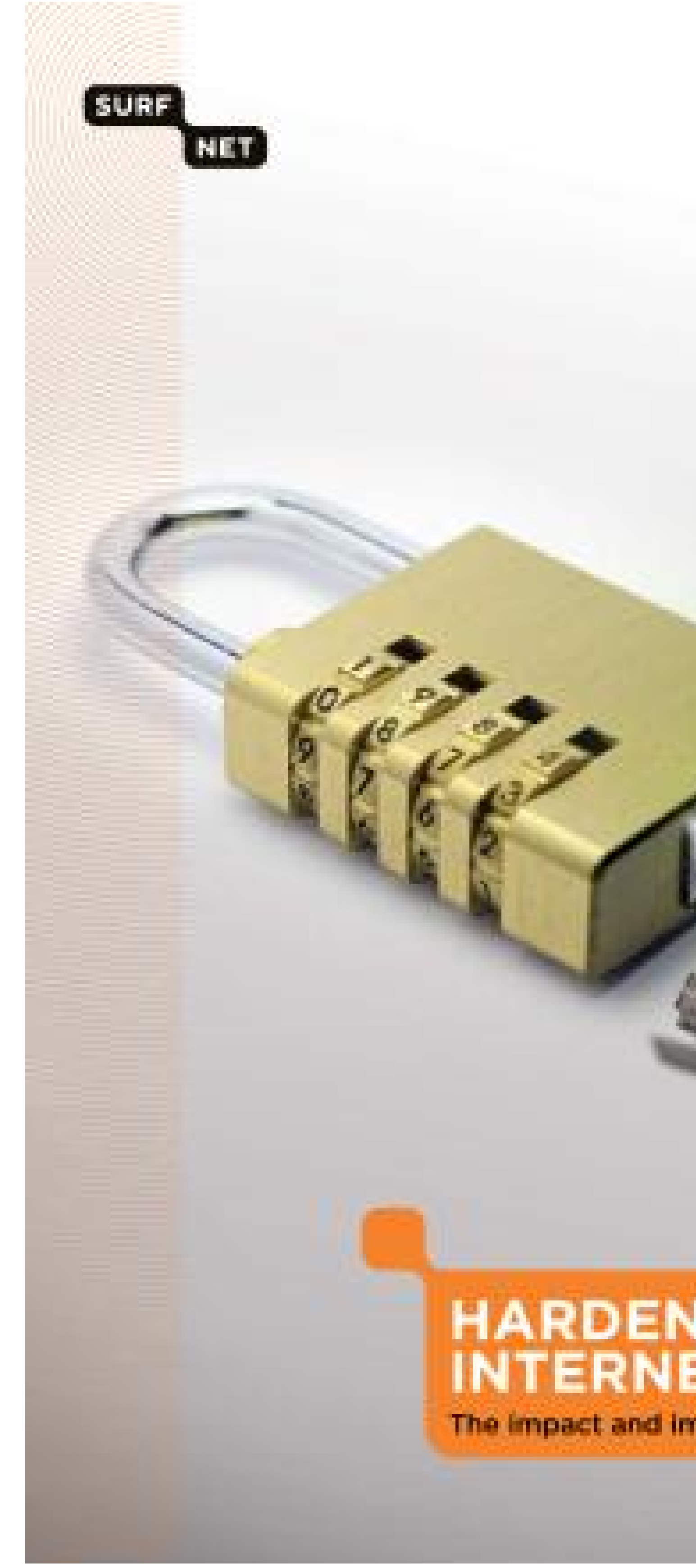

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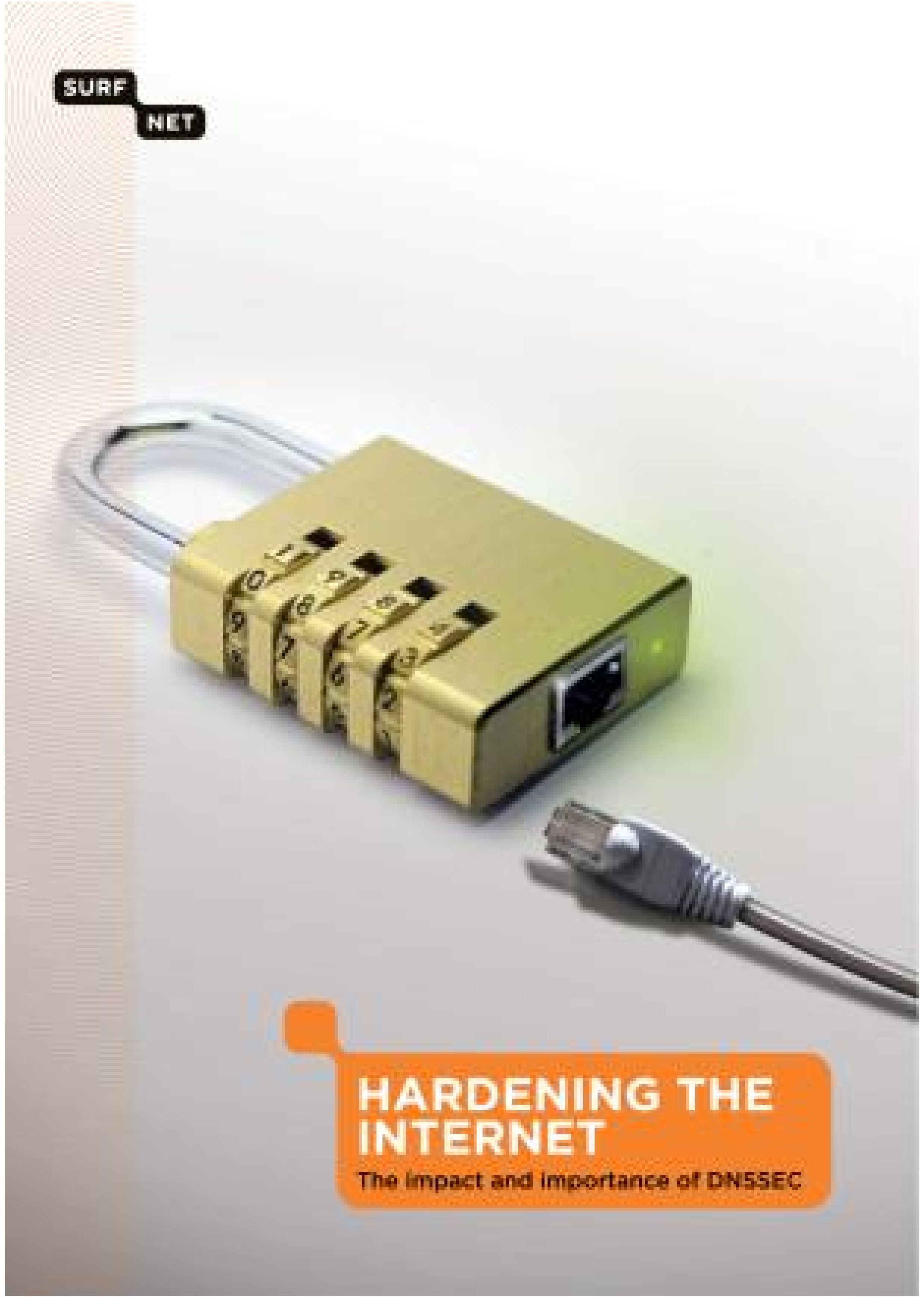

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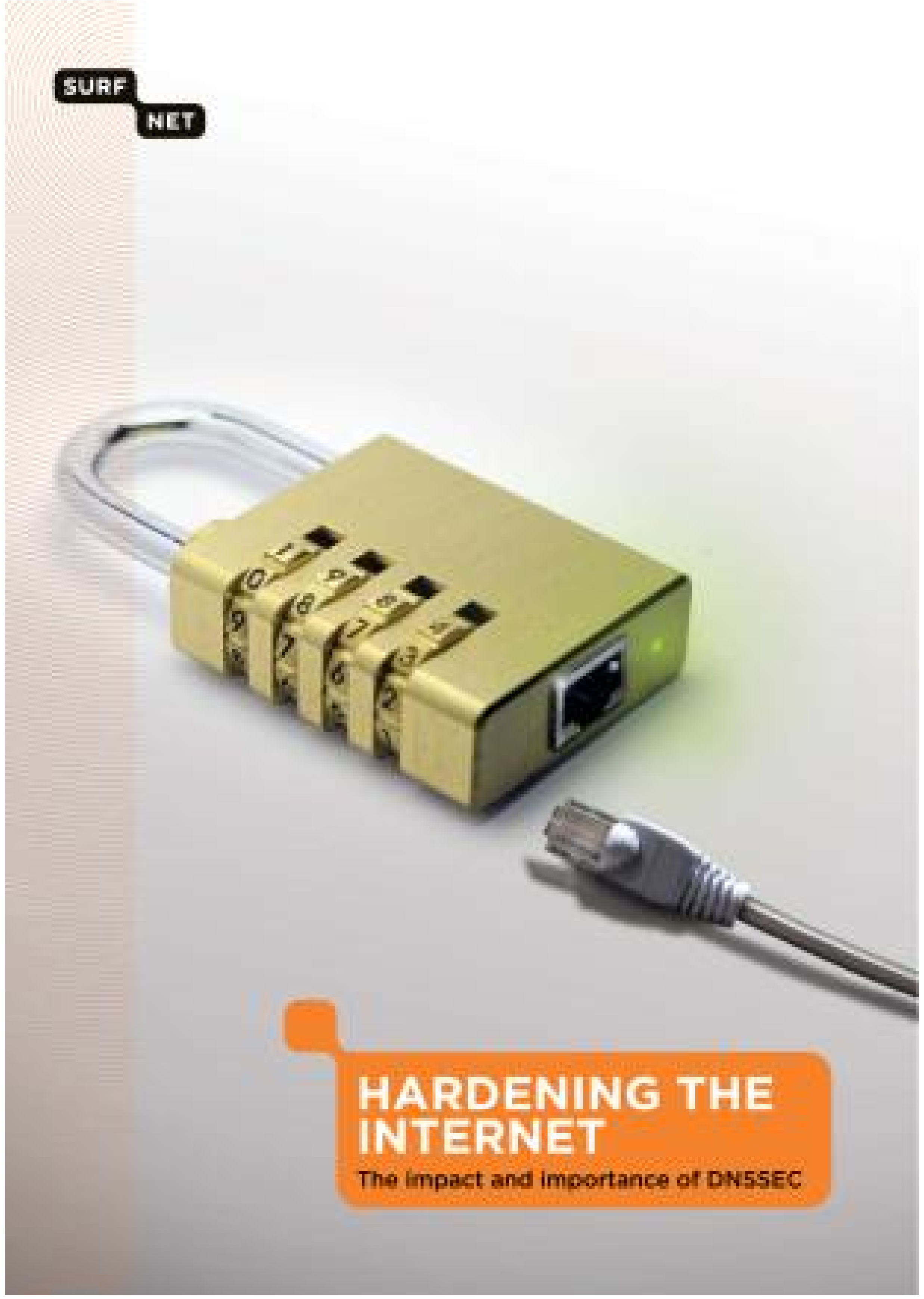

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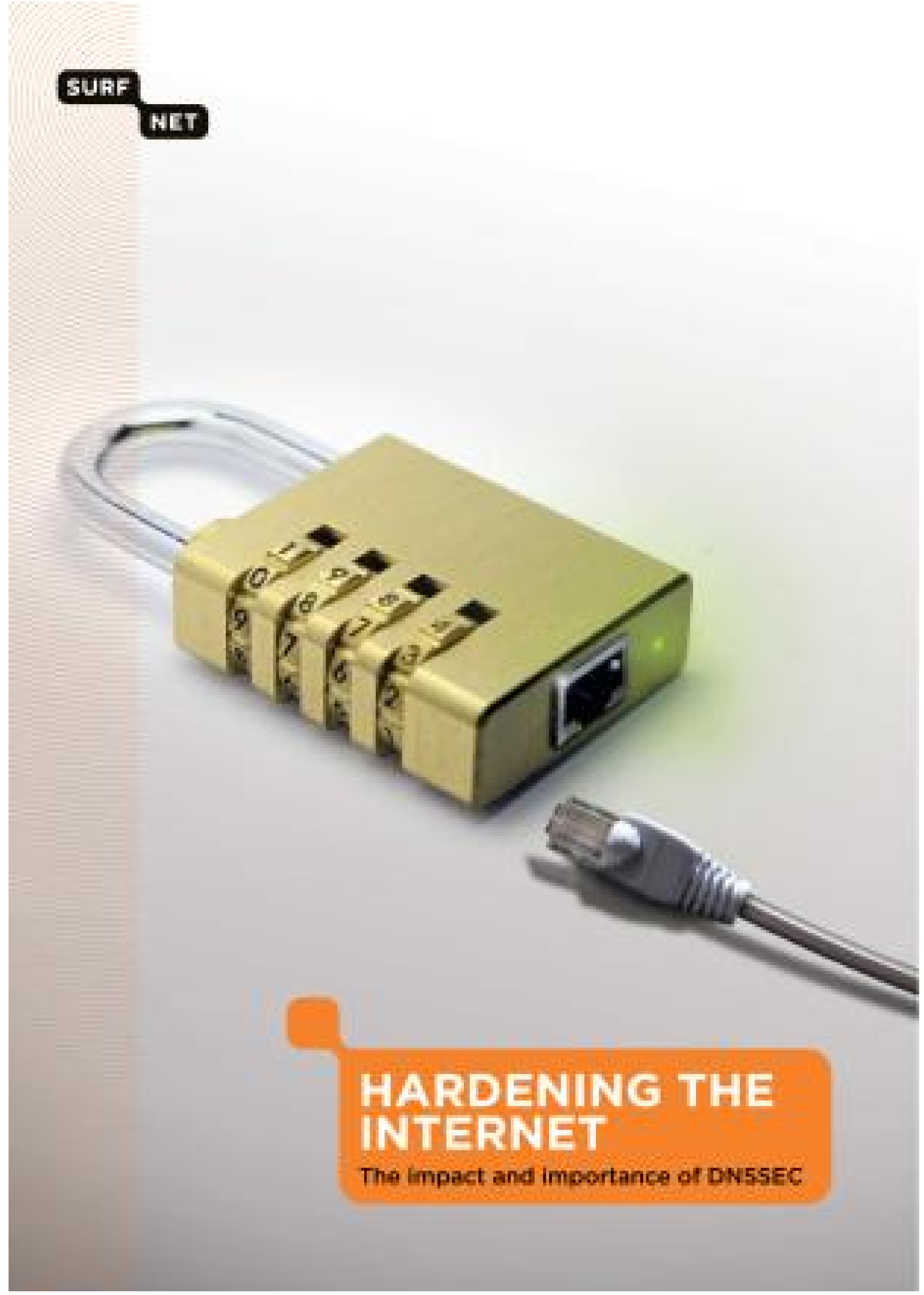

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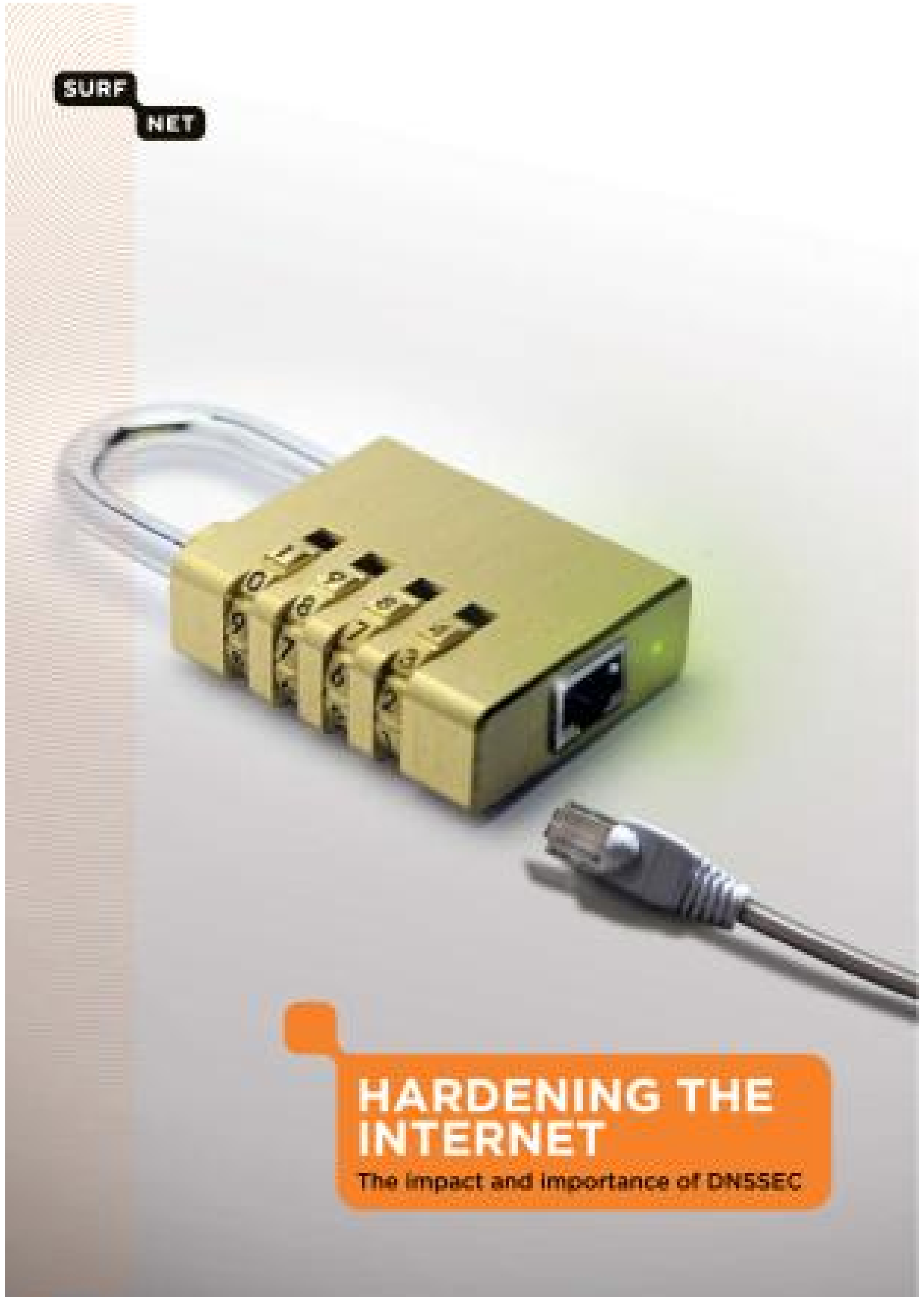

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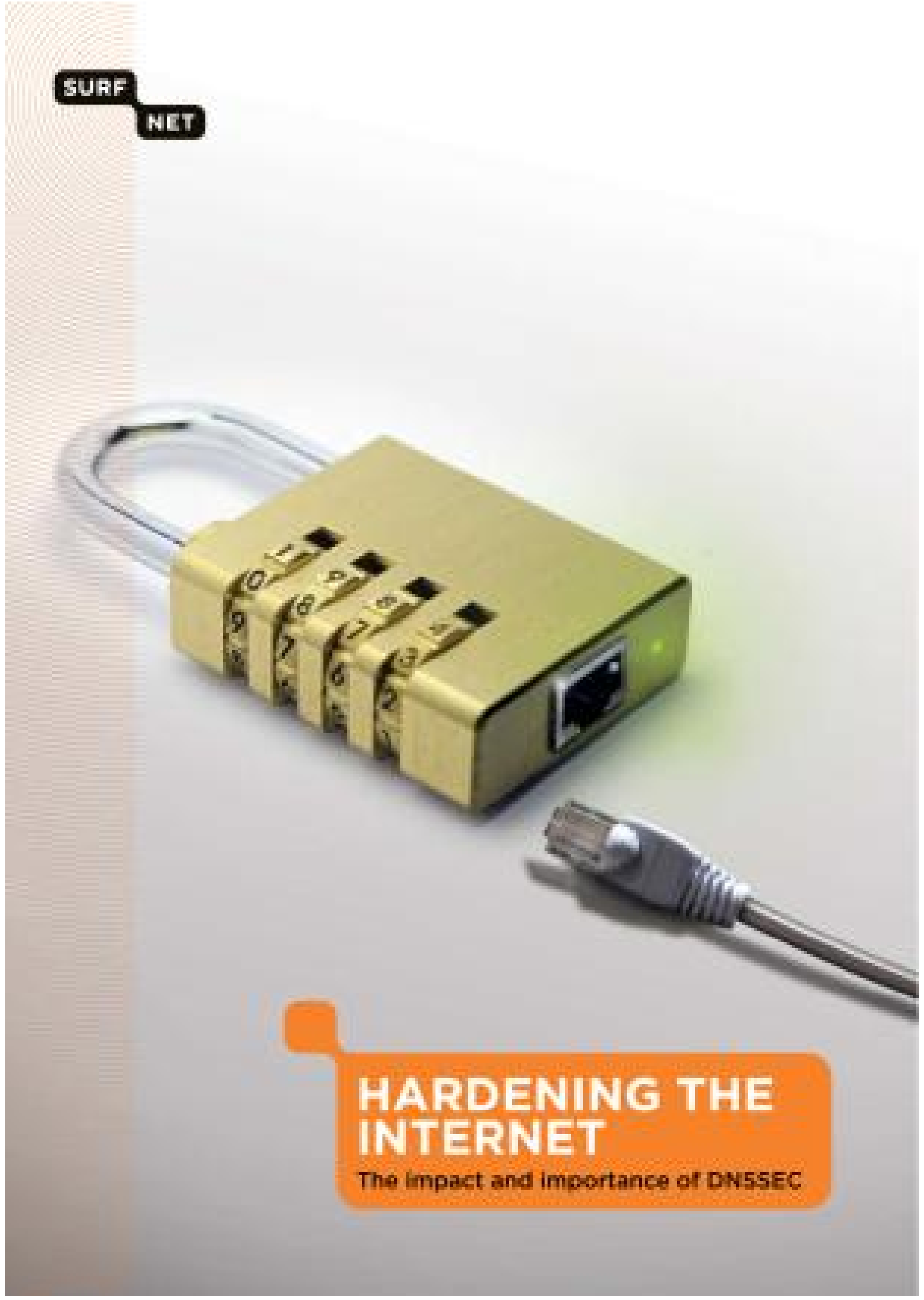

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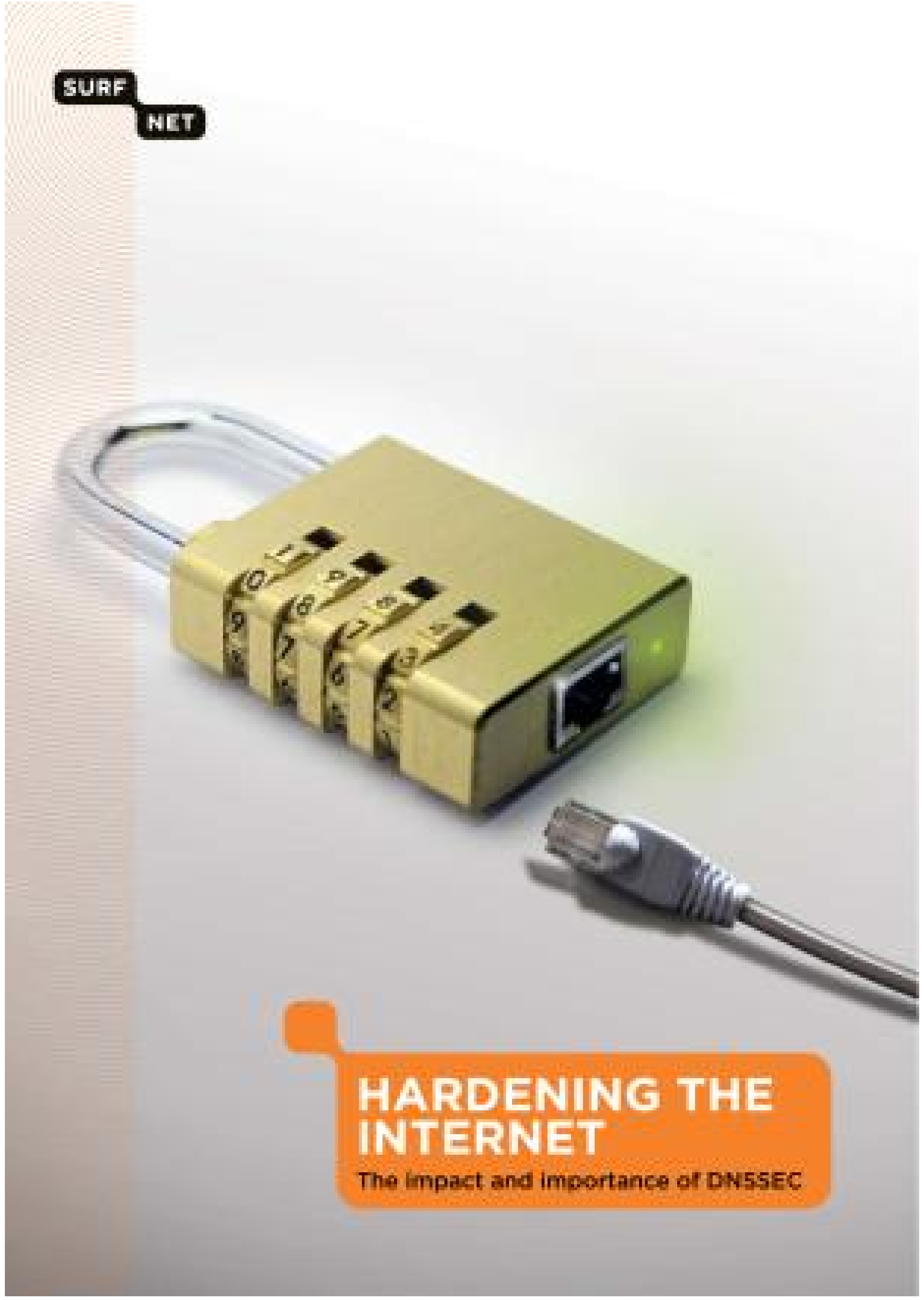

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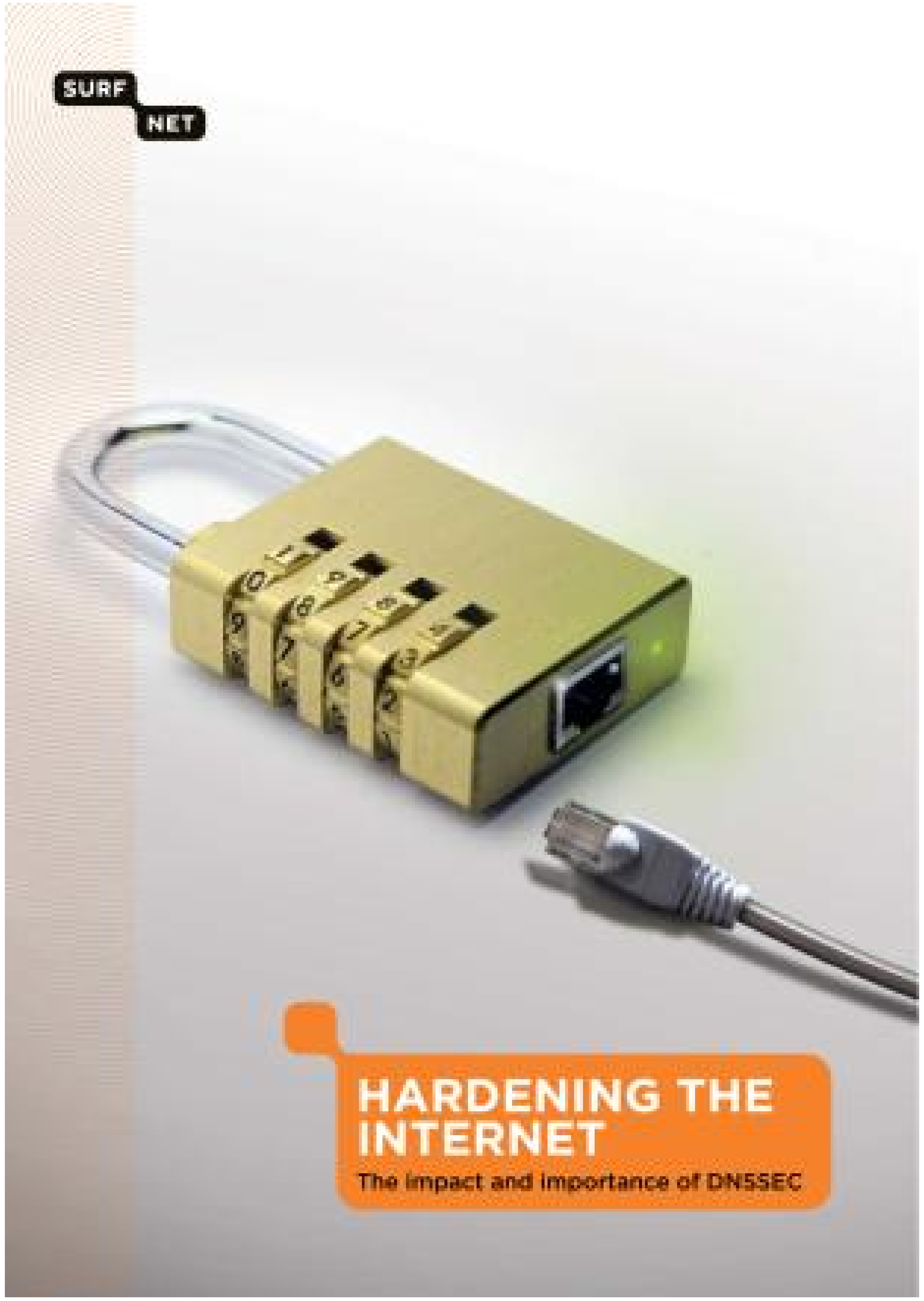

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Precomputation forced DNSSEC down a path of unreliability, insecurity, and unusability.
Let's see how this happened.

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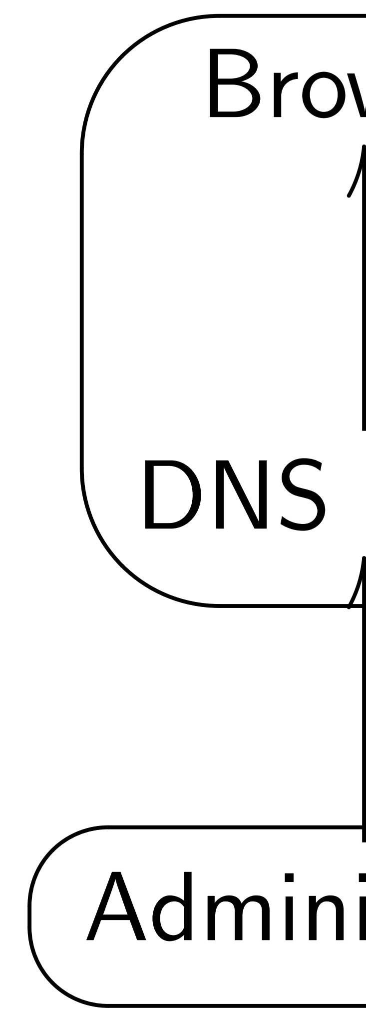

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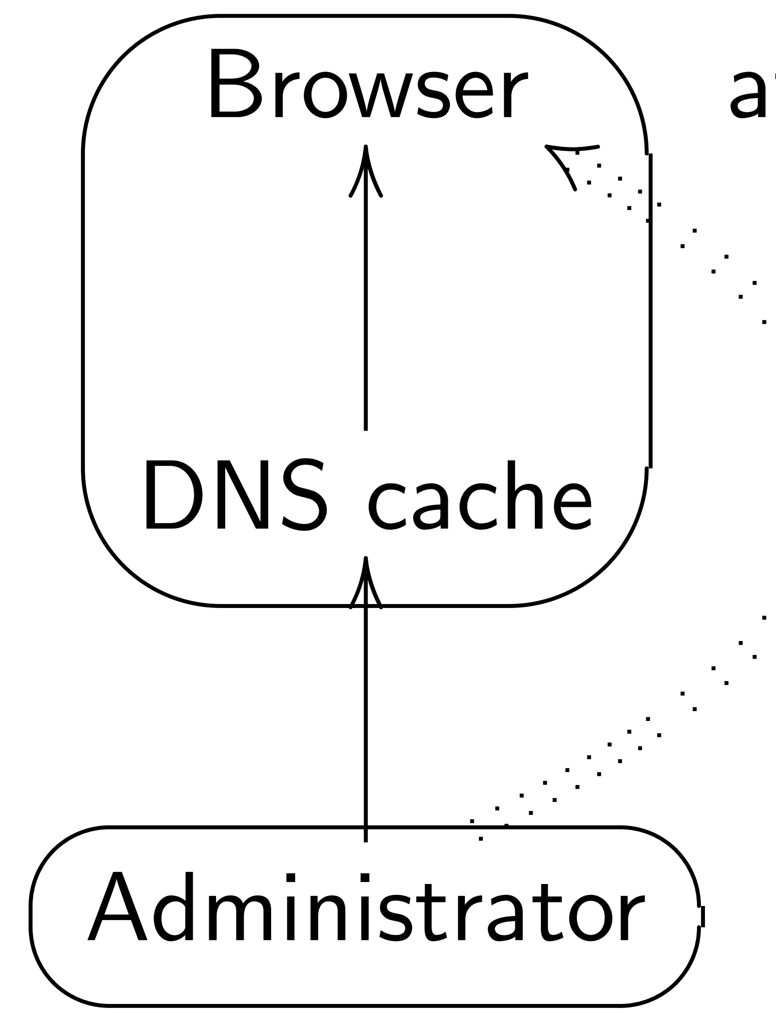

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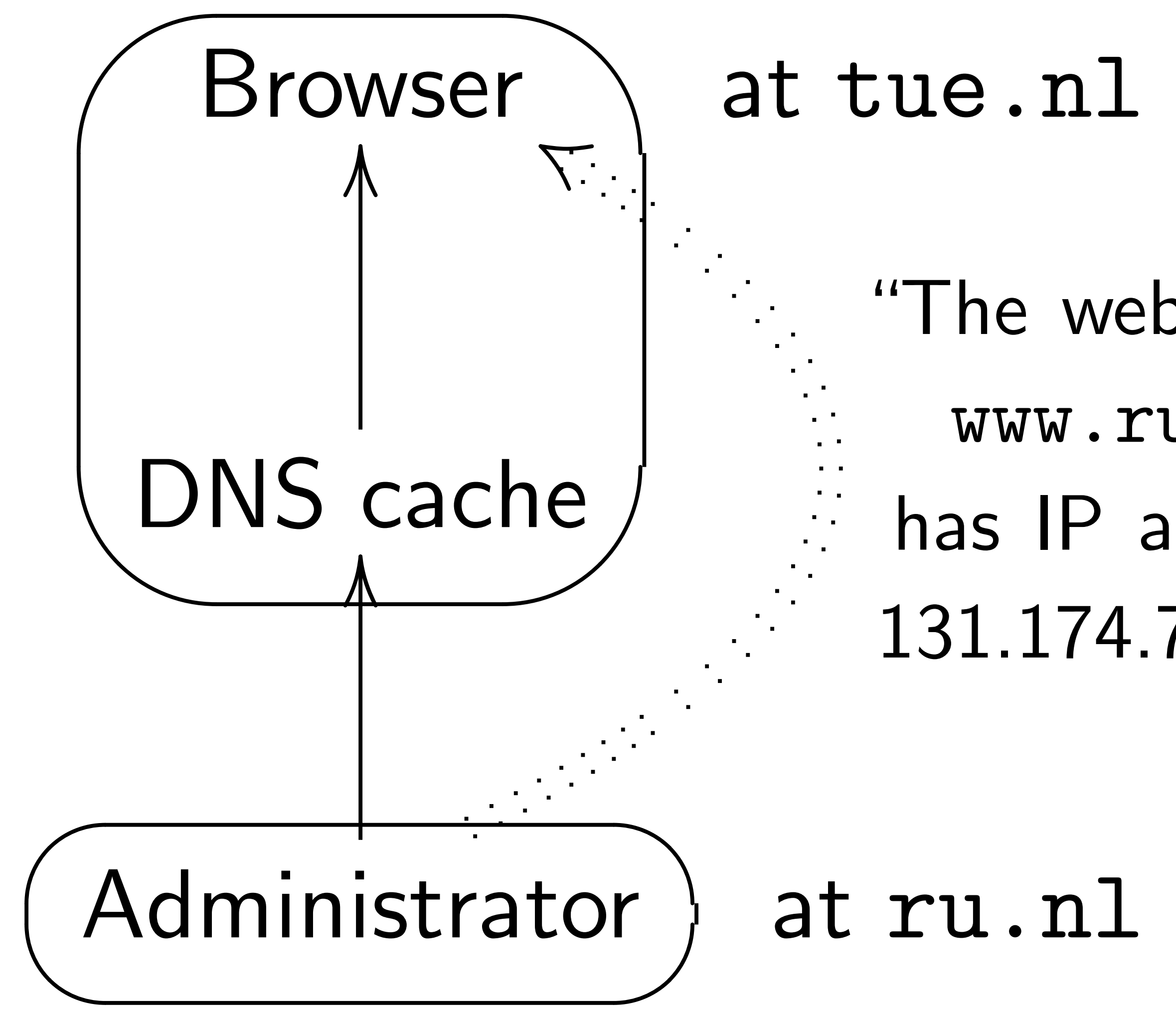

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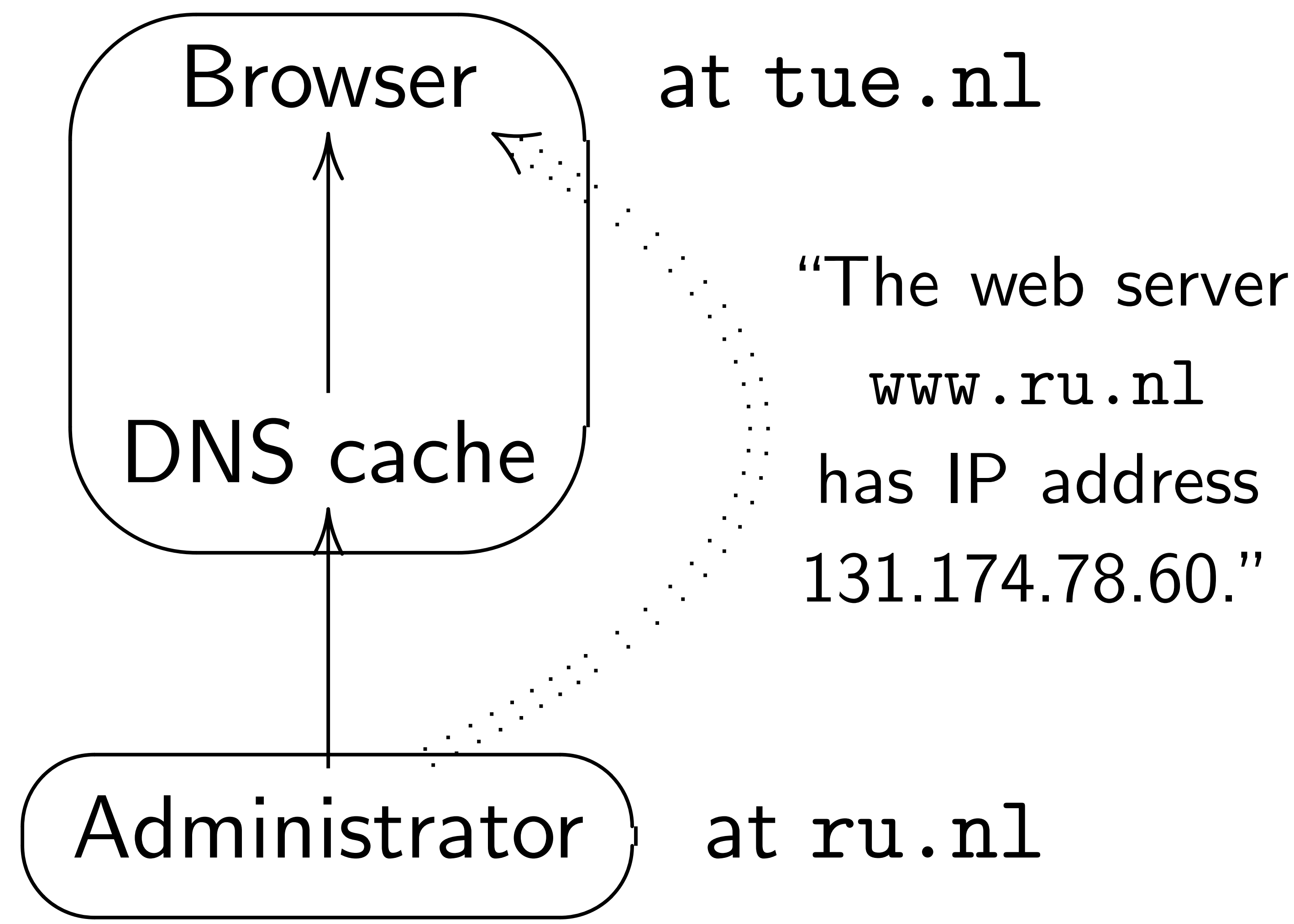

Cache pulls data from administrator if it doesn't already have the data.

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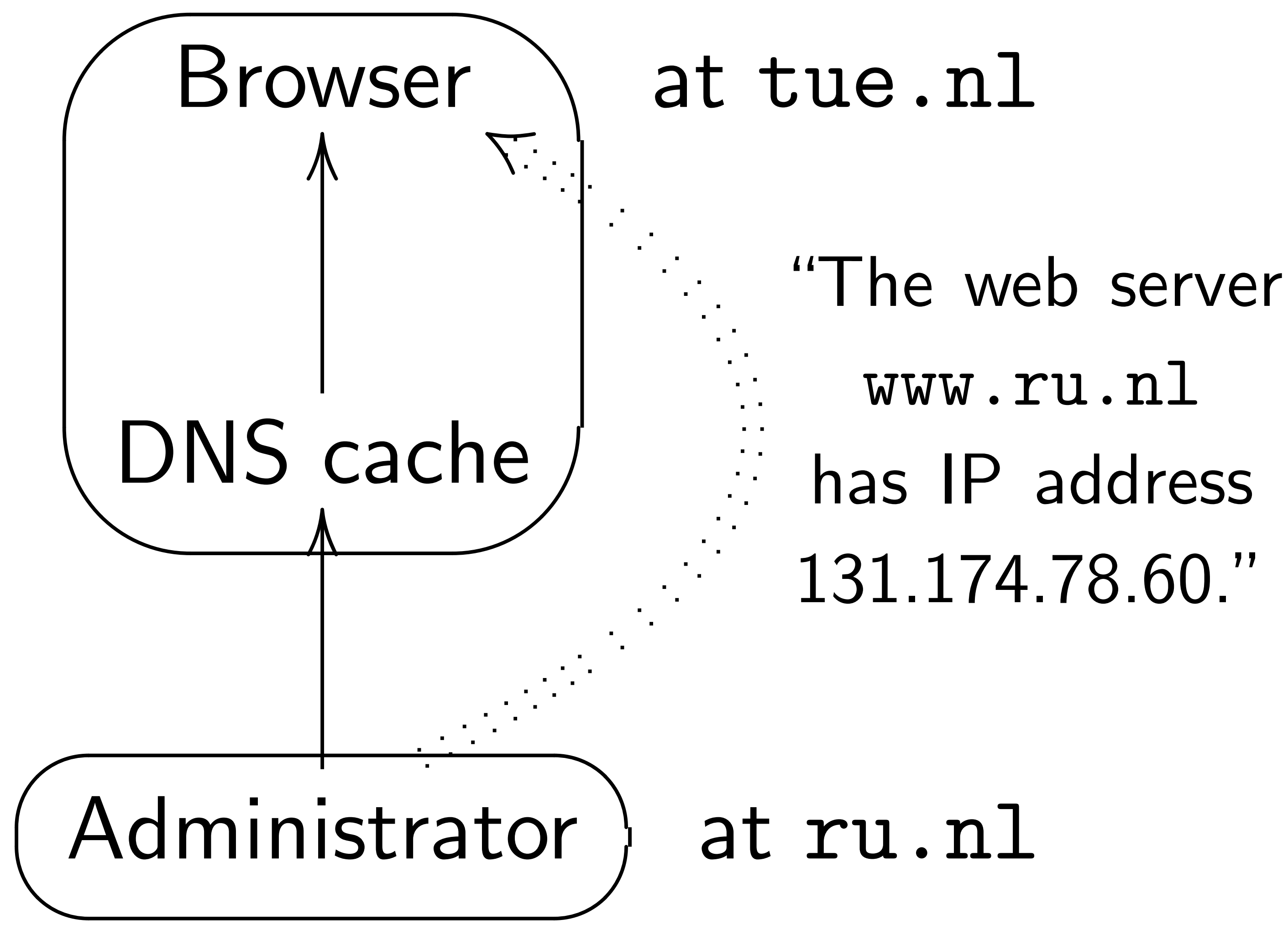

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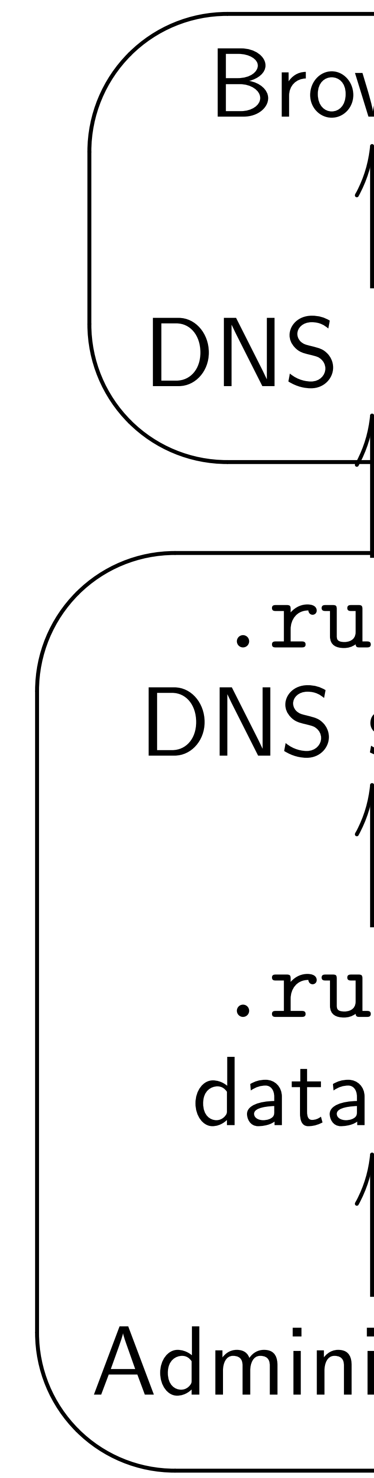

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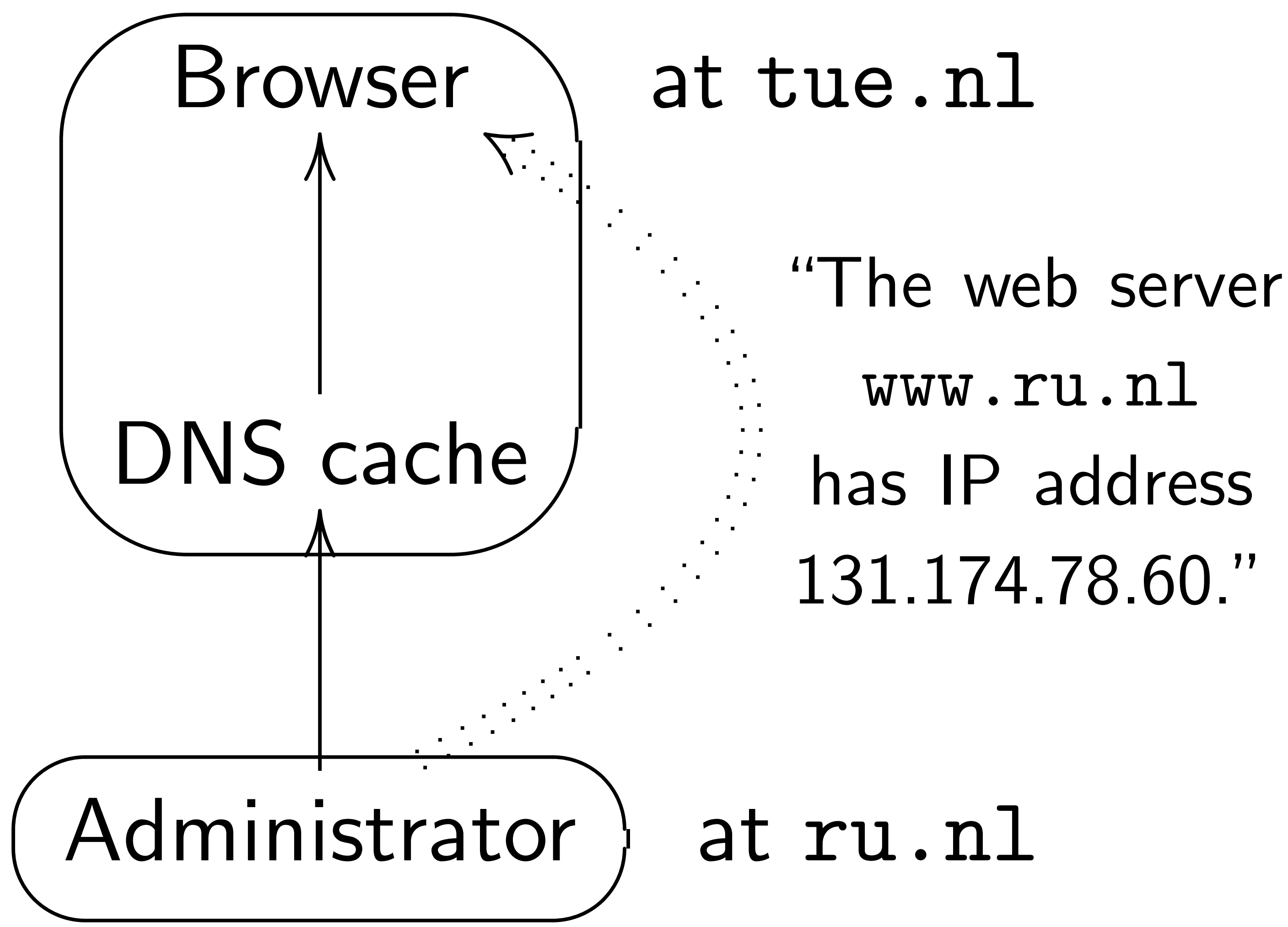

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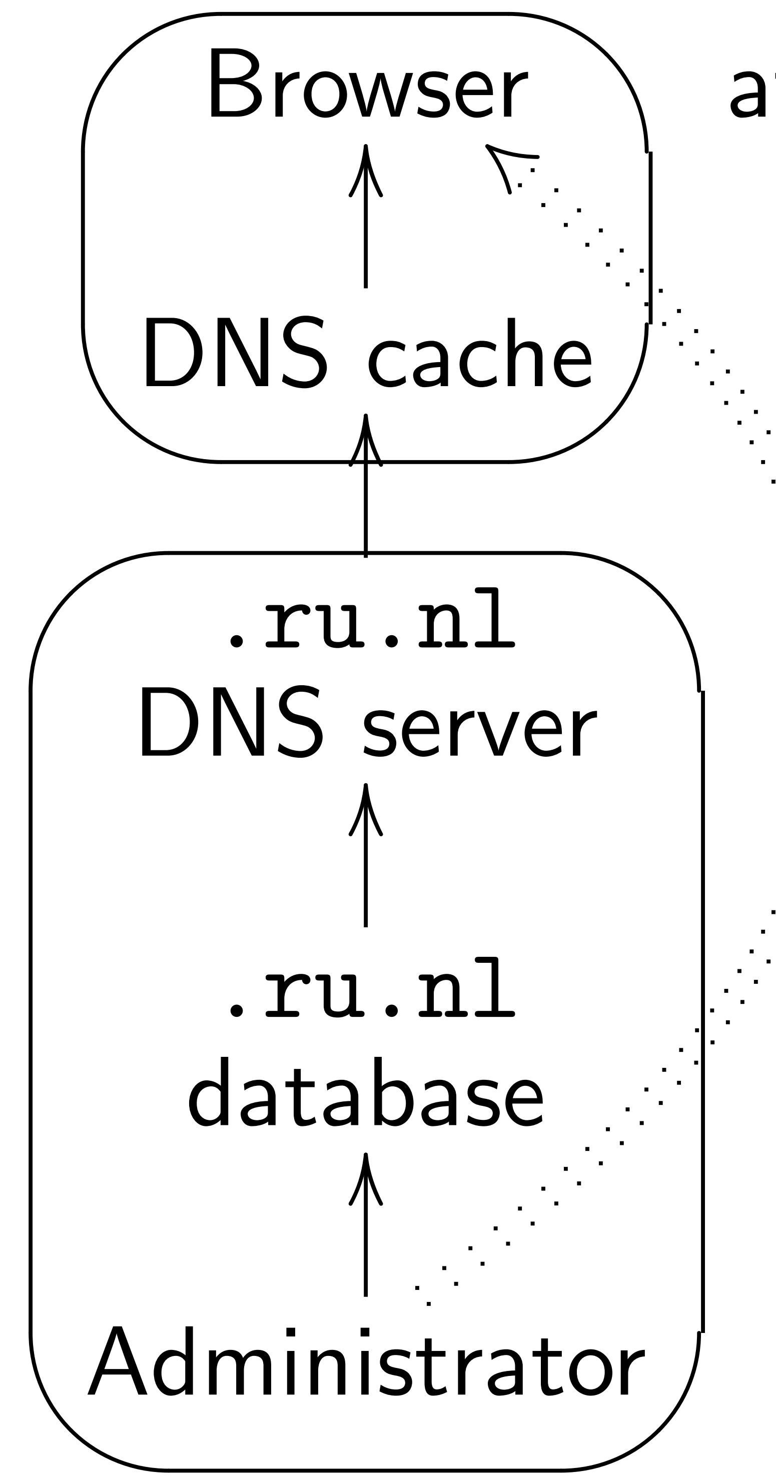

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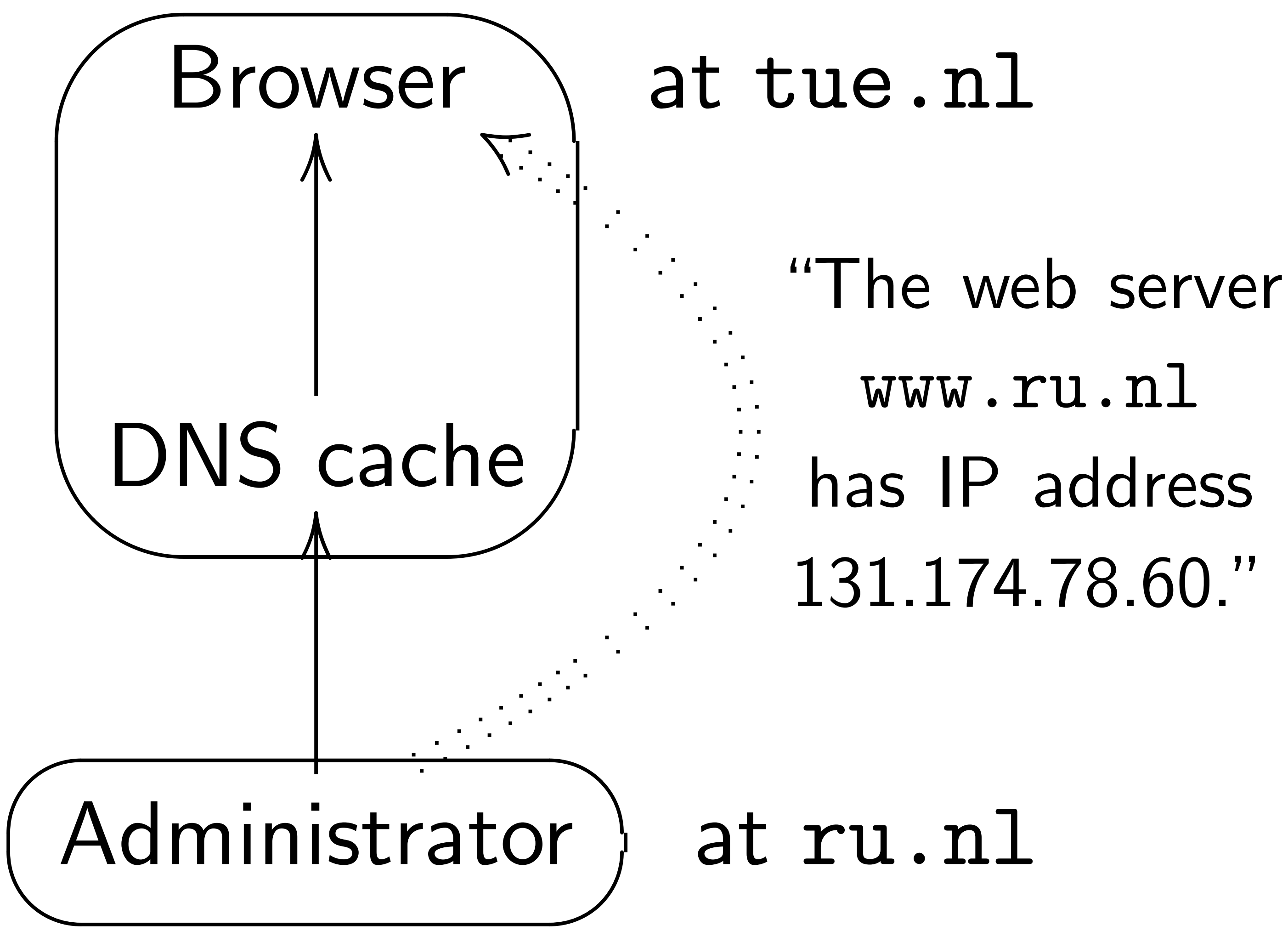

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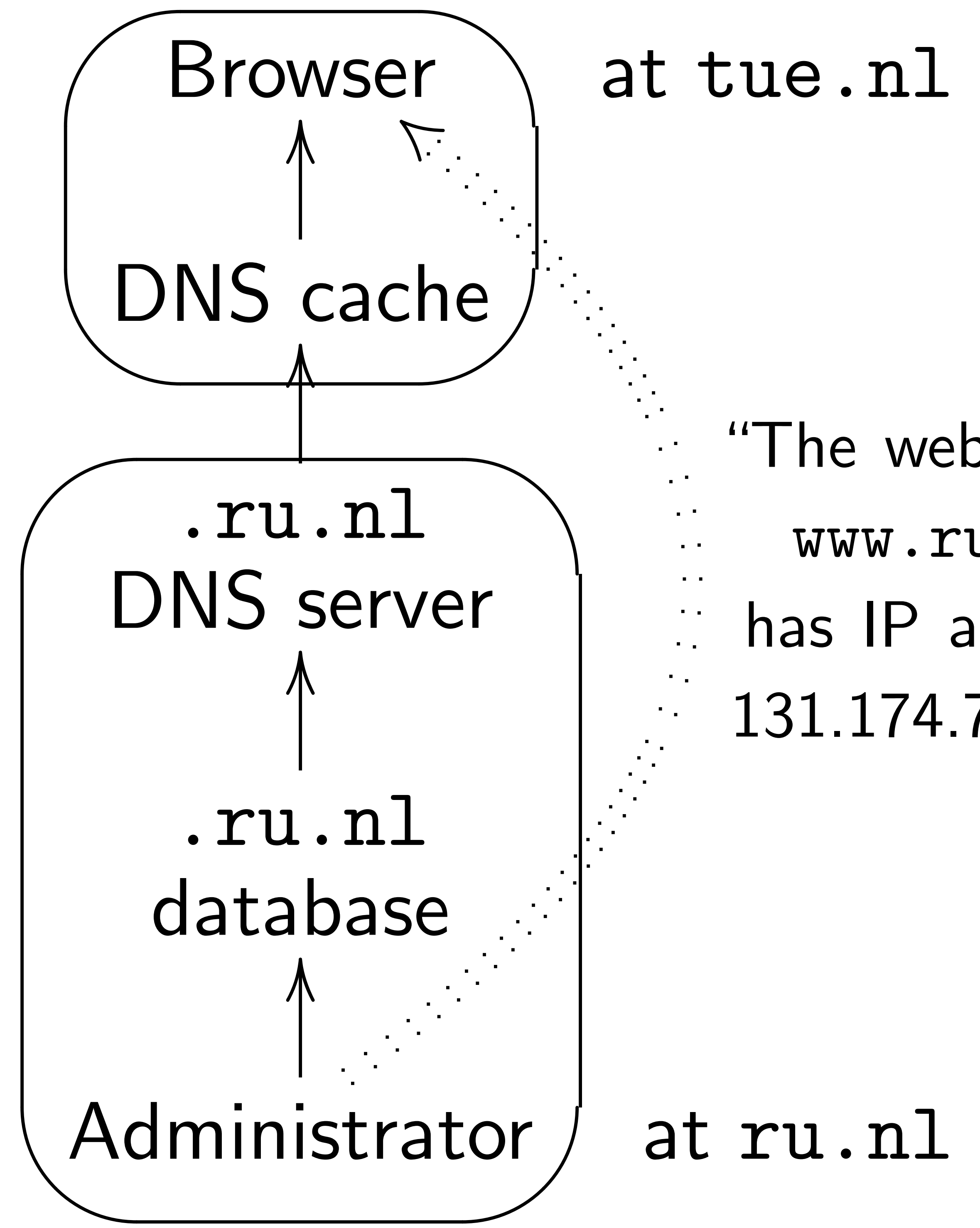

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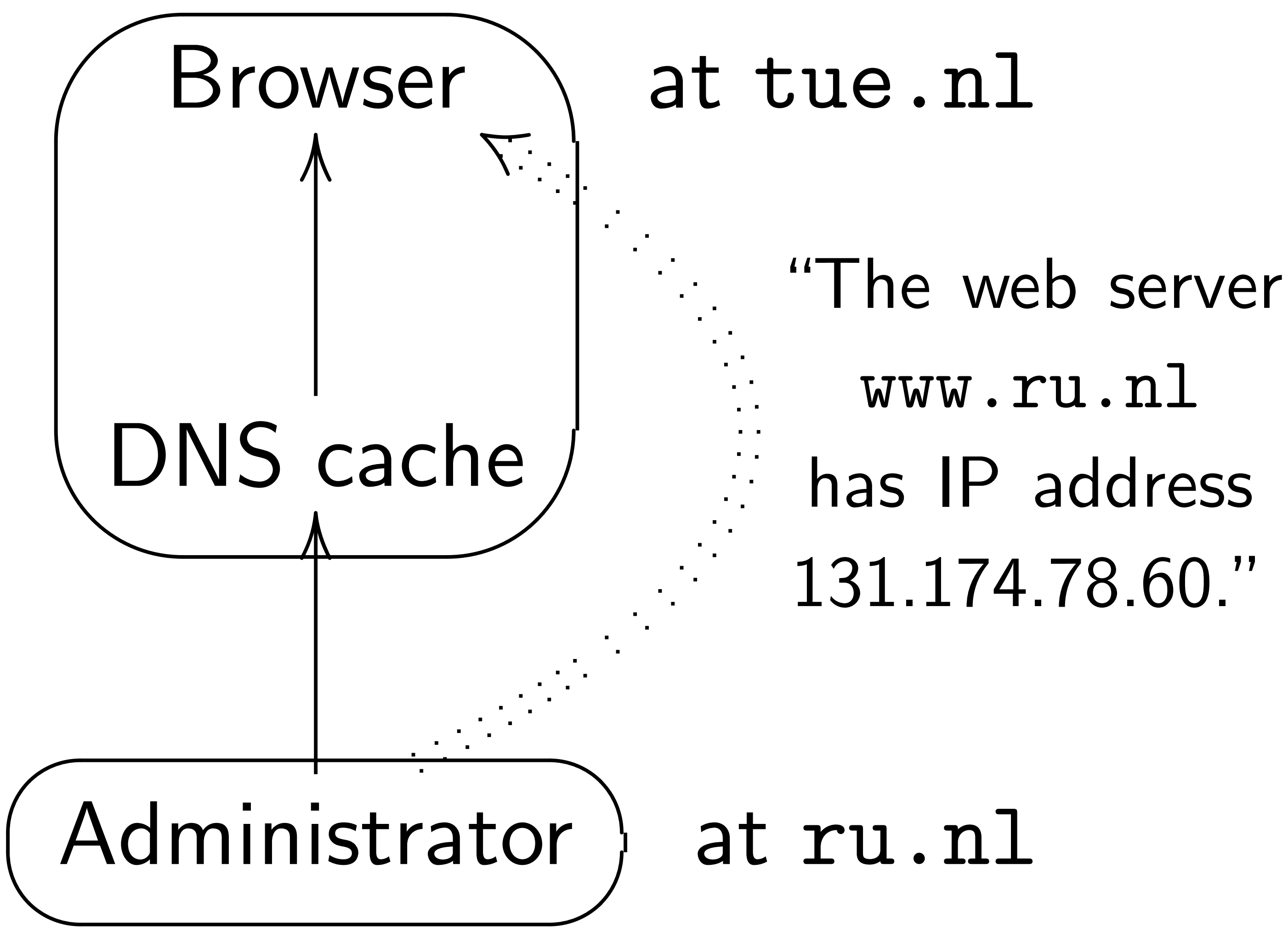

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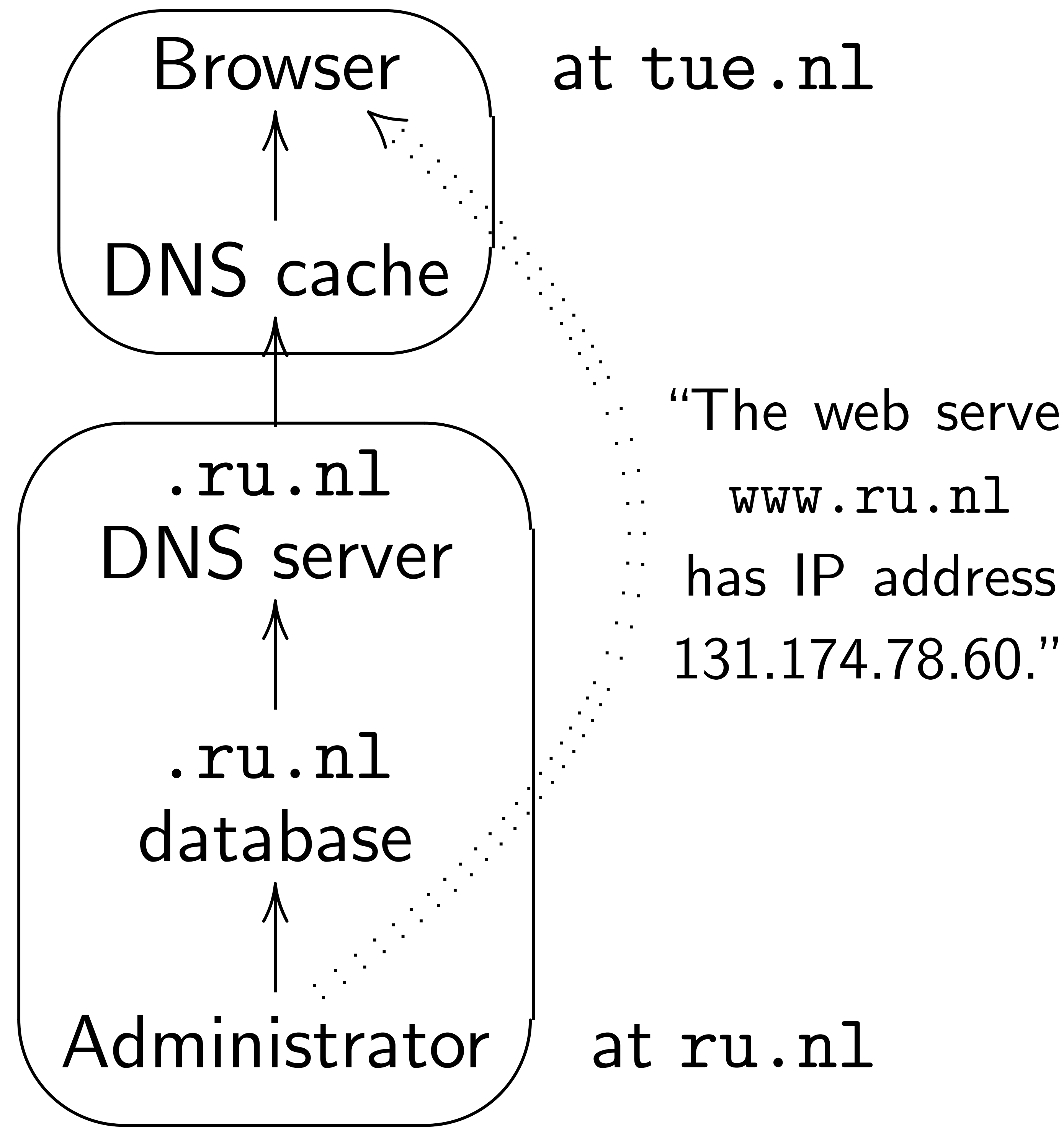

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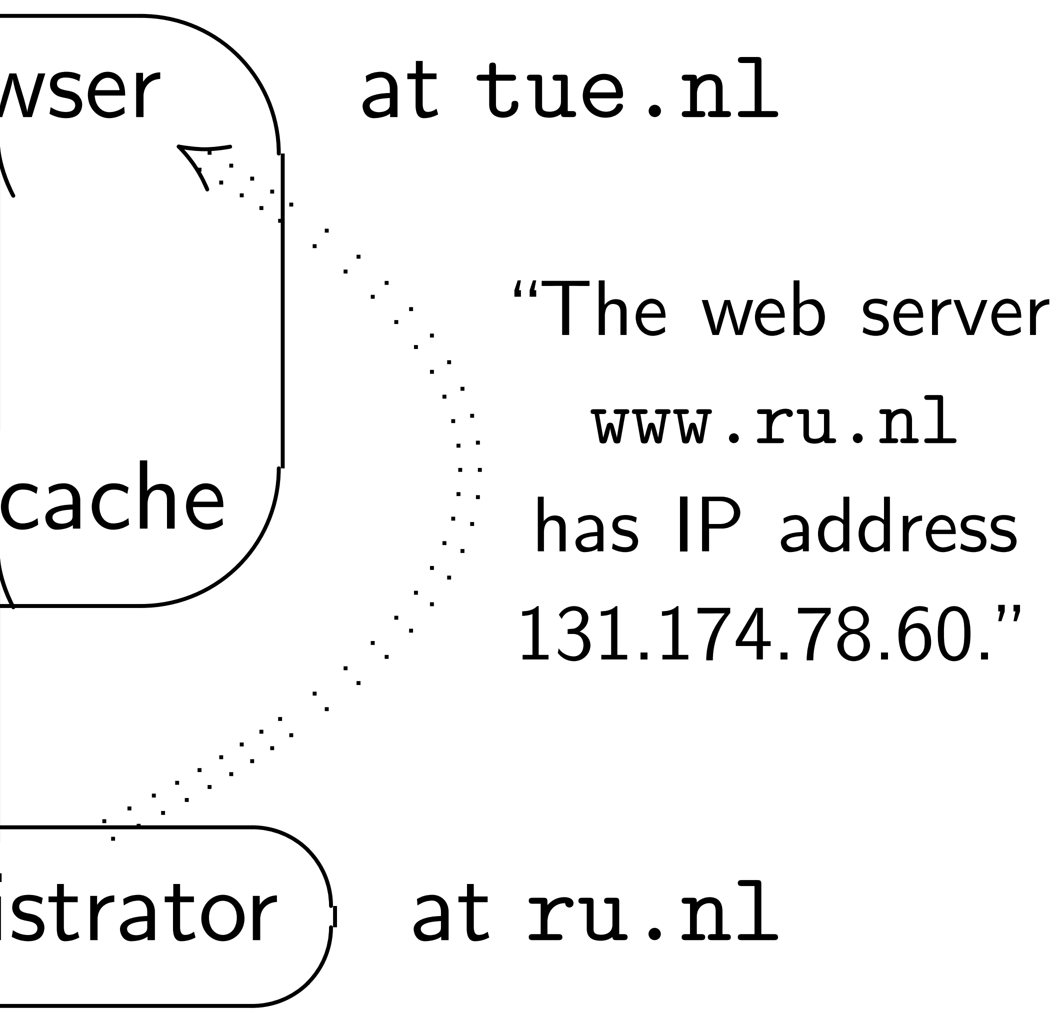

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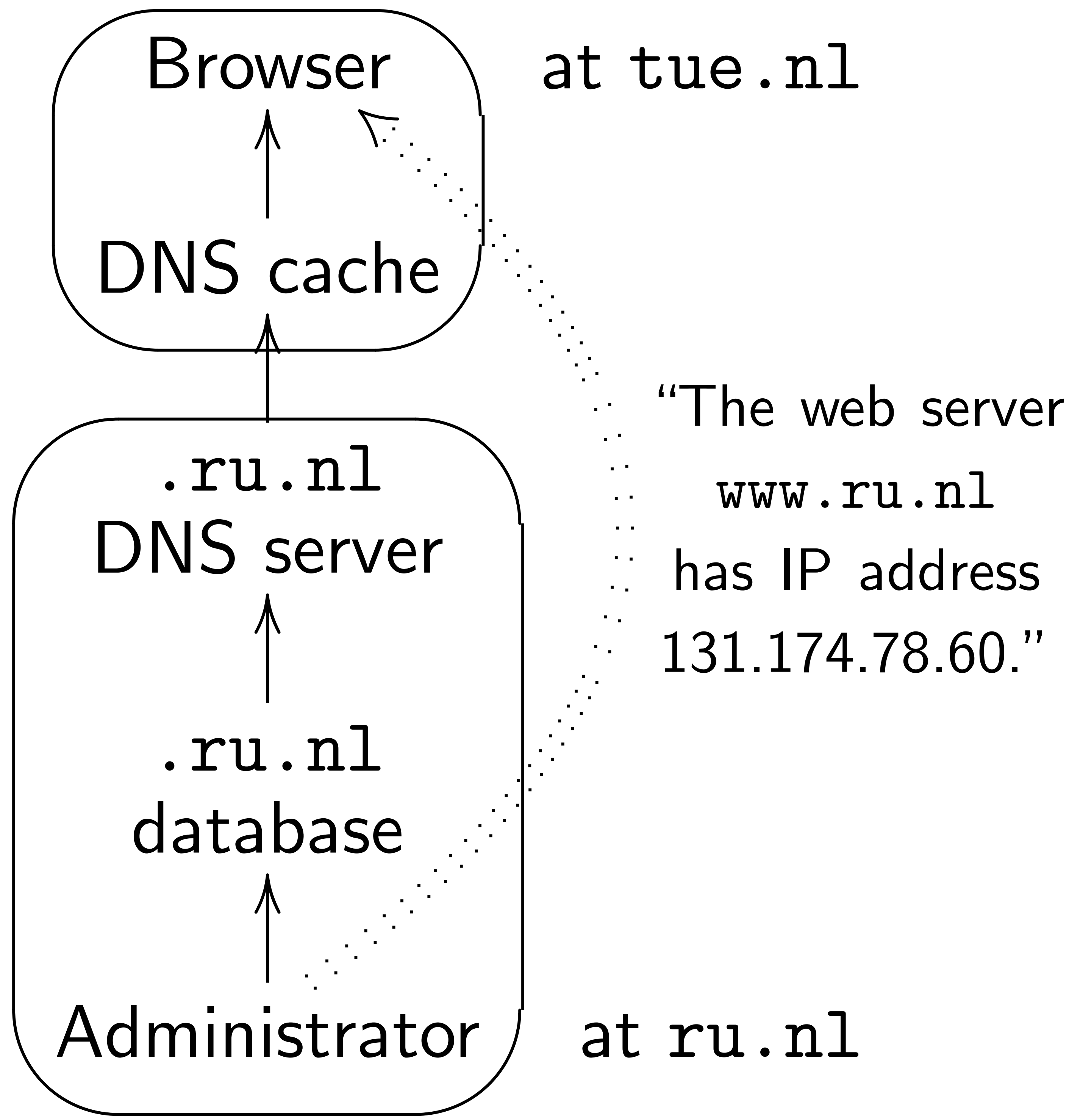

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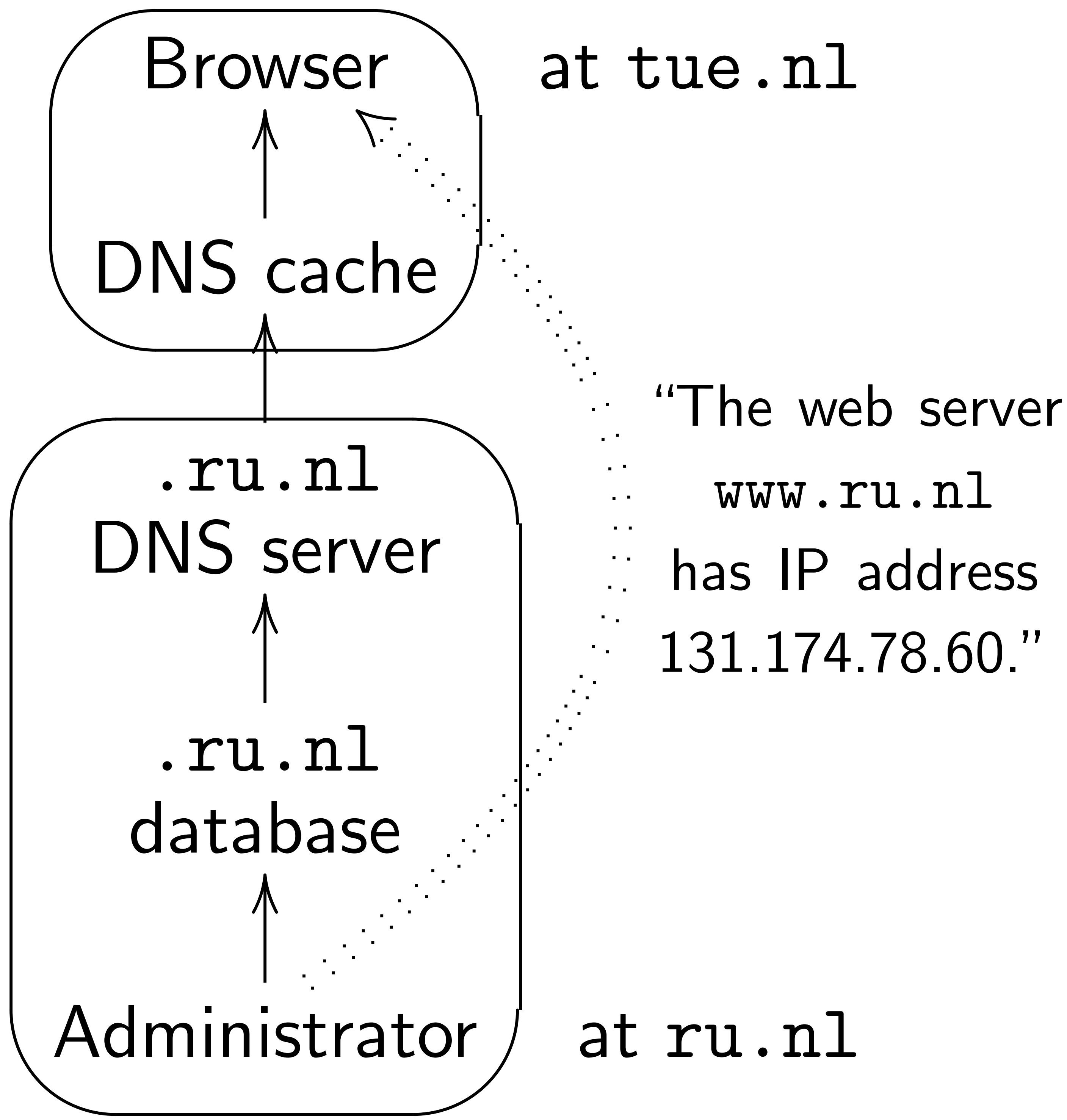

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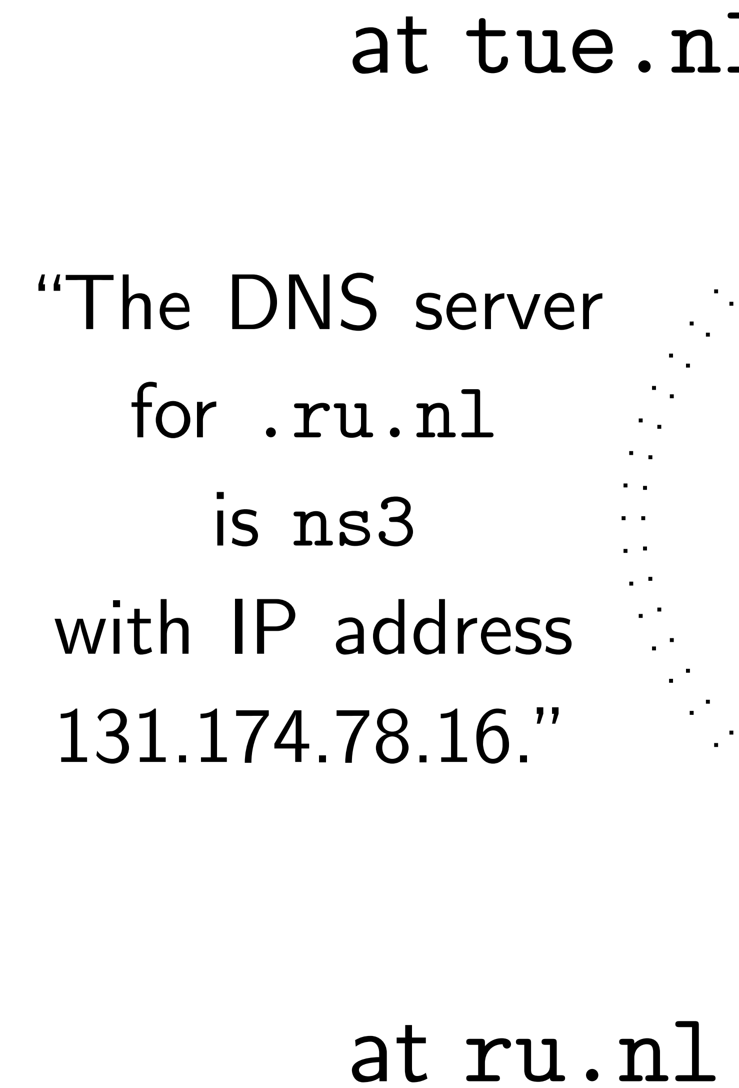

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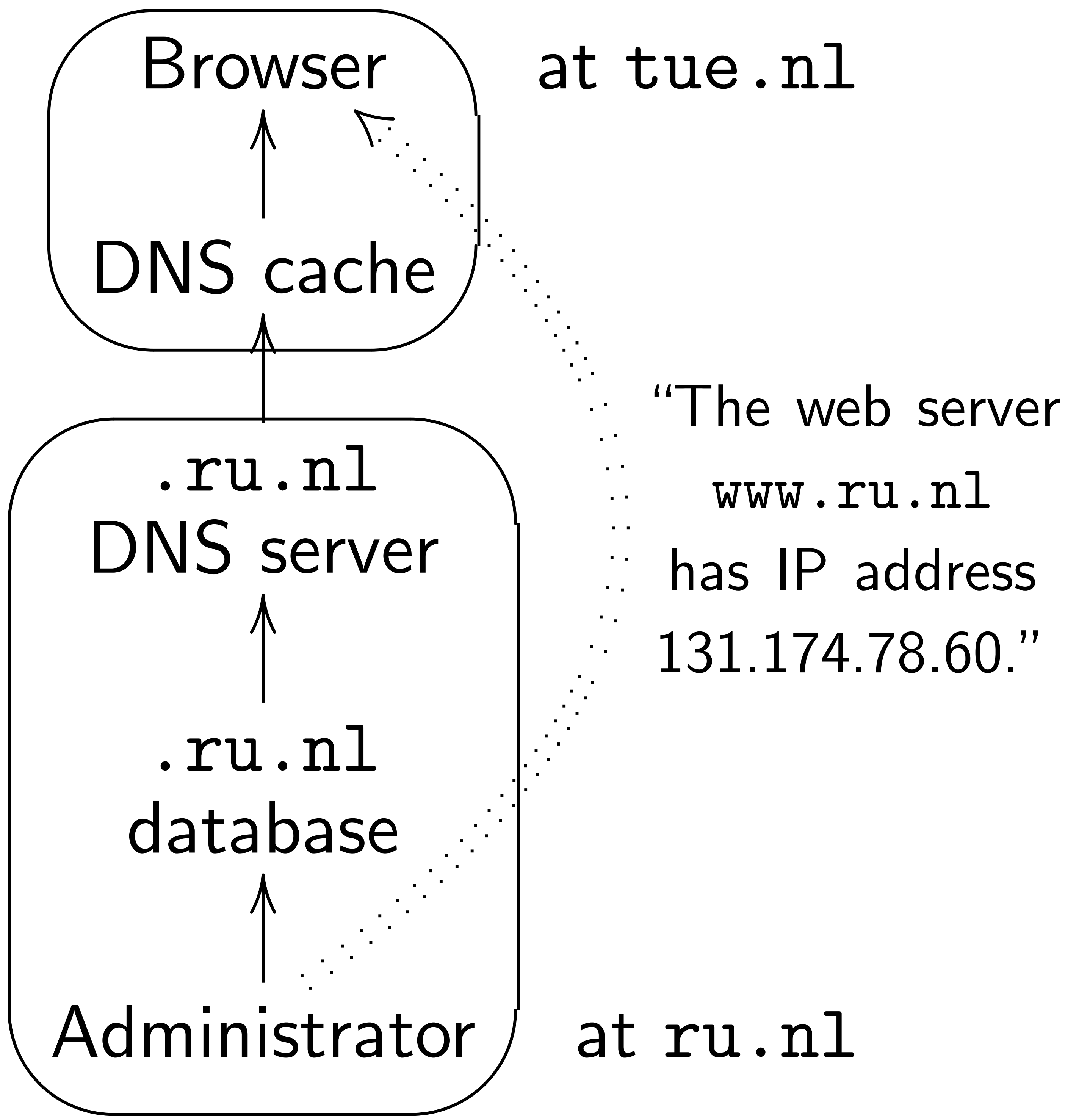

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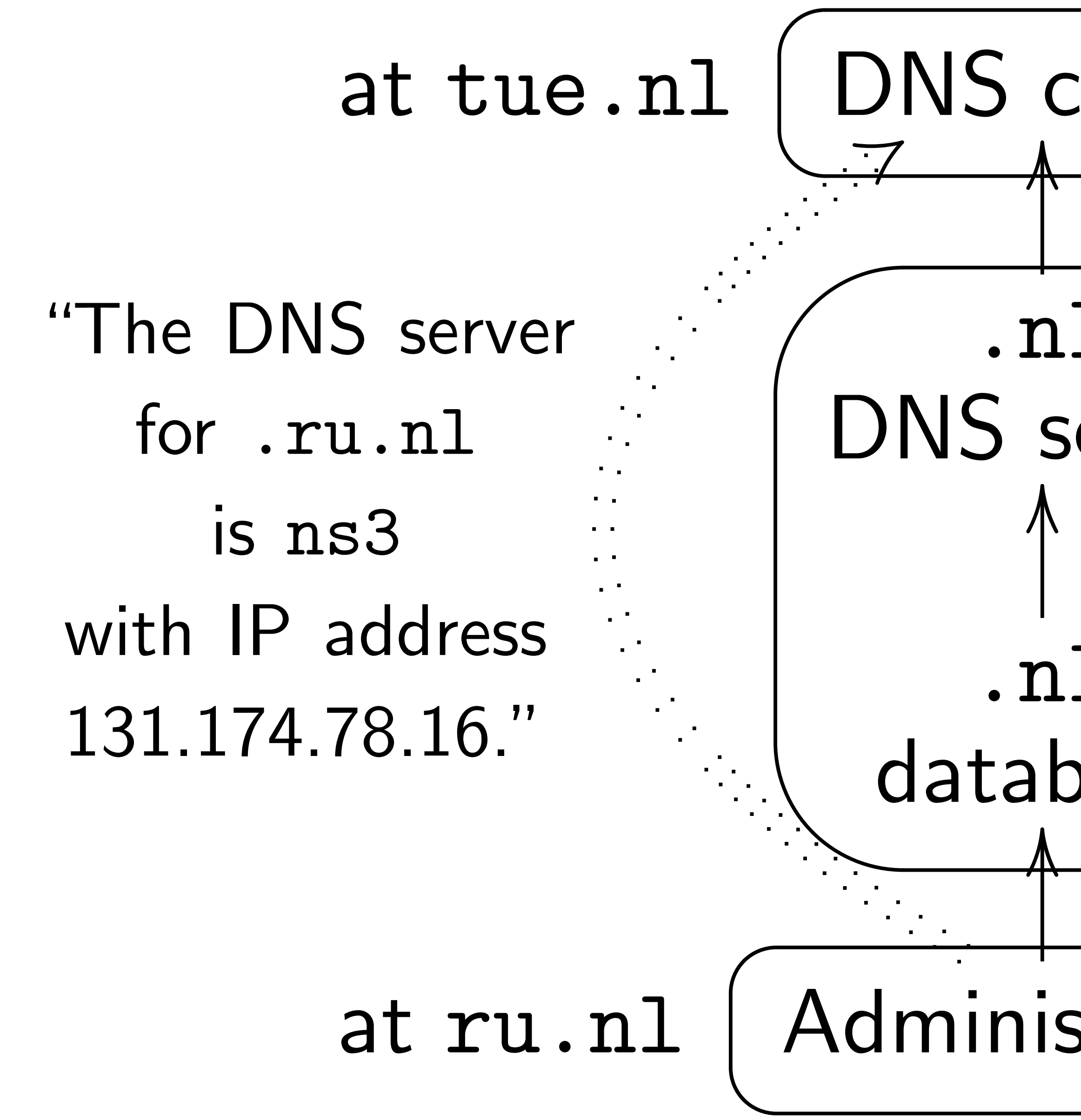

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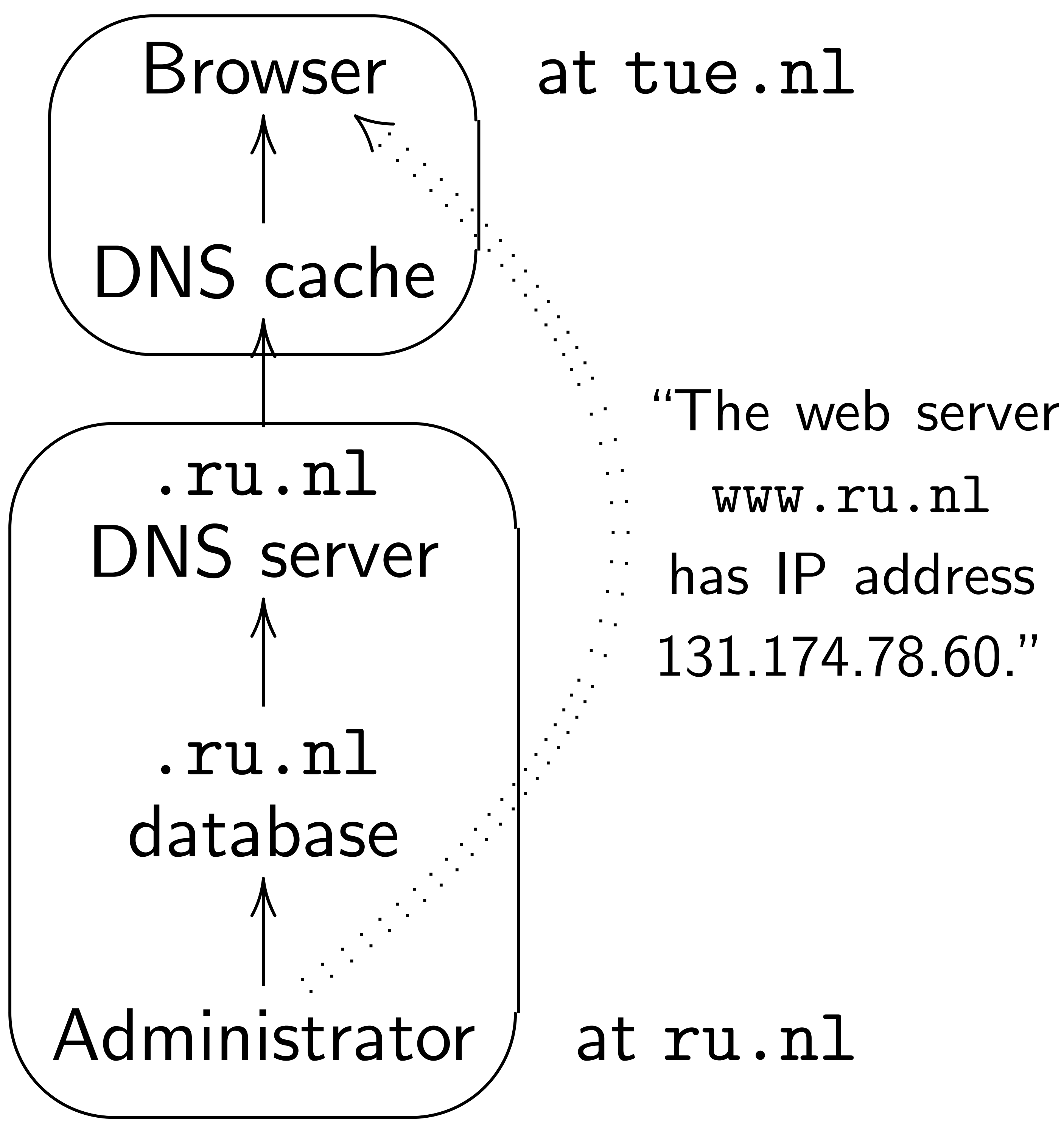

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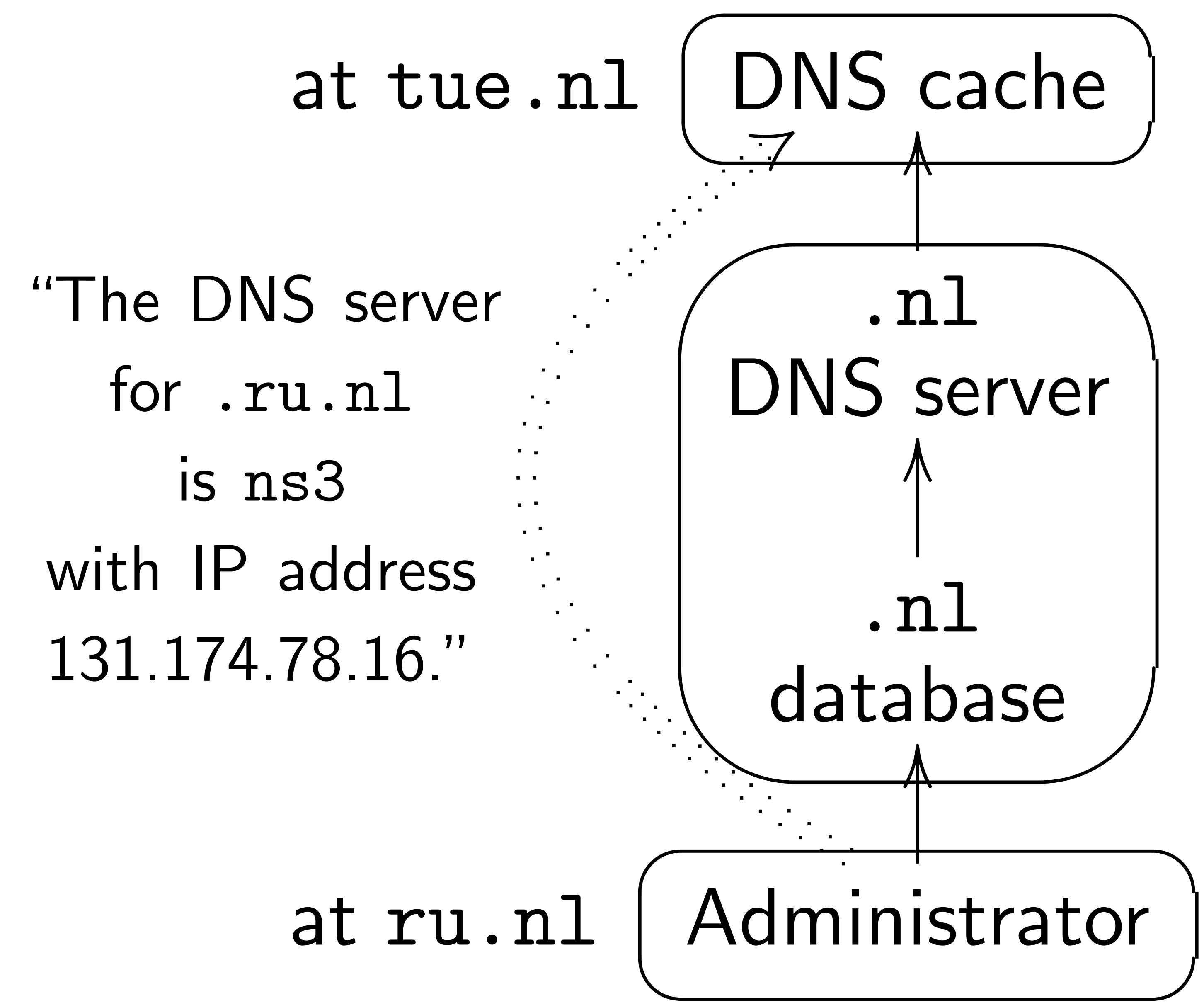

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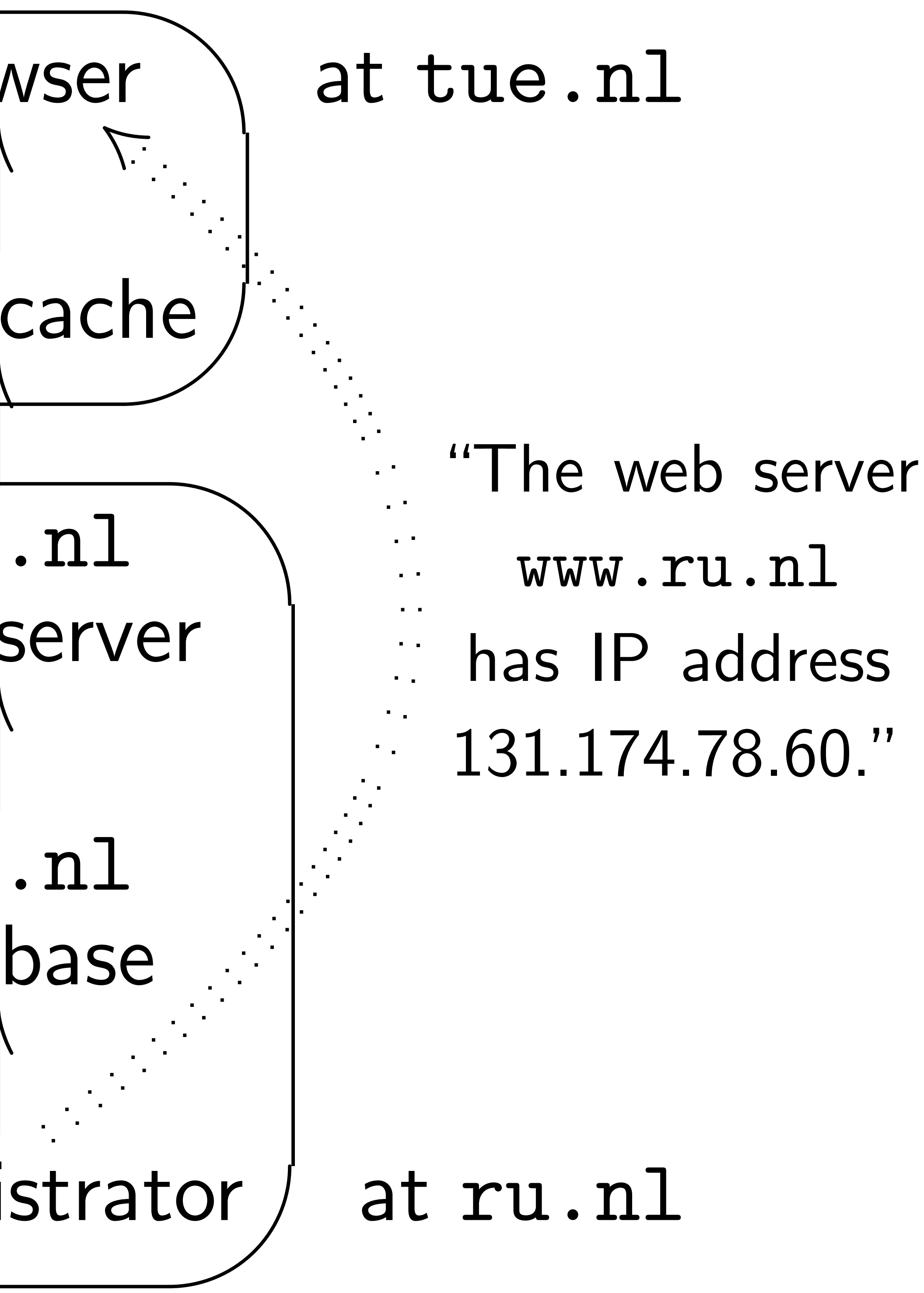

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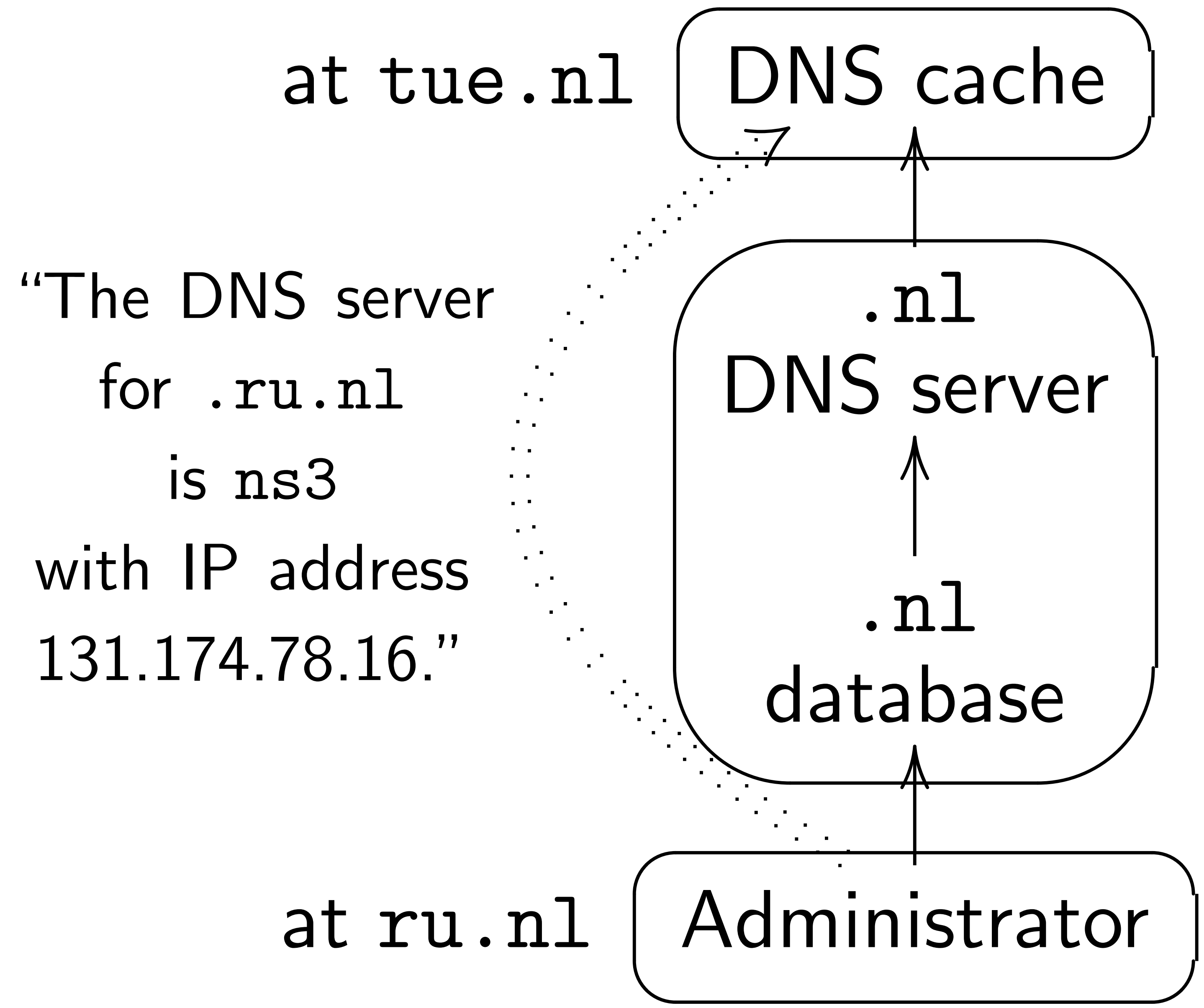

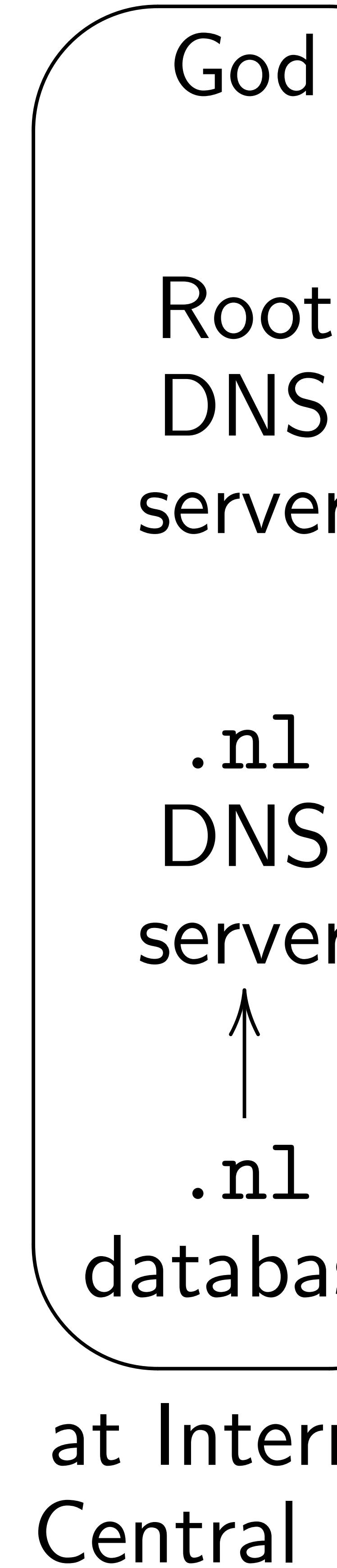

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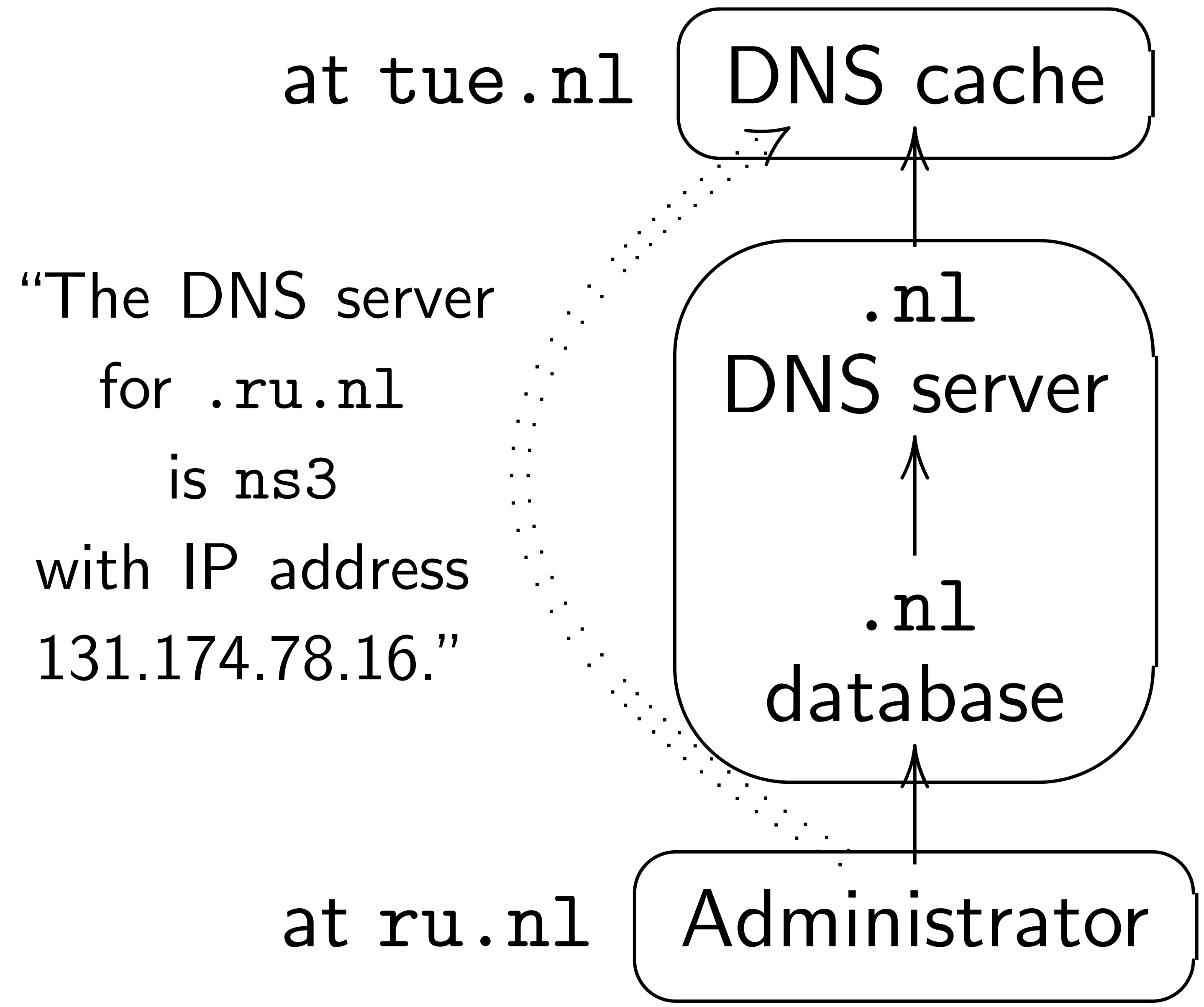

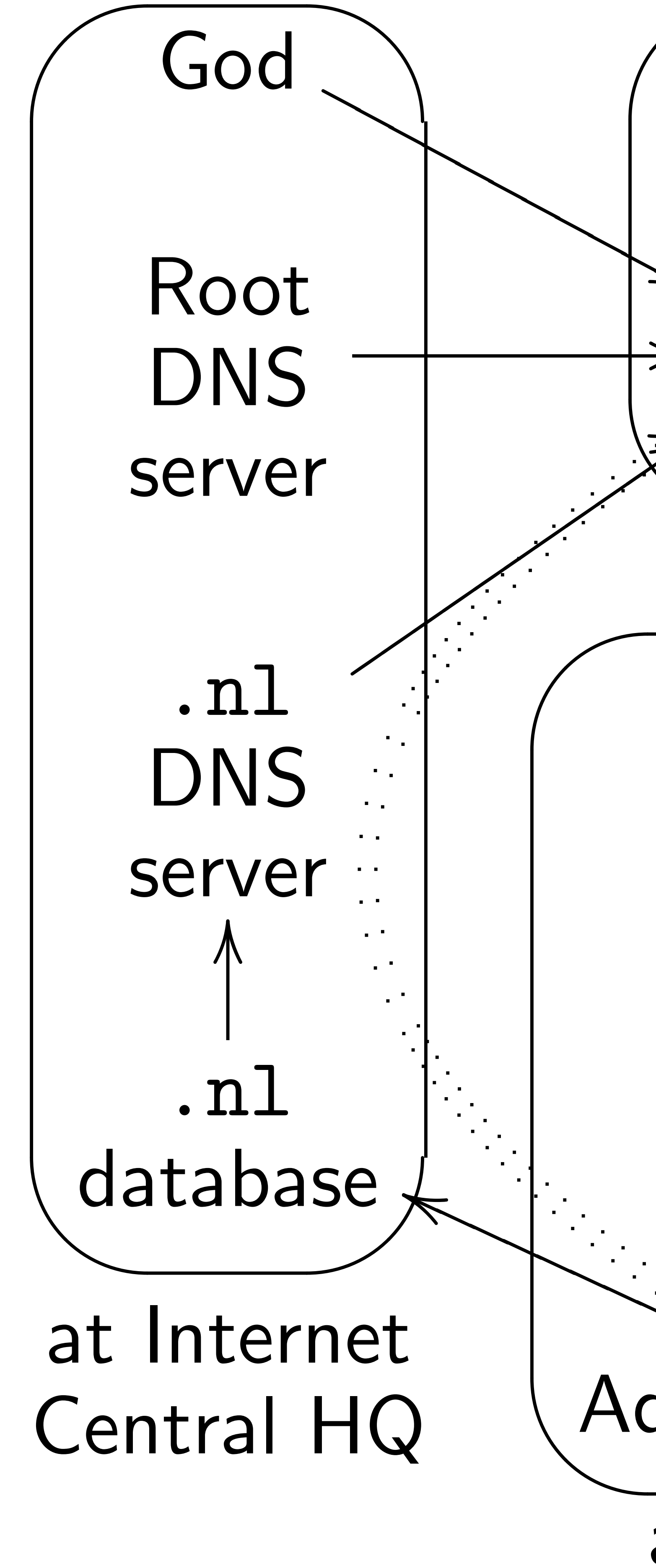

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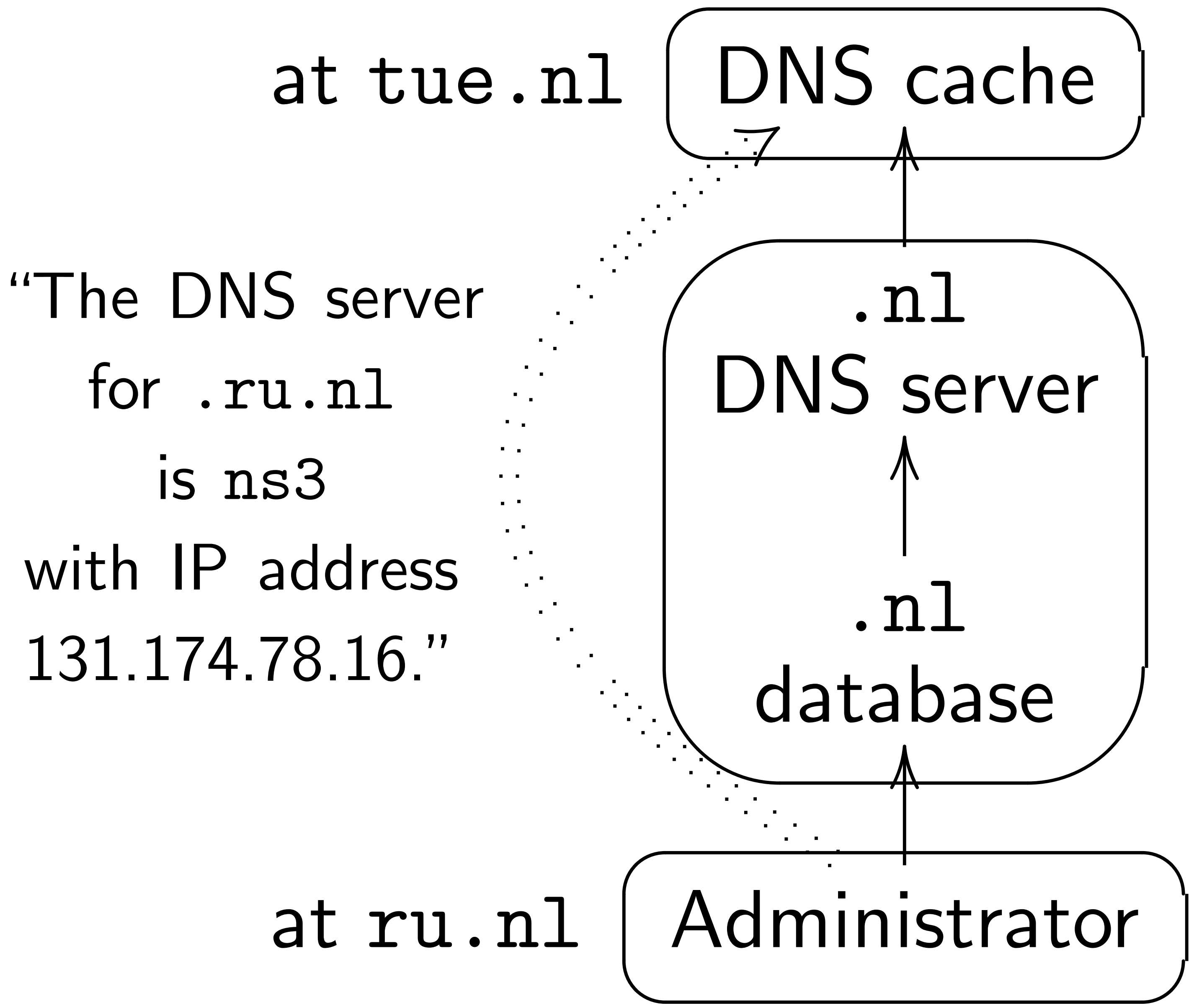

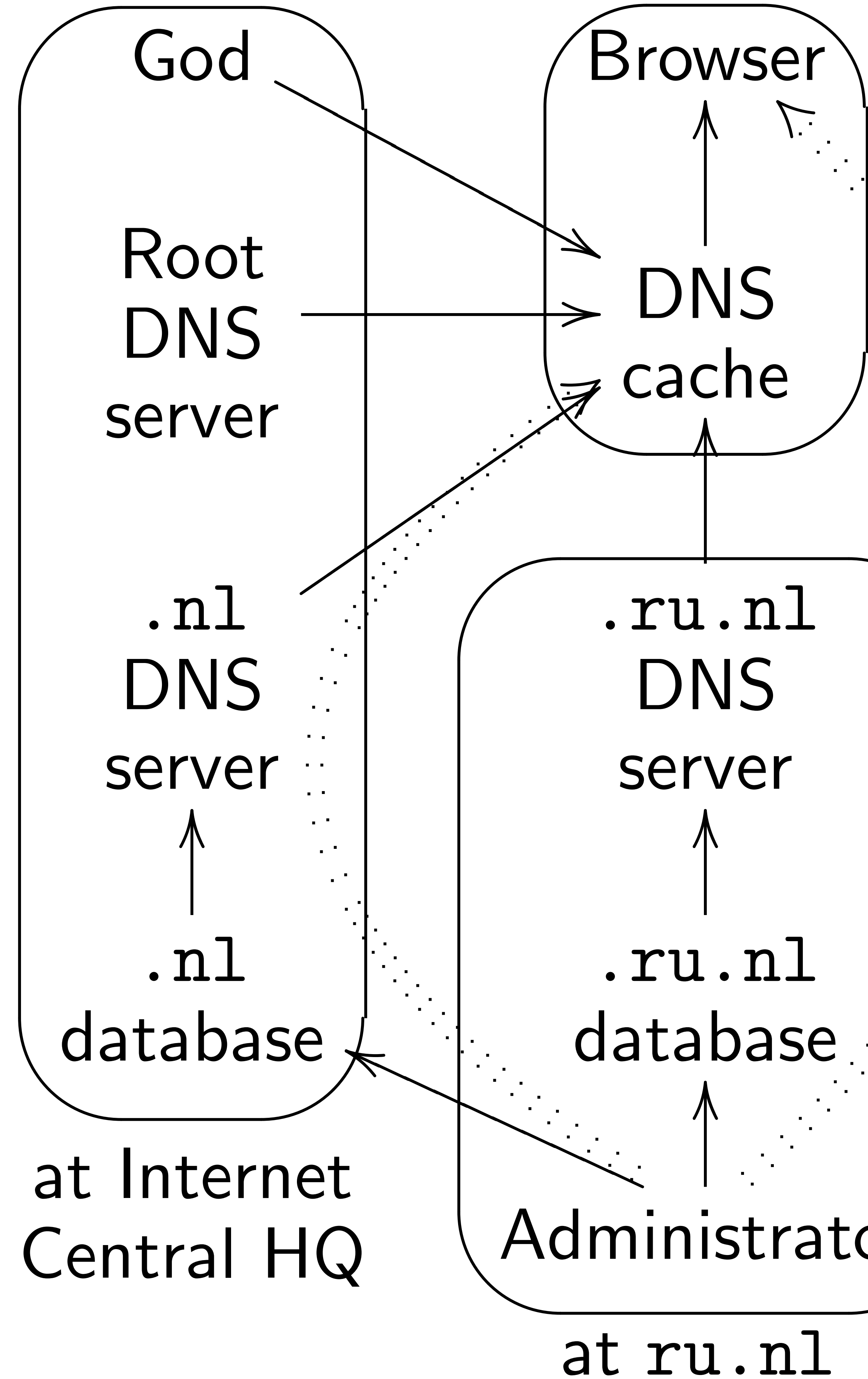

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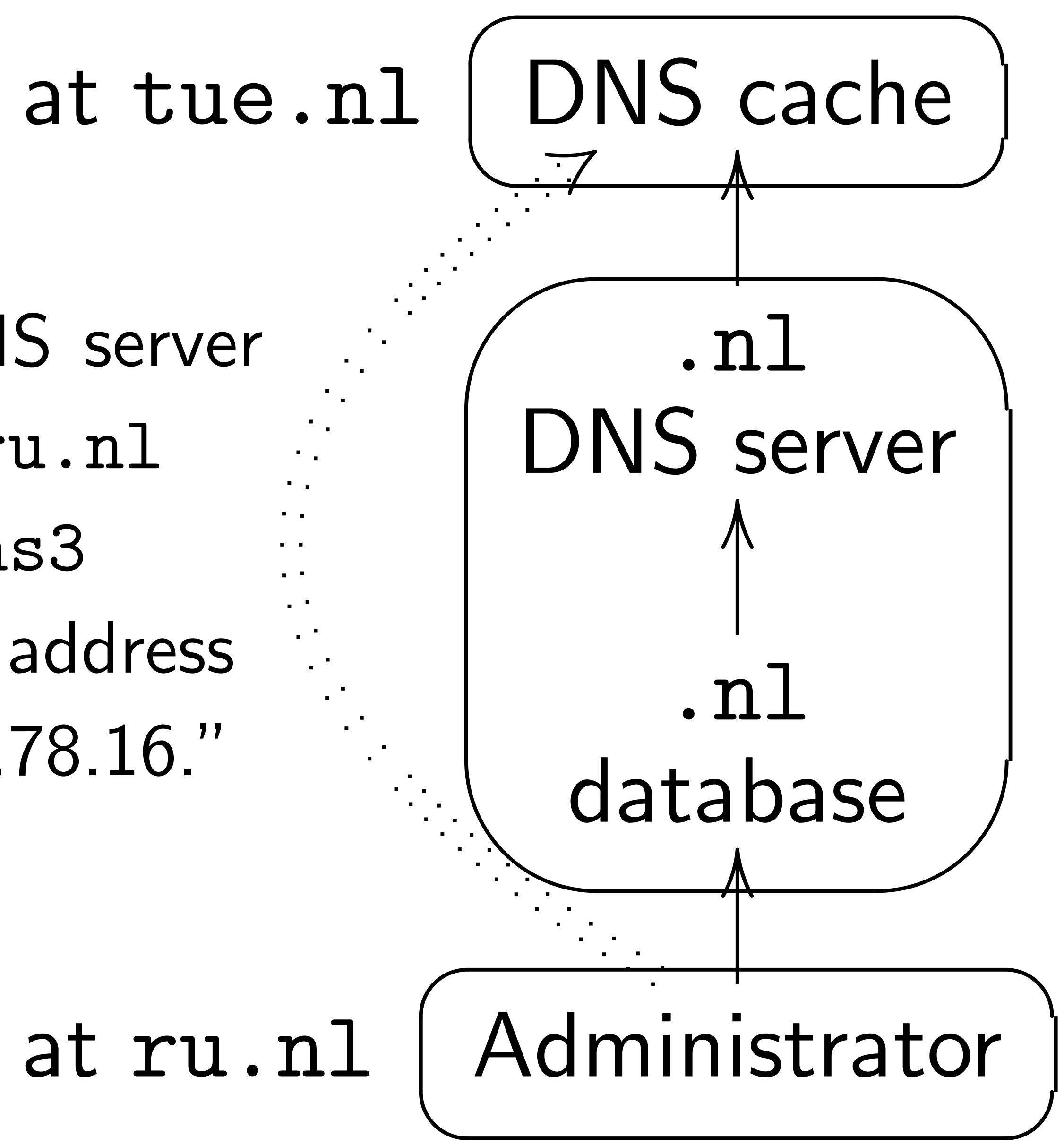

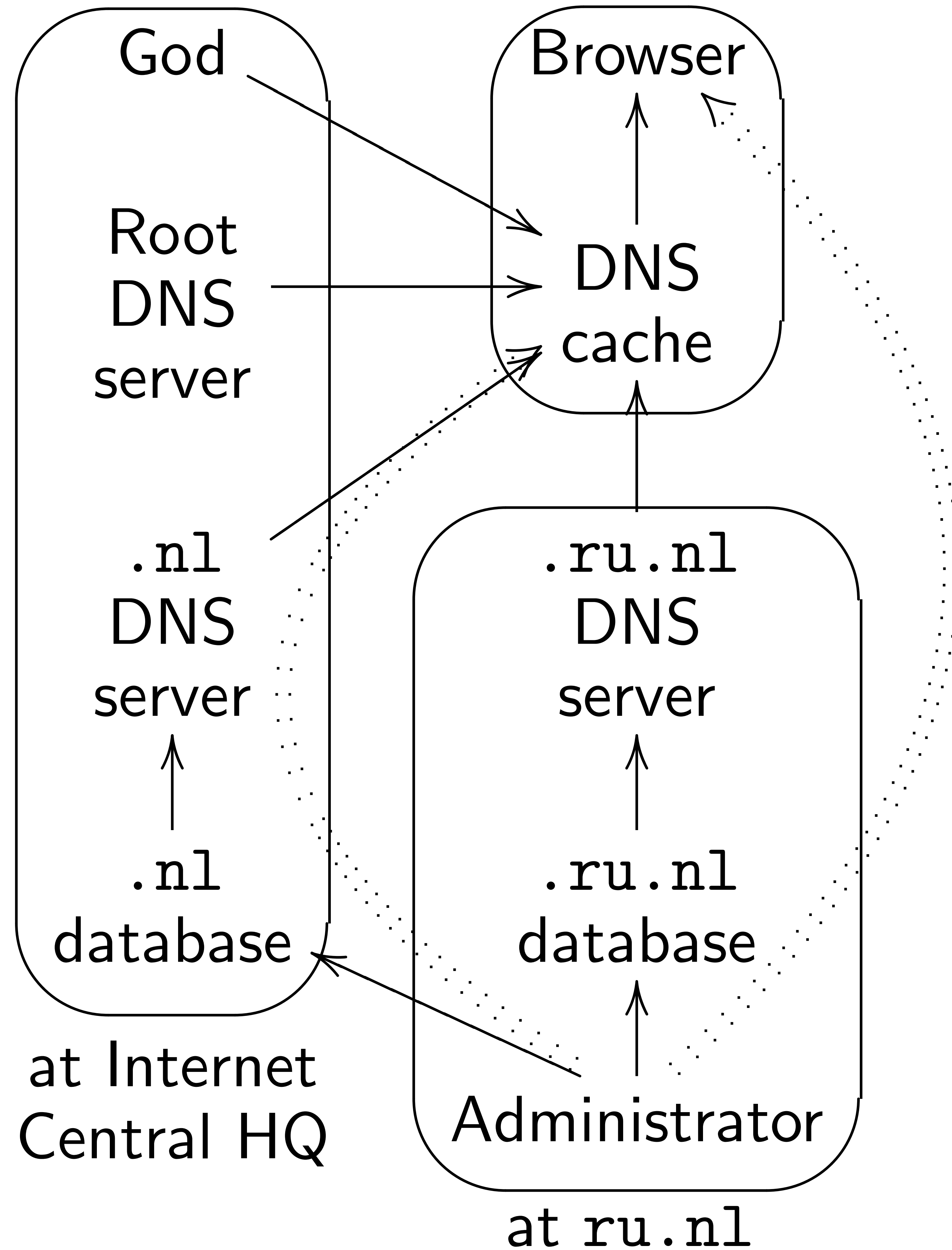

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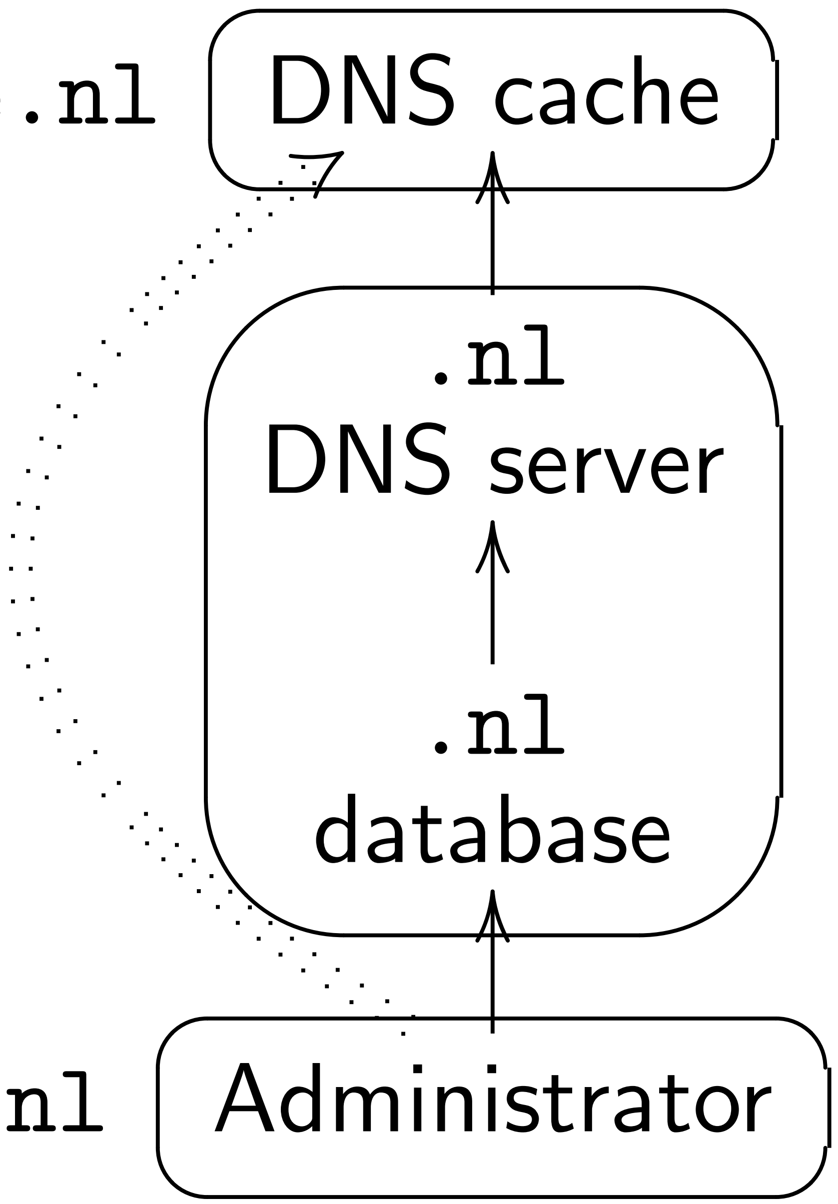

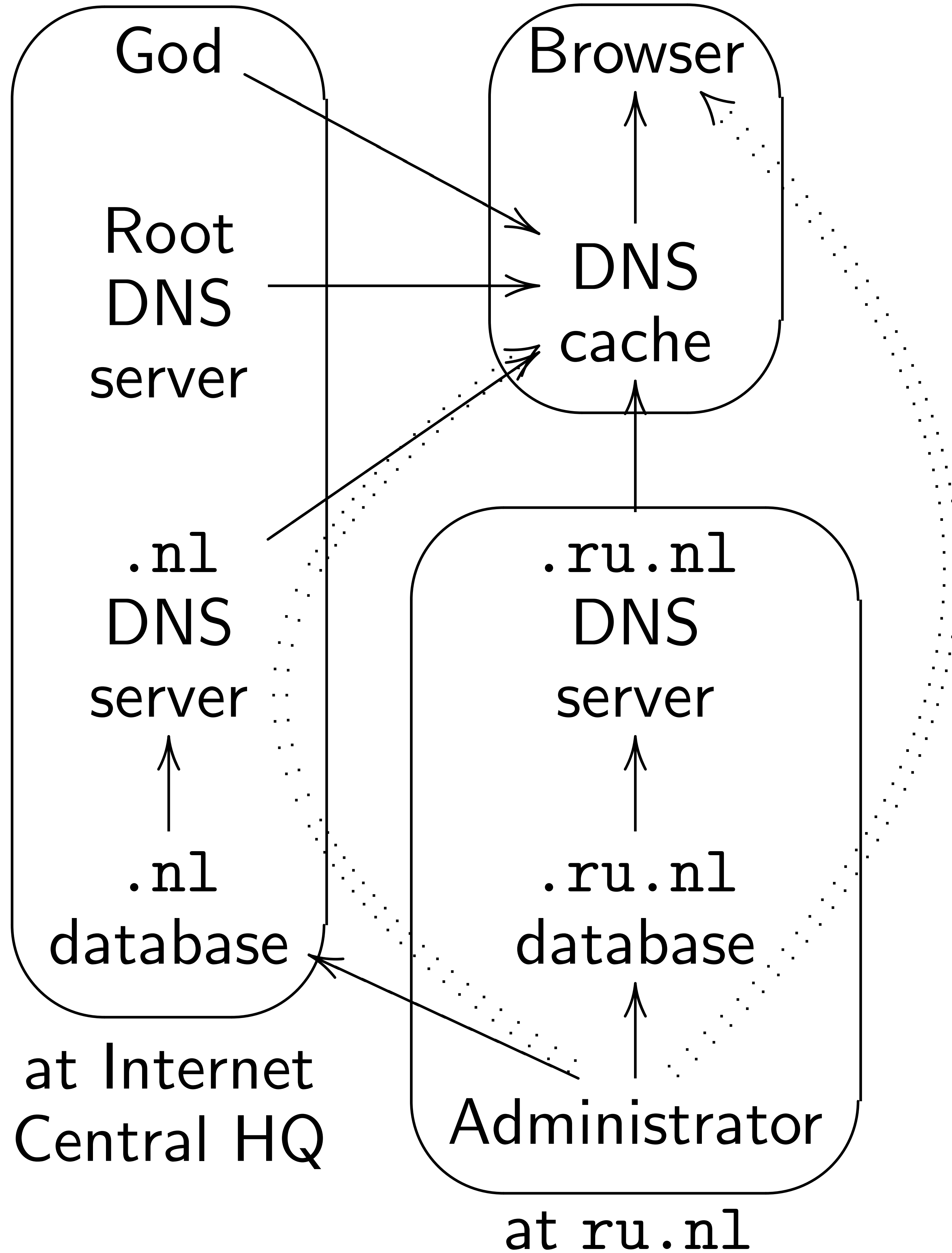

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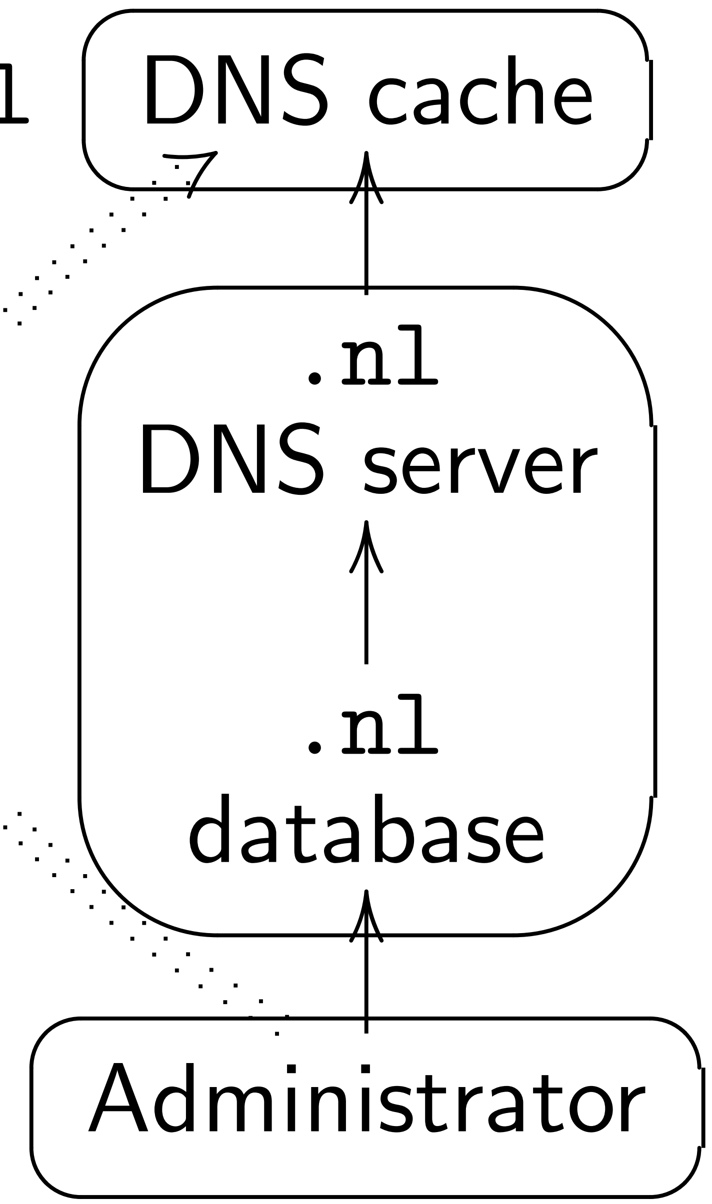

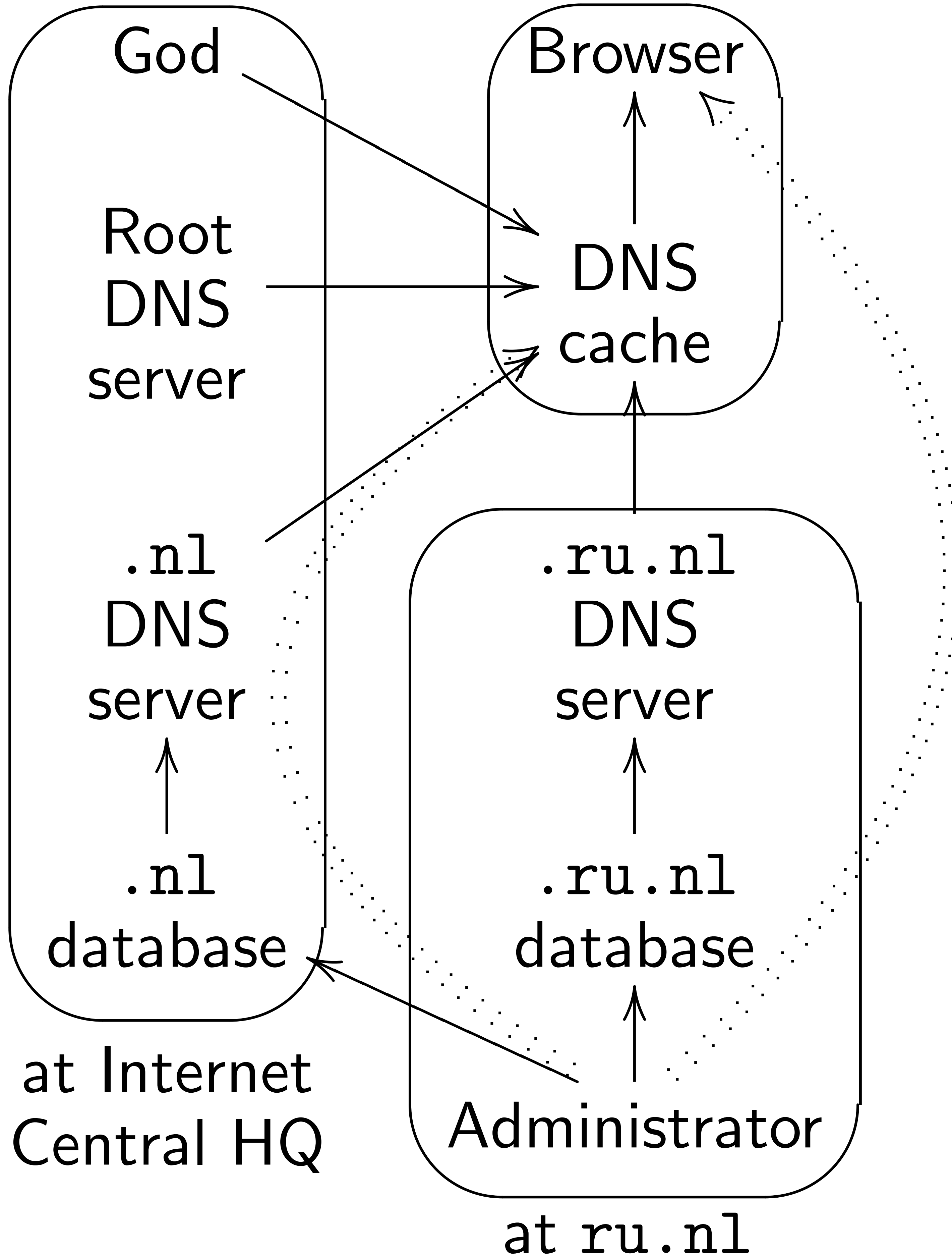

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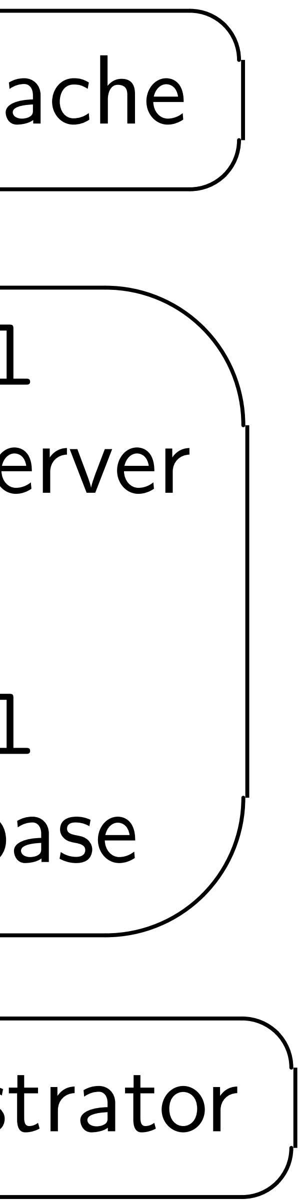

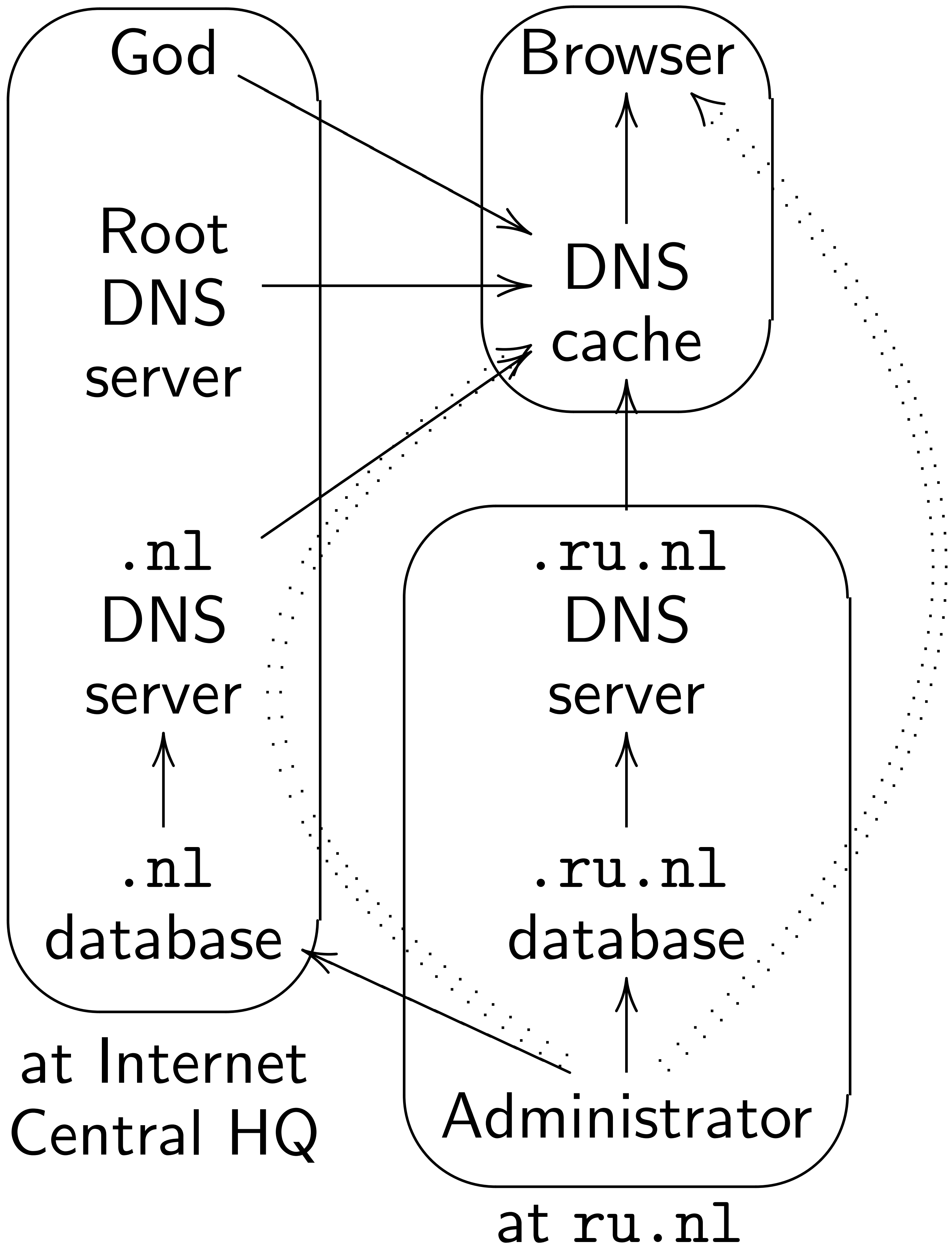

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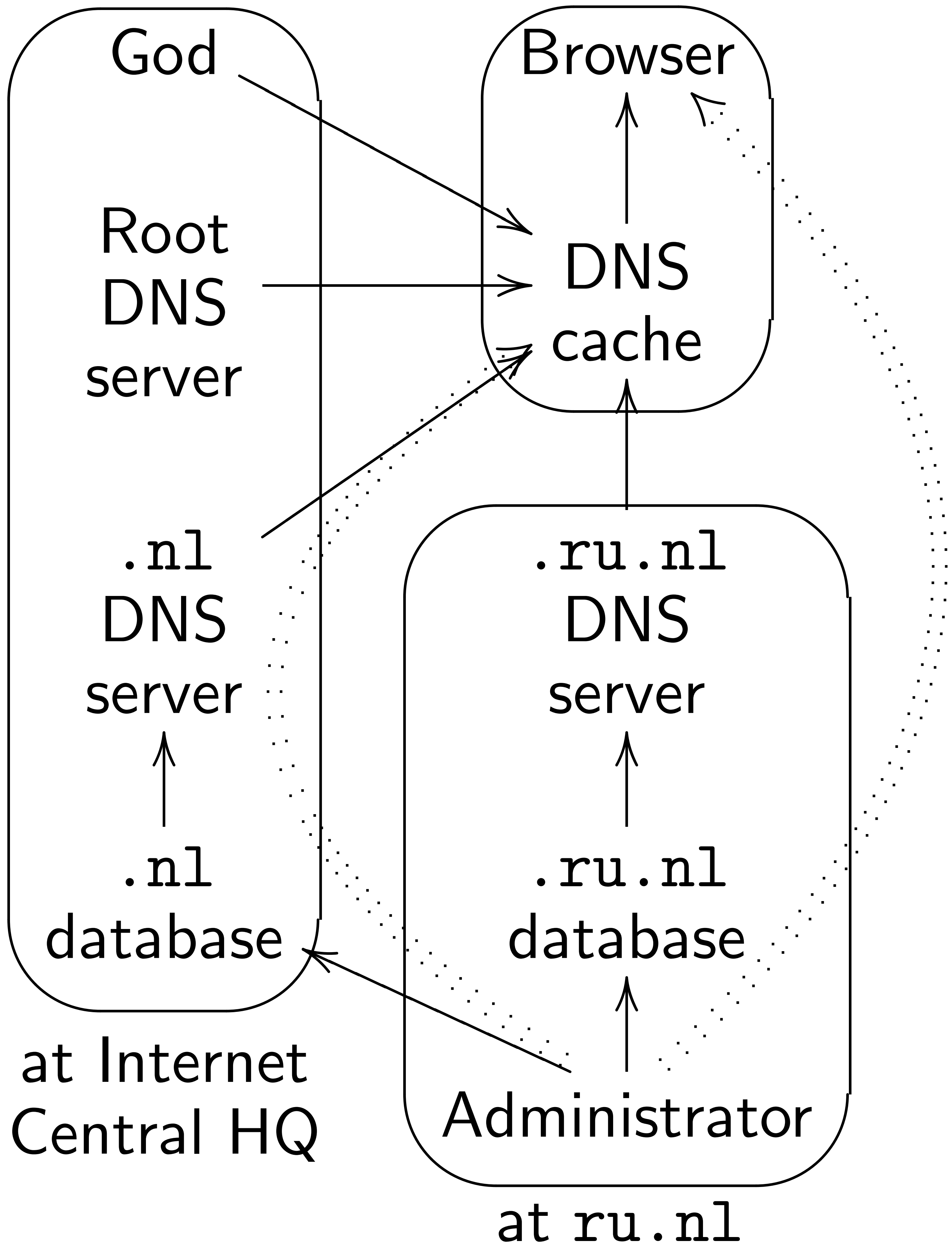

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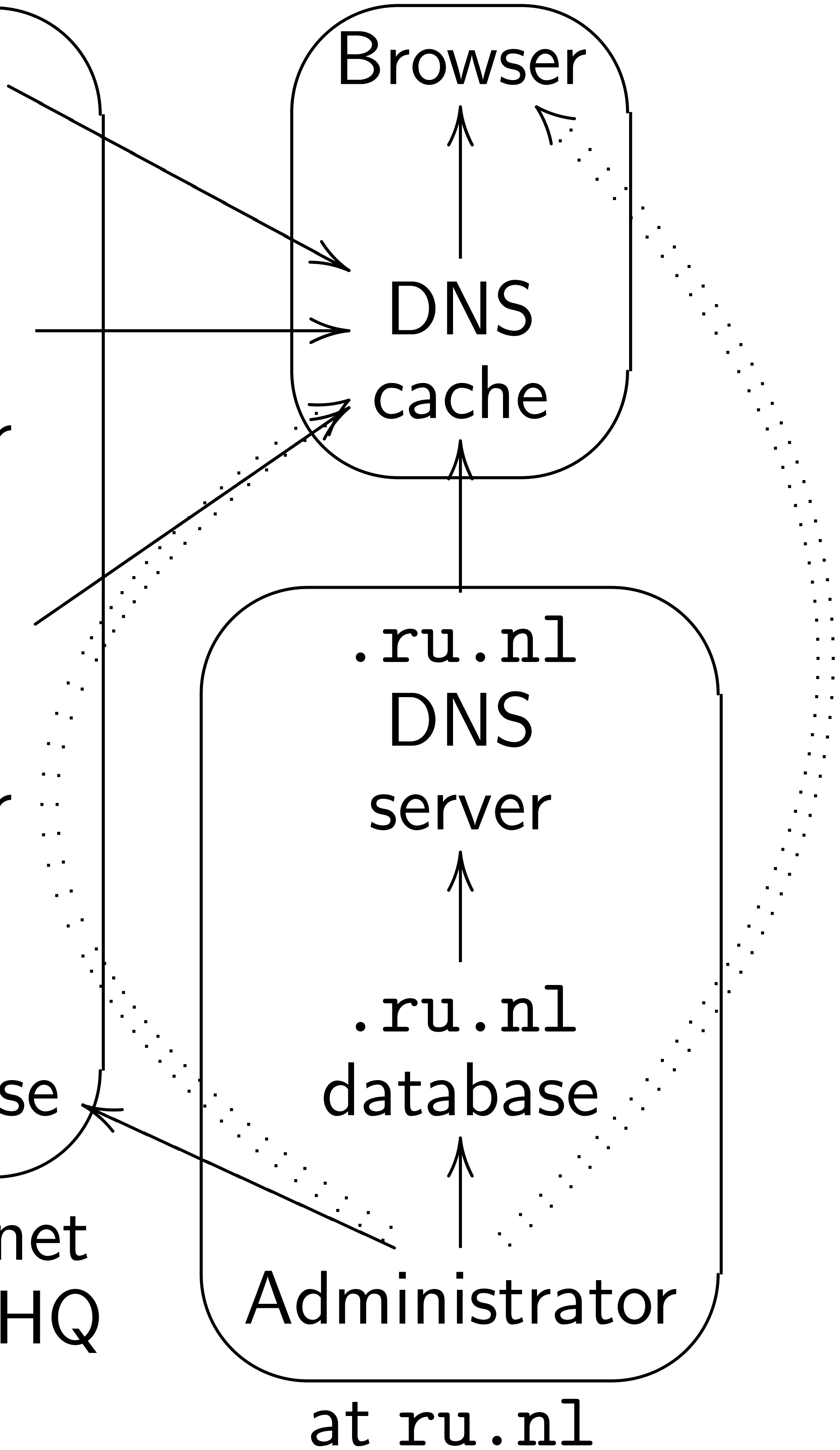

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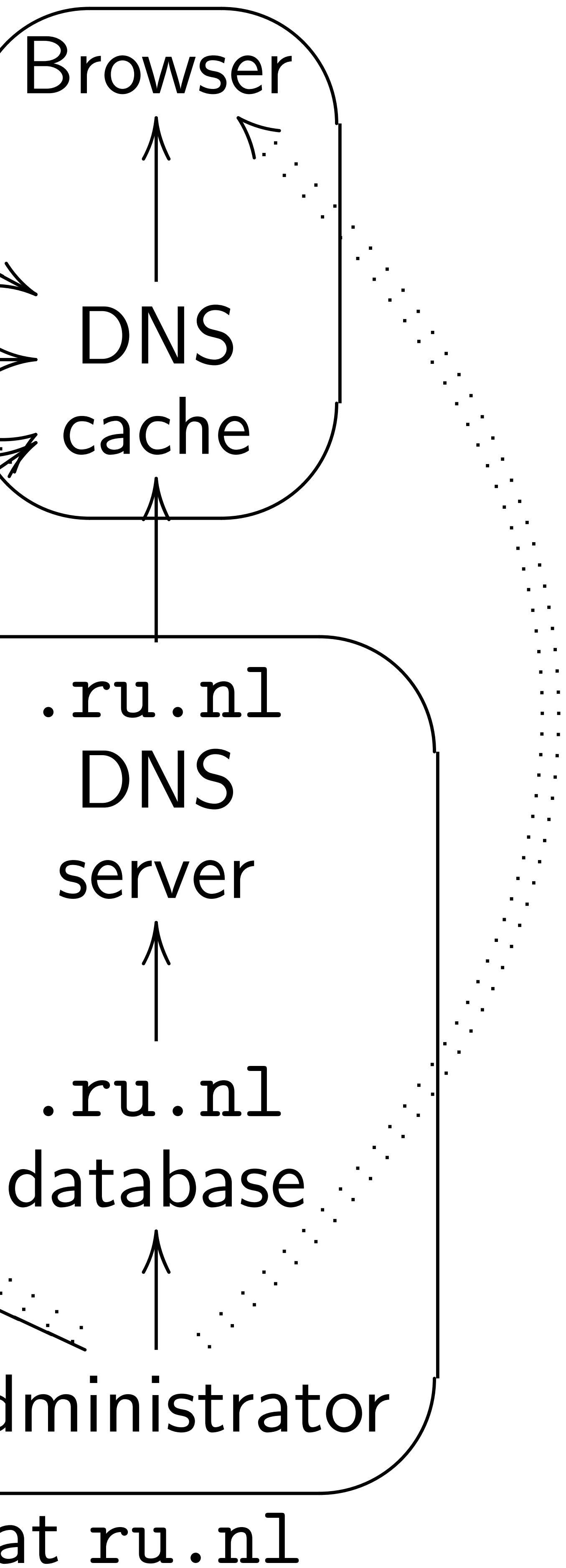

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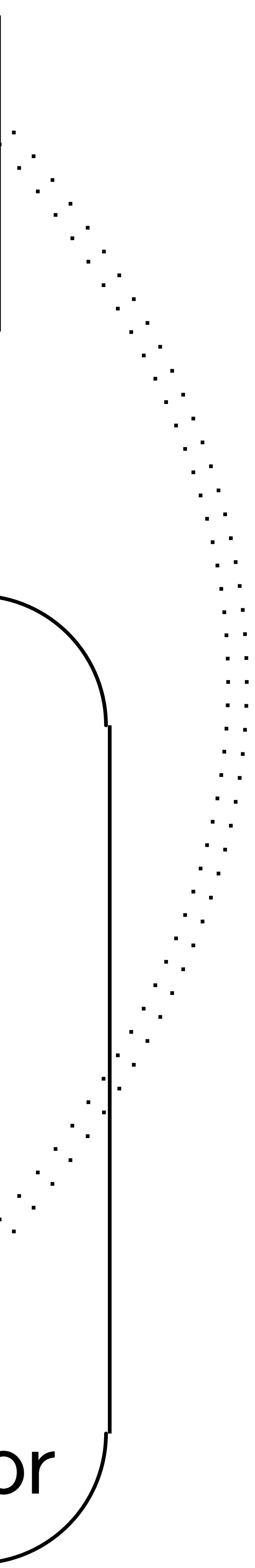

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What about *dynamic* DNS

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Try `foo.clegg.com` etc.

After several queries have complete `clegg.com` list: `_jabber._tcp`, `_xmpp-server._tcp`, `alan`, `alvis`, `andrew`, `brian`, `calendar`, `dlv`, `googleffffffffe91126e7`, `home`, `imogene`, `jennifer`, `localhost`, `mail`, `wiki`, `www`.

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

(This was a real example.)

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Getting out of the mess

State-of-the-art ECC
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Deployed: DNSCurve protects
DNS packets, server→cache.

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Work in progress: HTTPCurve
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Crypto is at edge of network
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Improved confidentiality:
e.g., is the user accessing
`firstaid.webmd.com` or
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