The DNS security mess

D. J. Bernstein

University of Illinois at Chicago;
Technische Universiteit Eindhoven

The Domain Name System

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Browser at `solaris.hr`

"The web server
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Administrator at `ru.nl`

Now `solaris.hr` retrieves web page from IP address 131.174.78.60.

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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?

June 20

Let's fin

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

$ dig
  b0.
199.1
```

an that the
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s the first part
est phase.
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itative data
one 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?

June 2016: reality

Let's find a `.org`

```
$ 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
```

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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?

June 2016: 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?

June 2016: 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!
ion! Authenticity!
! Sounds great!

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

it?

June 2016: 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
  @19
```

Everythi

```
;; AU
greenp
  864
  ns-
;; AD
ns-em
  864
  37.
```

thority!
enticity!
great!

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lic key
ware.
servers
NSSEC,
sible
rge
ervers!

June 2016: 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
```

June 2016: 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
```

June 2016: 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
```

16: 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 ansv

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

h9p7u
```

.

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
```

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
69T6U8O1GSG9E1LMITK4DEM
 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
69T6U801GSG9E1LMITK4DEM0T
 NS SOA RRSIG DNSKEY NSEC
3PARAM

h9p7u7tr2u91d0v0ljs9l1gid
```

```
np90u
IG NS
01024
2510
hQNsZ
+8qES
Rp+OR
4UlwH
GZ+xG
OF+/e
5/KYu

bgca0
qng3p
C3 1
```

ace.org:

```
ce.org \
```

ormal:

```
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
01024925 20160
2510 org. IZf8
hQNsZwHxGNfqId
+8qESeMke9vnXA
Rp+0RYCD6+Gu8y
4UlwHLdl8ZAnR5
GZ+xGPLJiicLQU
OF+/enHX1RtJ07
5/KYu dZg=

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

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
01024925 20160610014925
2510 org. IZf8HUKm/bwmO
hQNsZwHxGNfqId7gyQM1Lry
+8qESeMke9vnXAZZ GHCxsX
Rp+0RYCD6+Gu8yYFHN1F84o
4UlwHLdl8ZAnR5a/yLI9R1o
GZ+xGPLJiicLQUHQQ1wRI2x
OF+/enHX1RtJ074FMDEfTbo
5/KYu dZg=

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

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
```



```
np90u3h.org. 86400 IN RRS
IG NSEC3 7 2 86400 201607
01024925 20160610014925 1
2510 org. IZf8HUKm/bwmOG1
hQNsZwHxGNfqId7gyQM1Lryyh
+8qESeMke9vnXAZZ GHCxsXH6
Rp+ORYCD6+Gu8yYFHN1F84oul
4UlwHLdl8ZAnR5a/yLI9R1o r
GZ+xGPLJiicLQUHQQ1wRI2xx+
OF+/enHX1RtJO74FMDEfTboB6
5/KYu dZg=

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

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
801GSG9E1LMITK4DEMOT
OA RRSIG DNSKEY NSEC
M

7tr2u91d0v0ljs9l1gid

np90u3h.org. 86400 IN RRS
IG NSEC3 7 2 86400 201607
01024925 20160610014925 1
2510 org. IZf8HUKm/bwmOG1
hQNsZwHxGNfqId7gyQM1Lryyh
+8qESeMke9vnXAZZ GHCxsXH6
Rp+ORYCD6+Gu8yYFHN1F84oul
4UlwHLdl8ZAnR5a/yLI9R1o r
GZ+xGPLJiicLQUHQQ1wRI2xx+
OF+/enHX1RtJ074FMDEfTboB6
5/KYu dZg=

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

OPPOBI
A RRS

bgca0g
qng3p2
IG NSI
301503
2510 c
bXyJ0c
WZeb4i
FUB7B8
jVFnx4
DrUTbc
SeOnc
oROMI

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 201607

01024925 20160610014925 1

2510 org. IZf8HUKm/bwmOG1

hQNsZwHxGNfqId7gyQM1Lryyh

+8qESeMke9vnXAZZ GHCxsXH6

Rp+ORYCD6+Gu8yYFHN1F84oul

4UlwHLdl8ZAnR5a/yLI9R1o r

GZ+xGPLJiicLQUHQQ1wRI2xx+

OF+/enHX1RtJO74FMDEfTboB6

5/KYu dZg=

bgca0g0ug0p6o7425emkt9ue4

qng3p2f.org. 86400 IN NSE

C3 1 1 1 D399EAAB BGDHKIB

OPPOBENBFCGBMB

A RRSIG

bgca0g0ug0p6o7

qng3p2f.org. 8

IG NSEC3 7 2 8

30150330 20160

2510 org. R+rV

bXyJ0emN9dsPa8

WZeb41w97hsNI9

FUB7B8us/YvVIF

jVFnx49ZoaOEs2

DrUTbe/sr+KzOx

SeOnc06v7/5lpE

oROMI Uyc=

s:

id

SE

R6

OT

EC

id

np90u3h.org. 86400 IN RRS
IG NSEC3 7 2 86400 201607
01024925 20160610014925 1
2510 org. IZf8HUKm/bwmOG1
hQNsZwHxGNfqId7gyQM1Lryyh
+8qESeMke9vnXAZZ GHCxsXH6
Rp+ORYCD6+Gu8yYFHN1F84oul
4UlwHLdl8ZAnR5a/yLI9R1o r
GZ+xGPLJiicLQUHQQ1wRI2xx+
OF+/enHX1RtJ074FMDEfTboB6
5/KYu dZg=

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

OPPOBENBFCGBMB6RGT2JDC2
A RRSIG

bgca0g0ug0p6o7425emkt9u
qng3p2f.org. 86400 IN R
IG NSEC3 7 2 86400 2016
30150330 20160609140330
2510 org. R+rVmt6c2Gs/K
bXyJ0emN9dsPa8GZfzHsRiv
WZeb41w97hsNI9rg IvTWP1
FUB7B8us/YvVIF/QFjmONZ9
jVFnx49ZoaOEs2QjHU5a+mV
DrUTbe/sr+KzOxaurPSY0dQ
SeOnc06v7/5lpEleUYE/T+f
oROMI Uyc=

np90u3h.org. 86400 IN RRS
IG NSEC3 7 2 86400 201607
01024925 20160610014925 1
2510 org. IZf8HUKm/bwmOG1
hQNsZwHxGNfqId7gyQM1Lryyh
+8qESeMke9vnXAZZ GHCxsXH6
Rp+ORYCD6+Gu8yYFHN1F84oul
4UlwHLdl8ZAnR5a/yLI9R1o r
GZ+xGPLJiicLQUHQQ1wRI2xx+
OF+/enHX1RtJO74FMDEfTboB6
5/KYu dZg=

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

OPPOBENBFCGBMB6RGT2JDC21E
A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201606
30150330 20160609140330 1
2510 org. R+rVmt6c2Gs/KKa
bXyJ0emN9dsPa8GZfzHsRivg6
WZeb41w97hsNI9rg IvTWP1Ry
FUB7B8us/YvVIF/QFjmONZ9LE
jVFnx49ZoaOEs2QjHU5a+mV g
DrUTbe/sr+KzOxaurPSY0dQJz
SeOnc06v7/51pEleUYE/T+fNu
oROMI Uyc=

3h.org. 86400 IN RRS
EC3 7 2 86400 201607
925 20160610014925 1
org. IZf8HUKm/bwmOG1
wHxGNfqId7gyQM1Lryyh
eMke9vnXAZZ GHCxsXH6
YCD6+Gu8yYFHN1F84oul
Ldl8ZAnR5a/yLI9R1o r
PLJiicLQUHQQ1wRI2xx+
nHX1RtJO74FMDEfTboB6
 dZg=

g0ug0p6o7425emkt9ue4
2f.org. 86400 IN NSE
1 1 D399EAAB BGDHKIB

OPPOBENBFCGBMB6RGT2JDC21E
 A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201606
30150330 20160609140330 1
2510 org. R+rVmt6c2Gs/KKa
bXyJ0emN9dsPa8GZfzHsRivg6
WZeb41w97hsNI9rg IvTWP1Ry
FUB7B8us/YvVIF/QFjmONZ9LE
jVFnx49ZoaOEs2QjHU5a+mV g
DrUTbe/sr+KzOxaurPSY0dQJz
SeOnc06v7/5lpEleUYE/T+fNu
oROMI Uyc=

Wow, th
Must be

$ tcpdu
  host

shows pa
dig sen
to the .
receives

See mor

$ dig +
  org @

Sends 7
receives
totalling

```
6400 IN RRS
6400 201607
610014925 1
HUKm/bwmOG1
7gyQM1Lryyh
ZZ GHCxsXH6
YFHN1F84oul
a/yLI9R1o r
HQQ1wRI2xx+
4FMDEfTboB6



425emkt9ue4
6400 IN NSE
AAB BGDHKIB
```

```
OPPOBENBFCGBMB6RGT2JDC21E
 A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201606
30150330 20160609140330 1
2510 org. R+rVmt6c2Gs/KKa
bXyJ0emN9dsPa8GZfzHsRivg6
WZeb41w97hsNI9rg IvTWP1Ry
FUB7B8us/YvVIF/QFjmONZ9LE
jVFnx49ZoaOEs2QjHU5a+mV g
DrUTbe/sr+KzOxaurPSY0dQJz
SeOnc06v7/5lpEleUYE/T+fNu
oR0MI Uyc=
```


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 654-byte

See more DNSSEC

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

Sends 74-byte IP
receives two IP fra
totalling 2653 byte

```
RS
07
 1
G1
yh
H6
ul
 r
x+
B6

e4
SE
IB
```



```
OPPOBENBFCGBMB6RGT2JDC21E
 A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201606
30150330 20160609140330 1
2510 org. R+rVmt6c2Gs/KKa
bXyJ0emN9dsPa8GZfzHsRivg6
WZeb41w97hsNI9rg IvTWP1Ry
FUB7B8us/YvVIF/QFjmONZ9LE
jVFnx49Zoa0Es2QjHU5a+mV g
DrUTbe/sr+KzOxaurPSY0dQJz
Se0nc06v7/51pEleUYE/T+fNu
oROMI Uyc=
```


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 654-byte IP packet.

See more DNSSEC data:

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

Sends 74-byte IP packet,
receives two IP fragments
totalling 2653 bytes.

```
0PP0BENBFCGBMB6RGT2JDC21E
 A RRSIG

bgca0g0ug0p6o7425emkt9ue4
qng3p2f.org. 86400 IN RRS
IG NSEC3 7 2 86400 201606
30150330 20160609140330 1
2510 org. R+rVmt6c2Gs/KKa
bXyJ0emN9dsPa8GZfzHsRivg6
WZeb41w97hsNI9rg IvTWP1Ry
FUB7B8us/YvVIF/QFjm0NZ9LE
jVFnx49Zoa0Es2QjHU5a+mV g
DrUTbe/sr+Kz0xaurPSY0dQJz
Se0nc06v7/5lpEleUYE/T+fNu
oR0MI Uyc=
```


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 654-byte IP packet.

See more DNSSEC data:

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

Sends 74-byte IP packet,
receives two IP fragments
totalling 2653 bytes.

```
ENBFCGBMB6RGT2JDC21E
SIG

g0ug0p6o7425emkt9ue4
2f.org. 86400 IN RRS
EC3 7 2 86400 201606
330 20160609140330 1
org. R+rVmt6c2Gs/KKa
emN9dsPa8GZfzHsRivg6
1w97hsNI9rg IvTWP1Ry
8us/YvVIF/QFjmONZ9LE
49ZoaOEs2QjHU5a+mV g
e/sr+KzOxaurPSY0dQJz
06v7/5lpEleUYE/T+fNu
 Uyc=
```


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 654-byte IP packet.

See more DNSSEC data:

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

Sends 74-byte IP packet,
receives two IP fragments
totalling 2653 bytes.

Interlude

What ha
this data

```
6RGT2JDC21E


425emkt9ue4
6400 IN RRS
6400 201606
609140330 1
mt6c2Gs/KKa
GZfzHsRivg6
rg IvTWP1Ry
/QFjmONZ9LE
QjHU5a+mV g
aurPSYOdQJz
leUYE/T+fNu
```


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 654-byte IP packet.

See more DNSSEC data:

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

Sends 74-byte IP packet, receives two IP fragments totalling 2653 bytes.

Interlude: the atta

What happens if w
this data at somec

```
1E
e4
RS
06
 1
Ka
g6
Ry
LE
 g
Jz
Nu
```


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 654-byte IP packet.

See more DNSSEC data:

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

Sends 74-byte IP packet, receives two IP fragments totalling 2653 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, receives 654-byte IP packet.

See more DNSSEC data:

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

Sends 74-byte IP packet, receives two IP fragments totalling 2653 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 654-byte IP packet.

See more DNSSEC data:

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

Sends 74-byte IP packet,
receives two IP fragments
totalling 2653 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 654-byte IP packet.

See more DNSSEC data:

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

Sends 74-byte IP packet, receives two IP fragments totalling 2653 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.

at's a lot of data.

strong cryptography!

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

acket sizes:

ds 89-byte IP packet

org DNS server,

654-byte IP packet.

e DNSSEC data:

```
dnssec any \
199.19.54.1
```

4-byte IP packet,

two IP fragments

2653 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 secsp
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
    }
    /GRI
      sp
      su
      pi
    }'
) | 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 name

```
( 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 r
do
  dig +
  +time
  awk -
    if
    if
    if
    if
    est
    pri
  }'
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
providing
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 < 
```

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:

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  5.6.7.8 \
  netmask 255.255.255.25
while read est ip z
do
  dig -b 5.6.7.8 \
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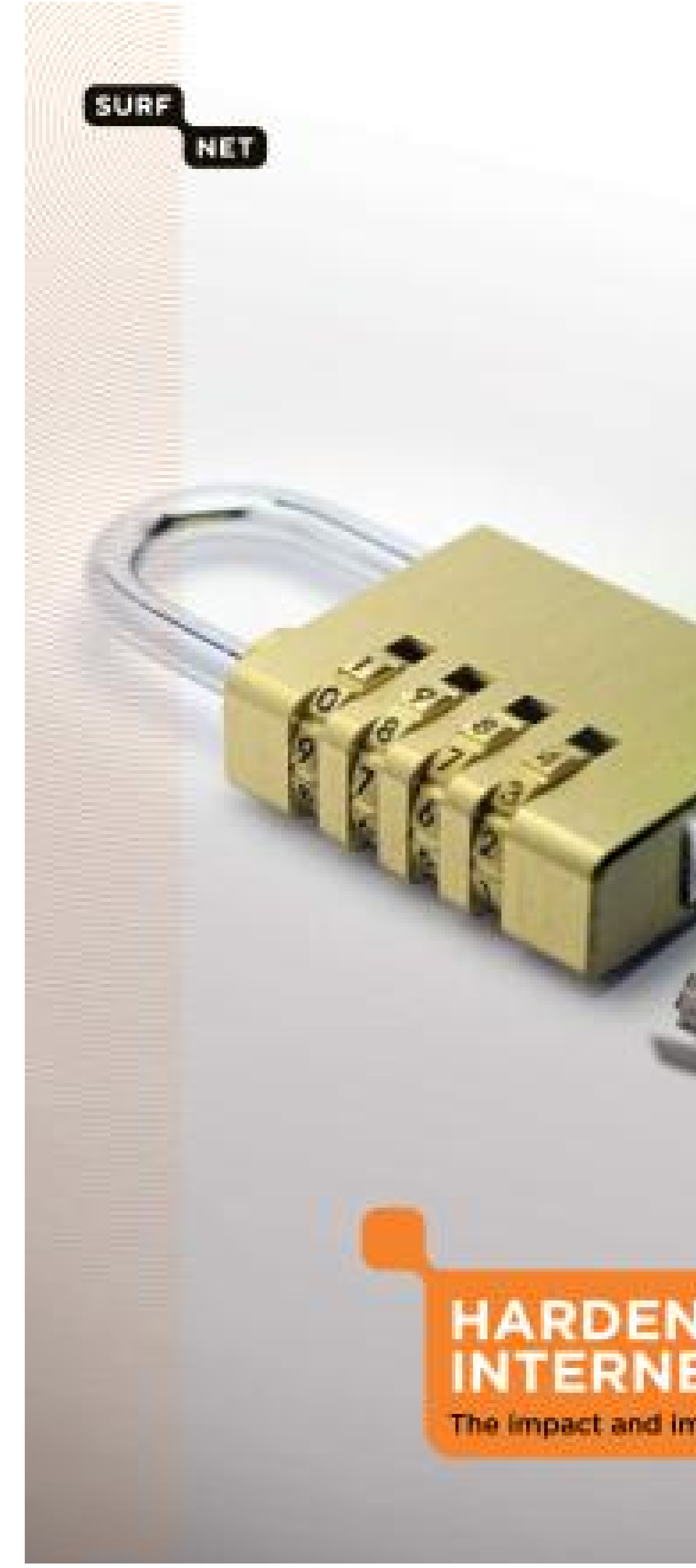

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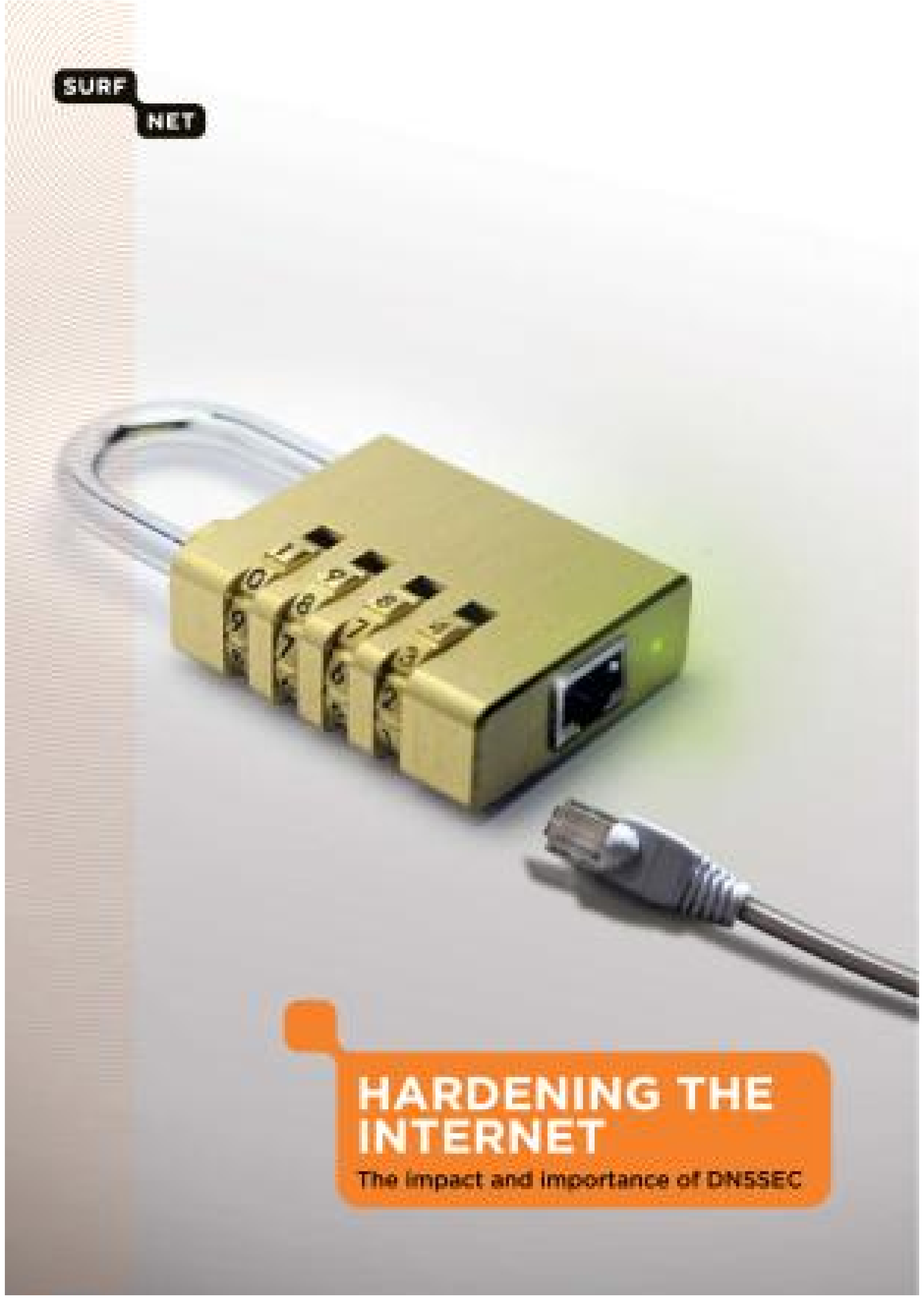

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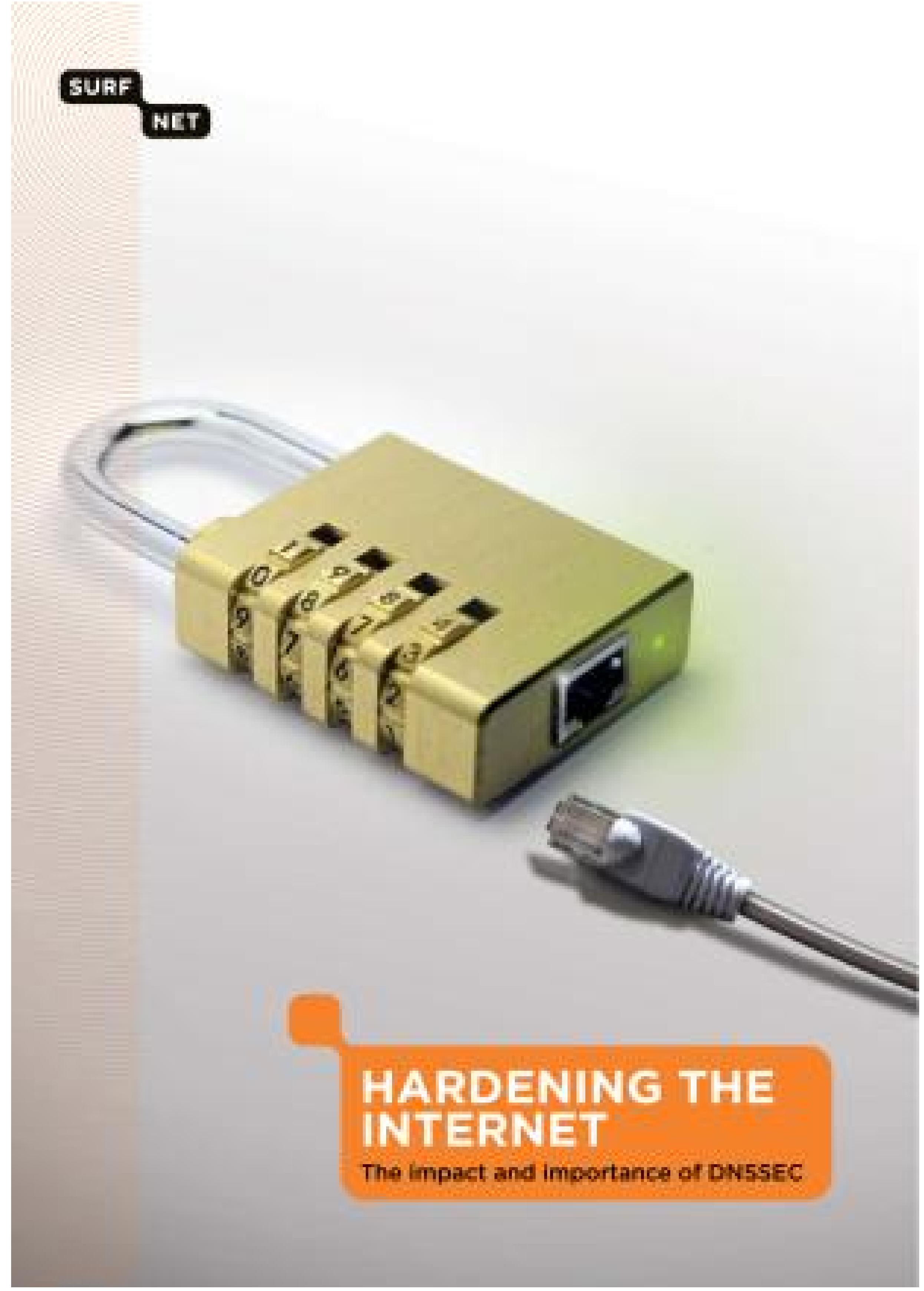

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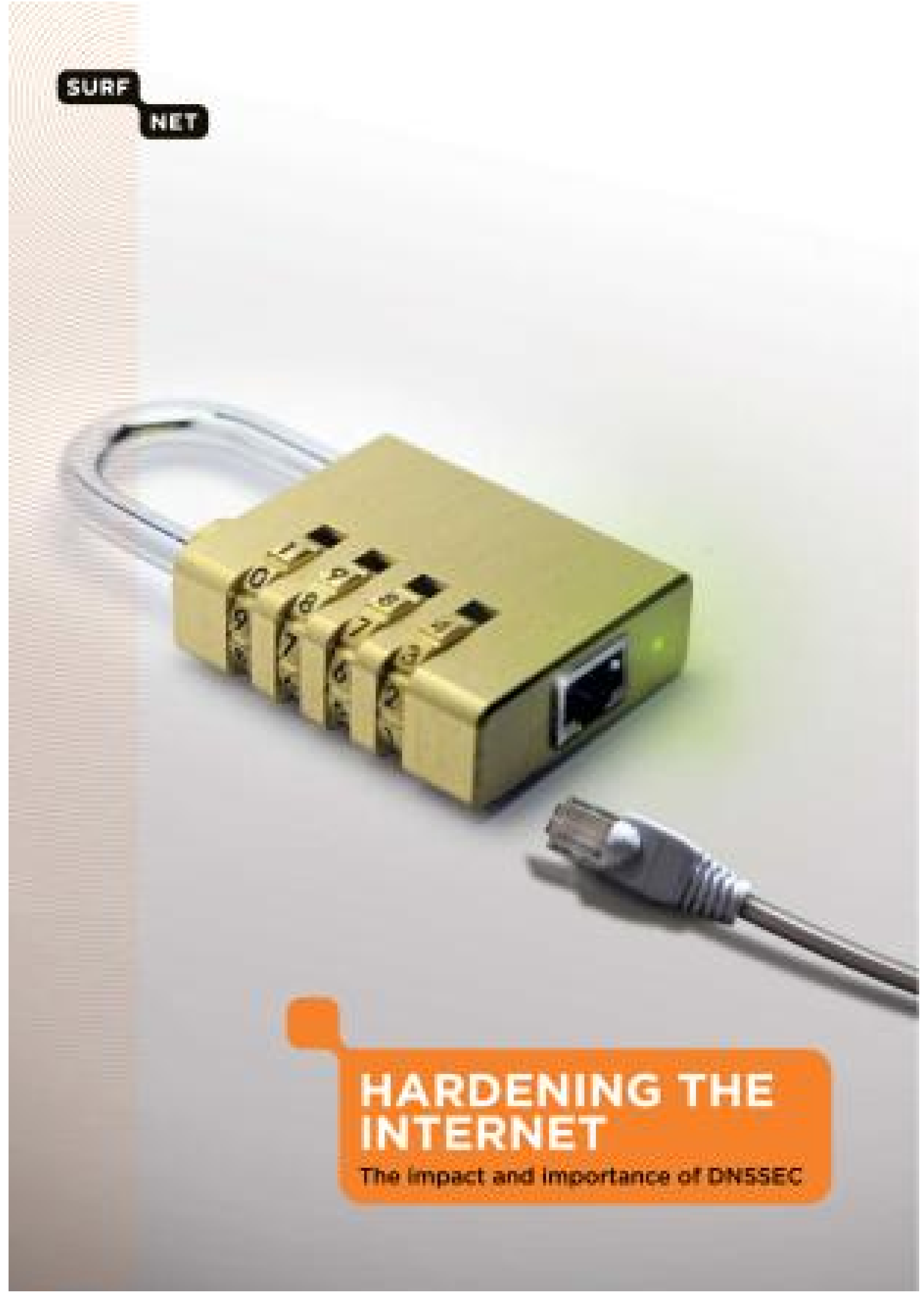

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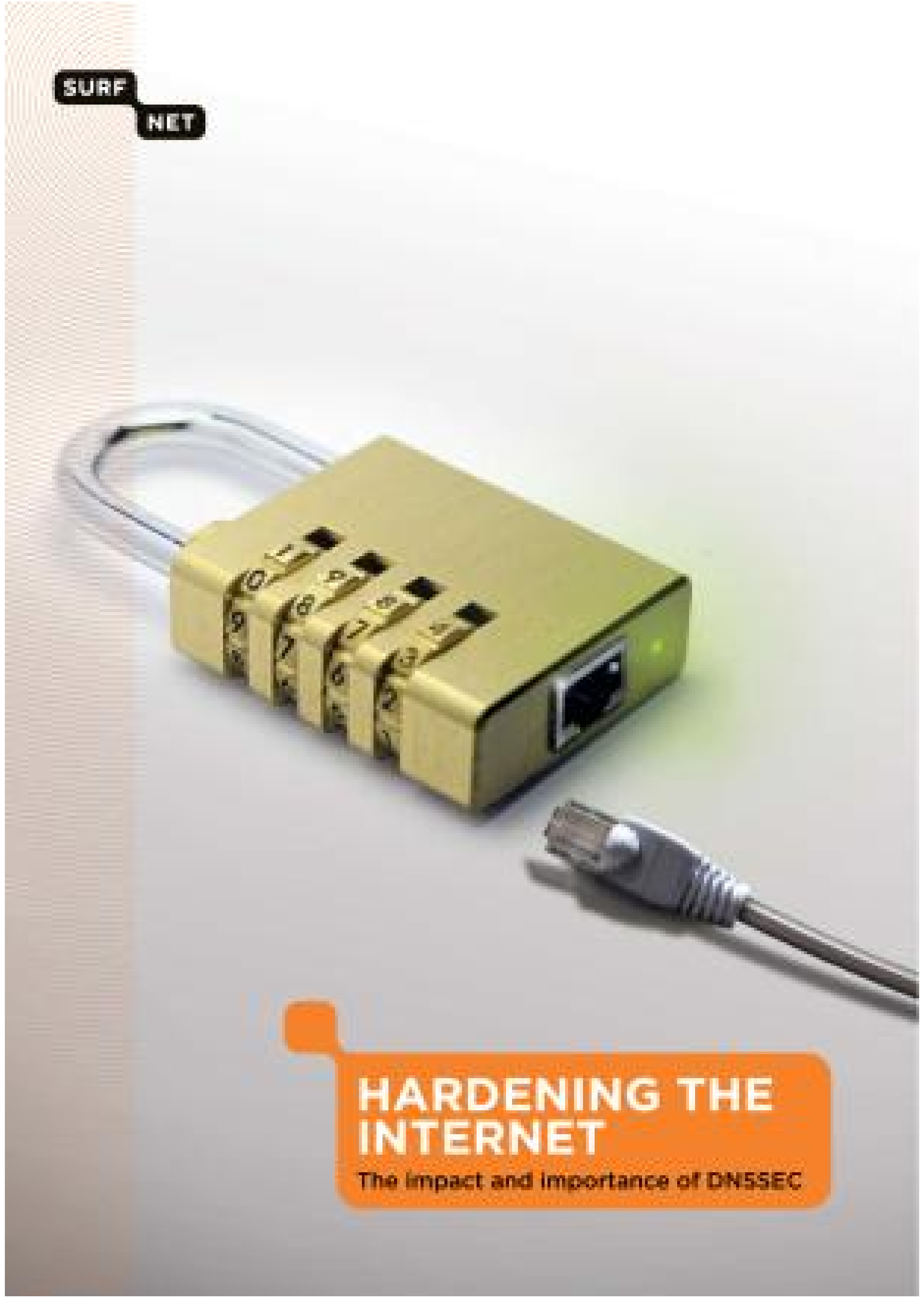

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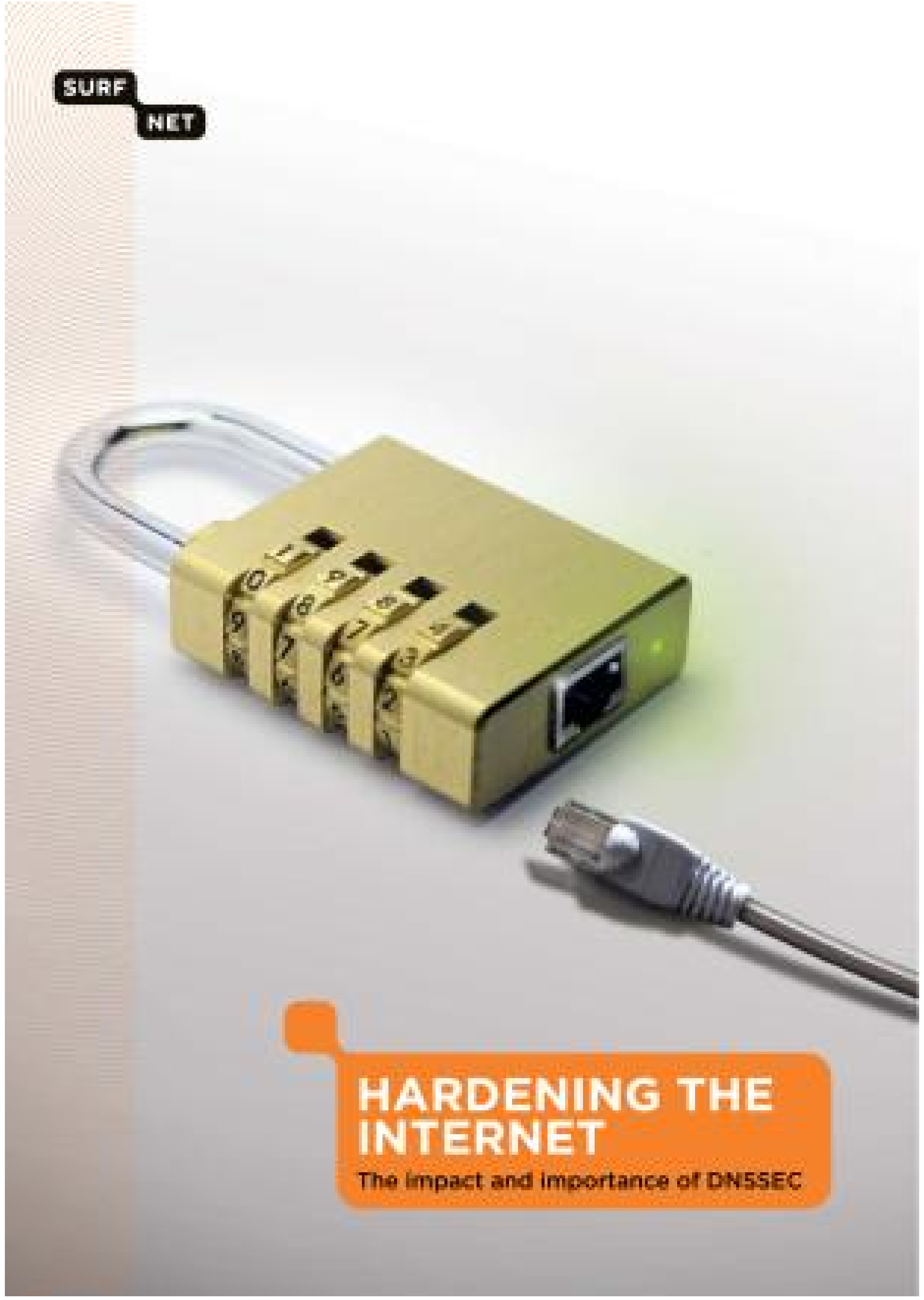

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Suppose an attacker forges
a DNS packet from `.org`,
including exactly the same
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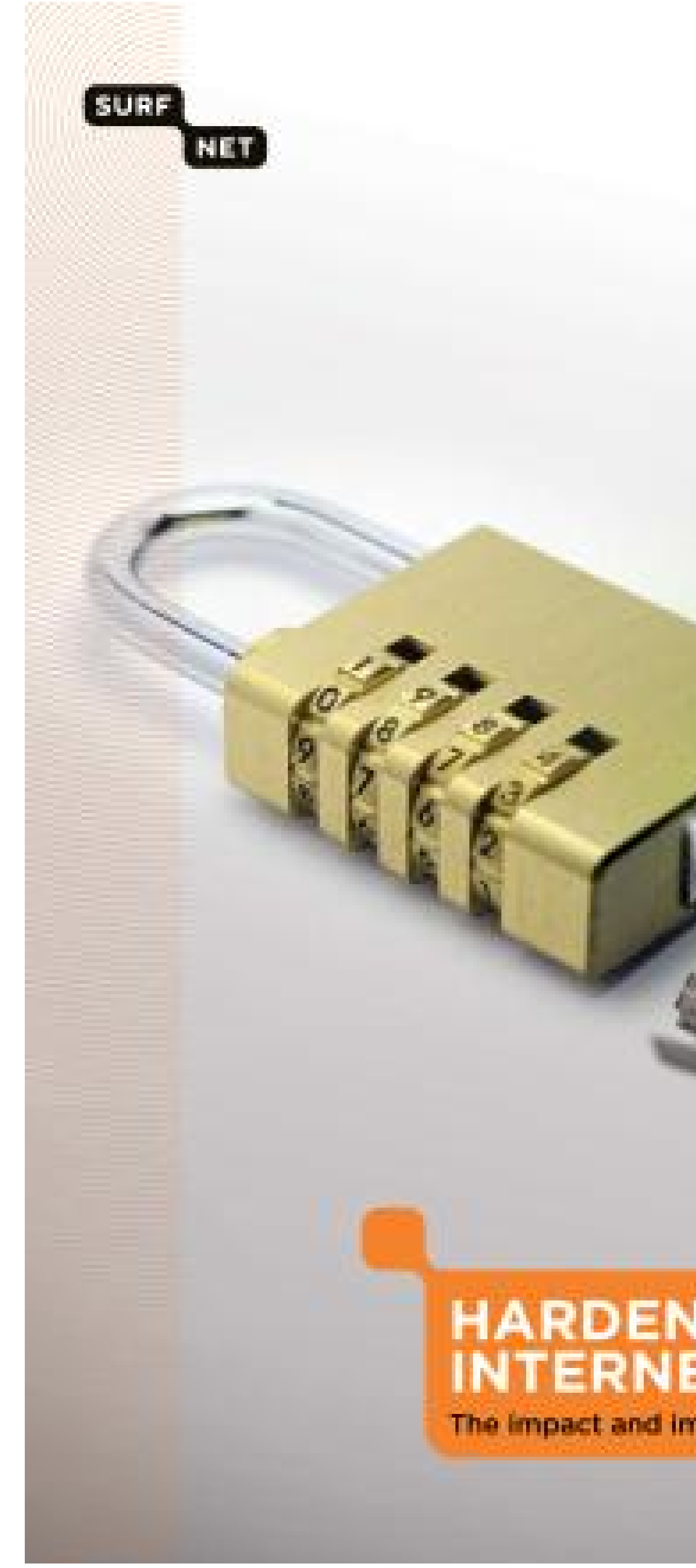

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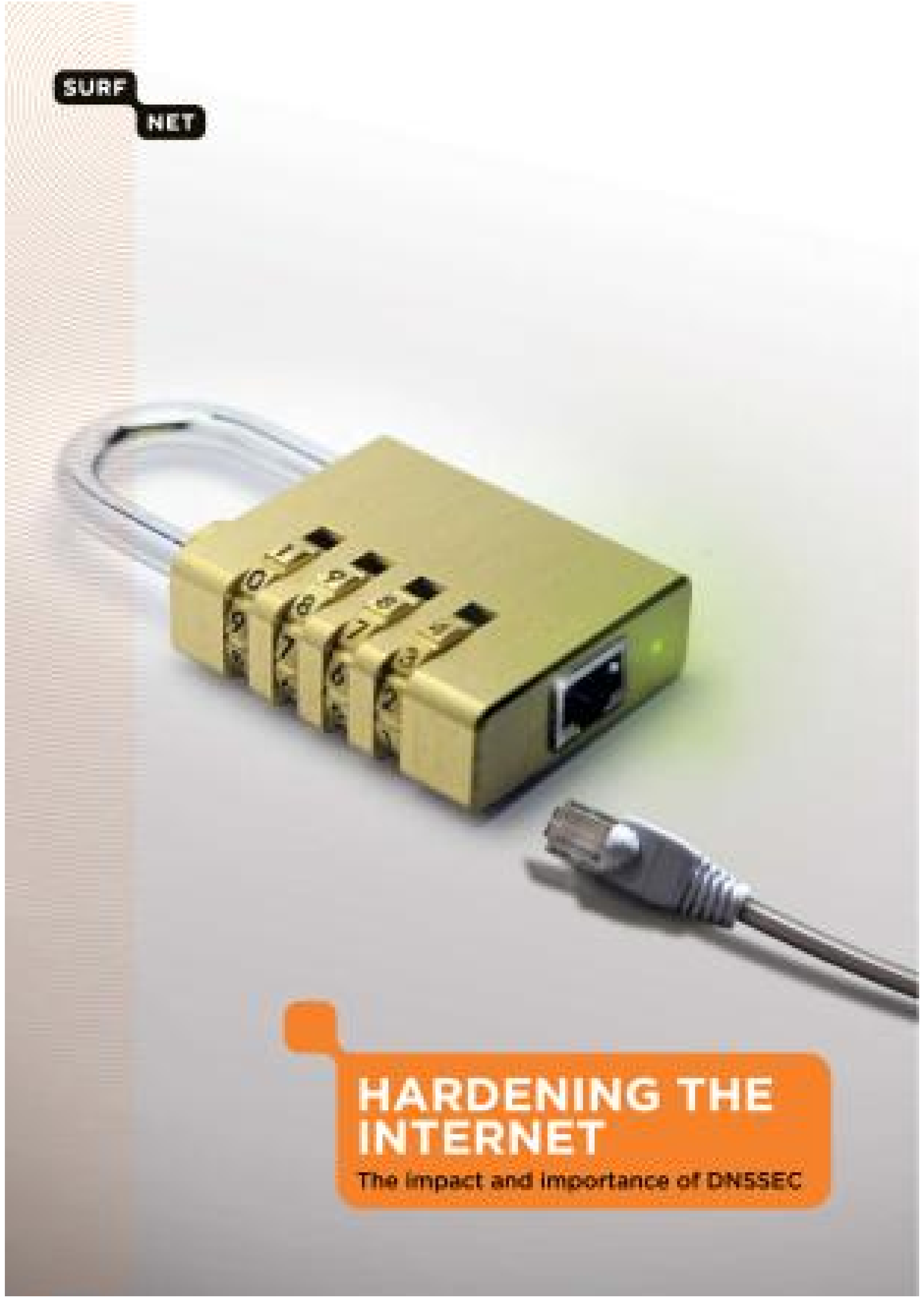

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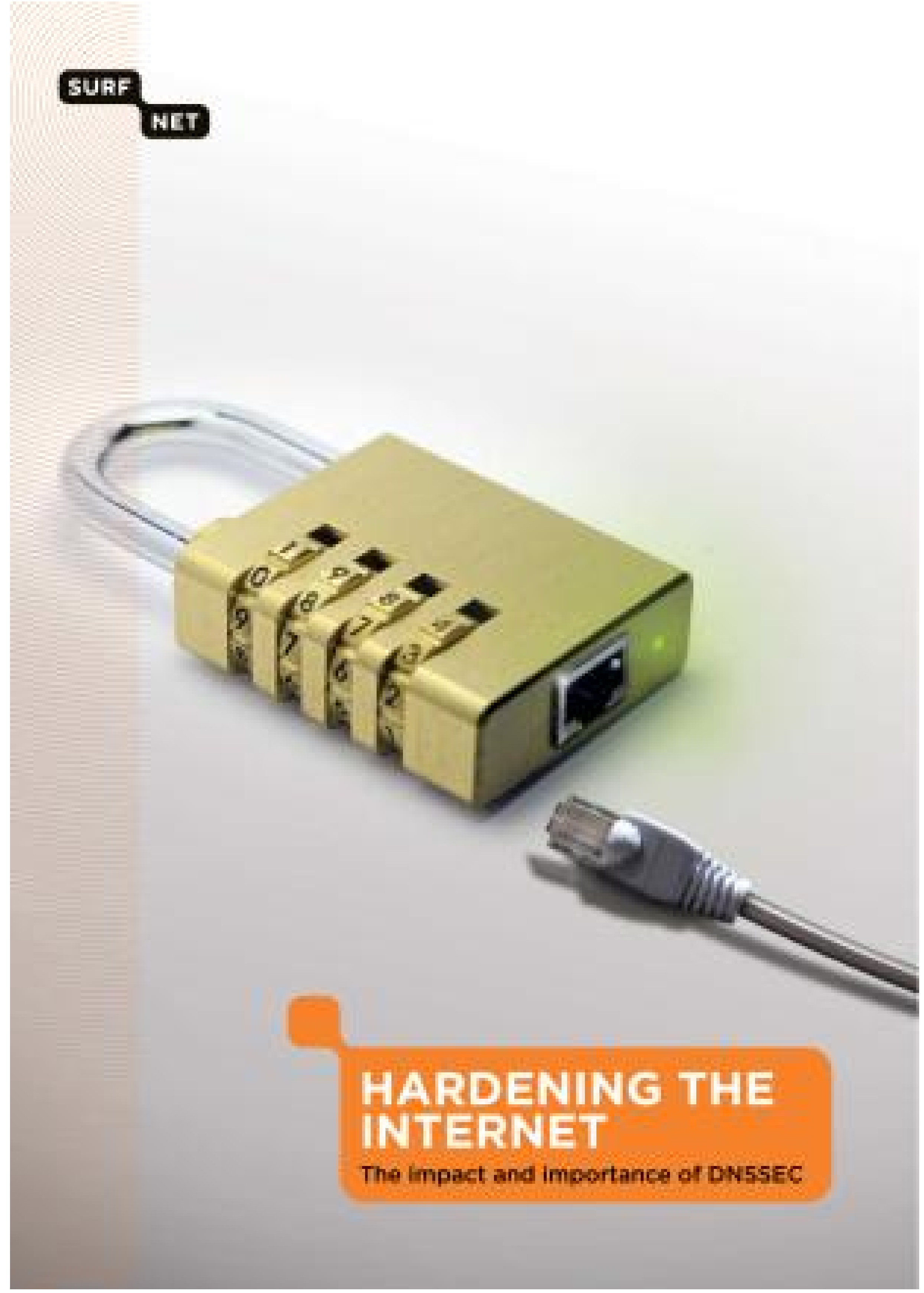

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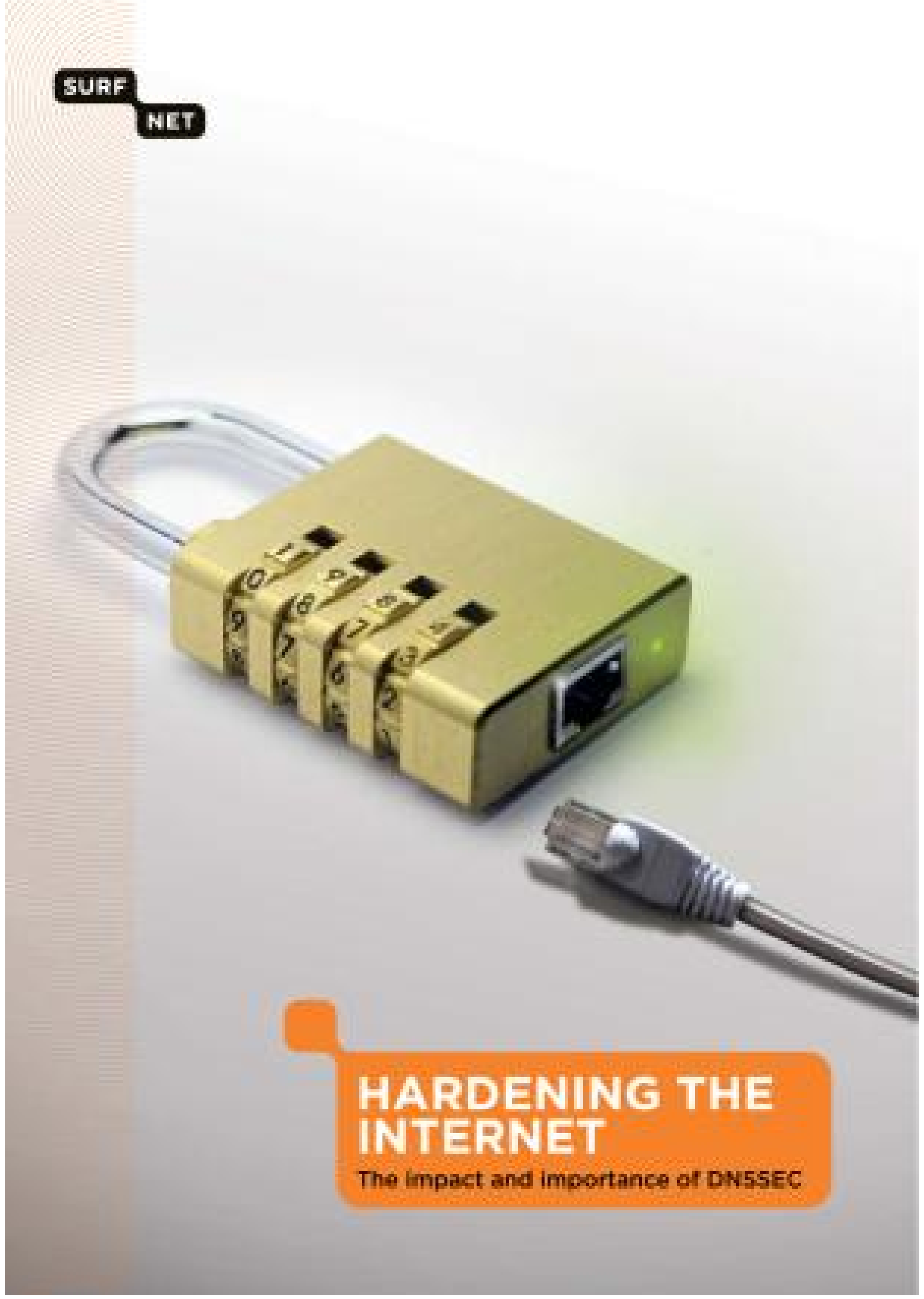

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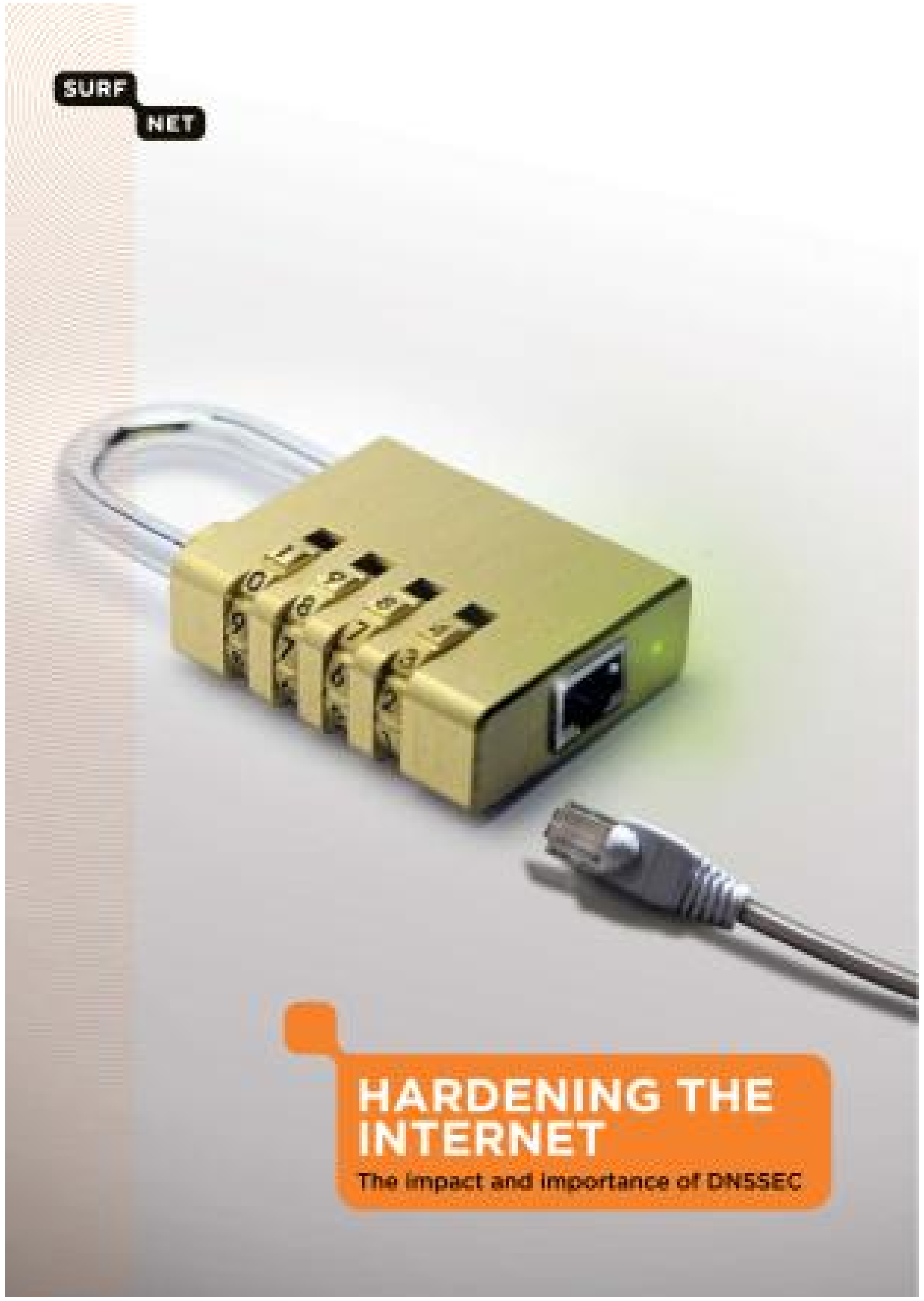

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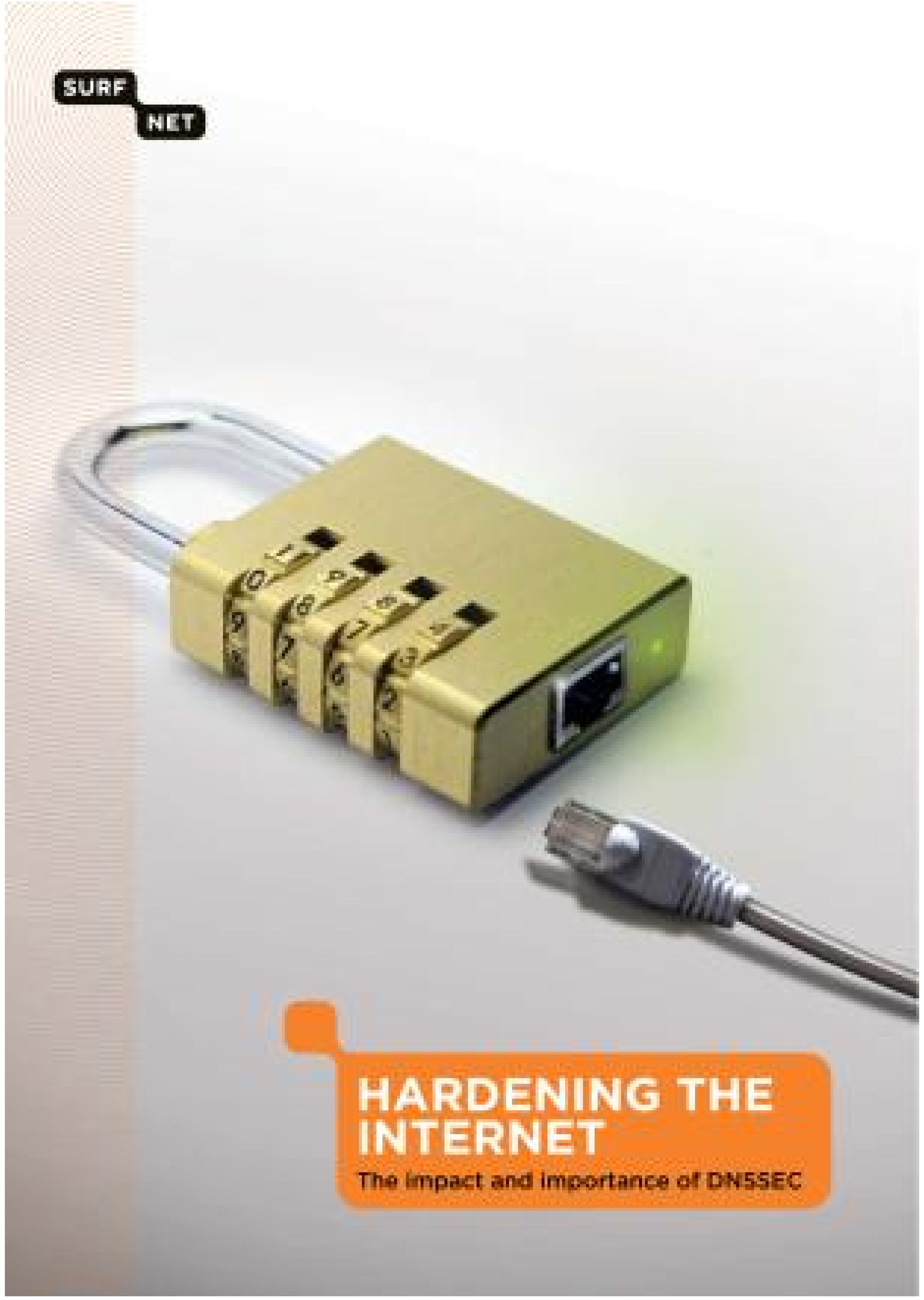

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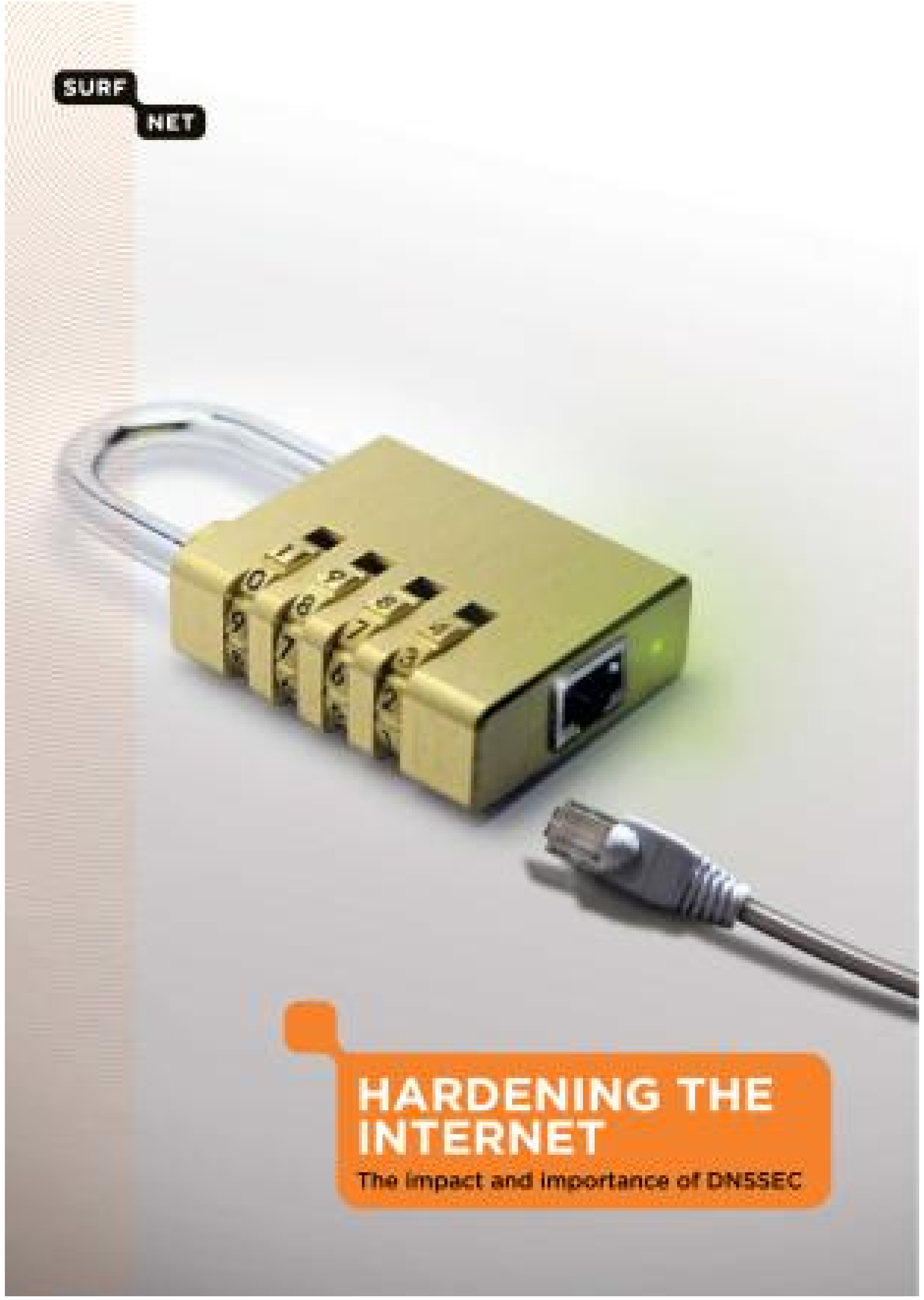

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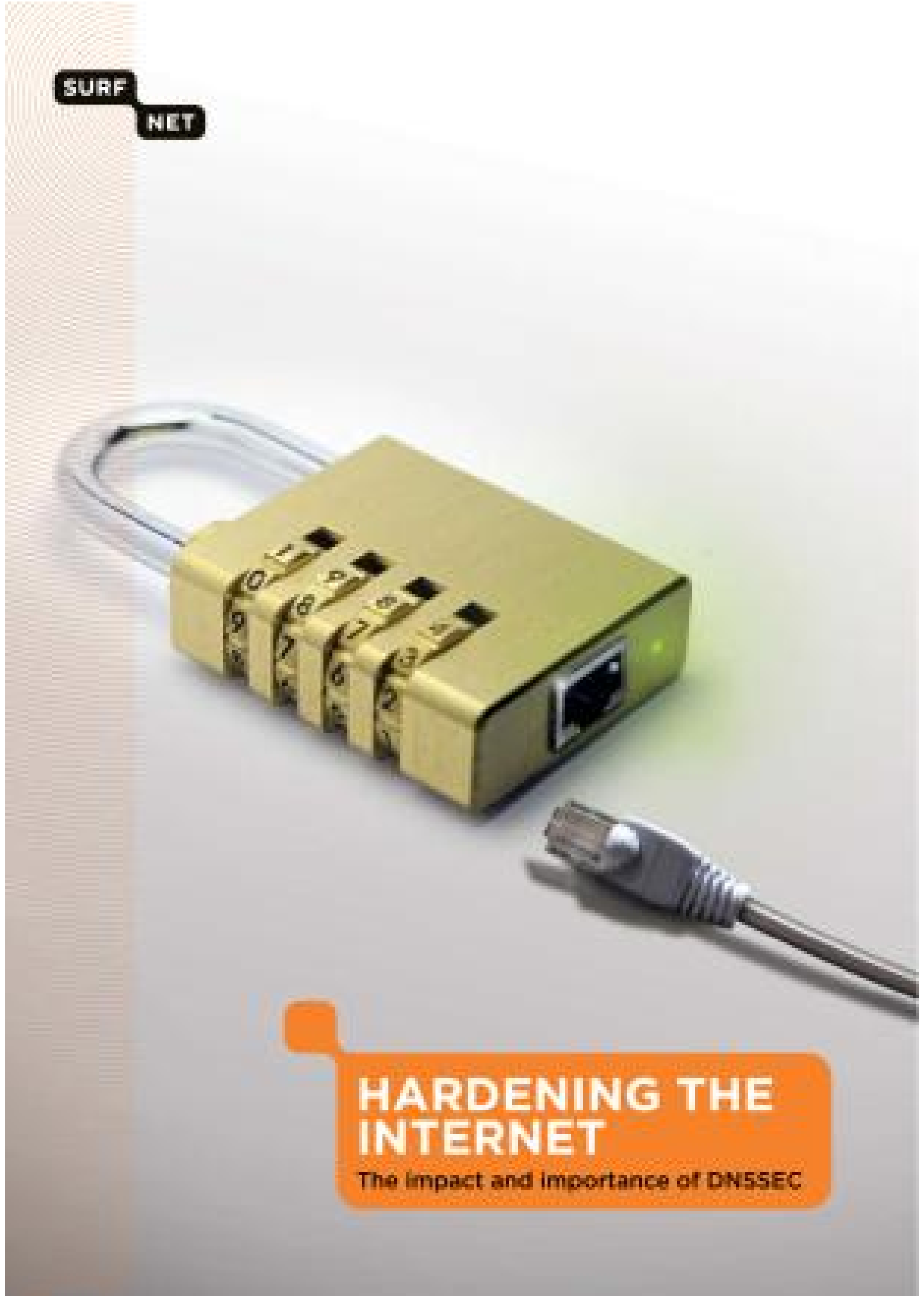

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Precomputation forced DNSSEC down a path of unreliability, insecurity, and unusability.
Let's see how this happened.

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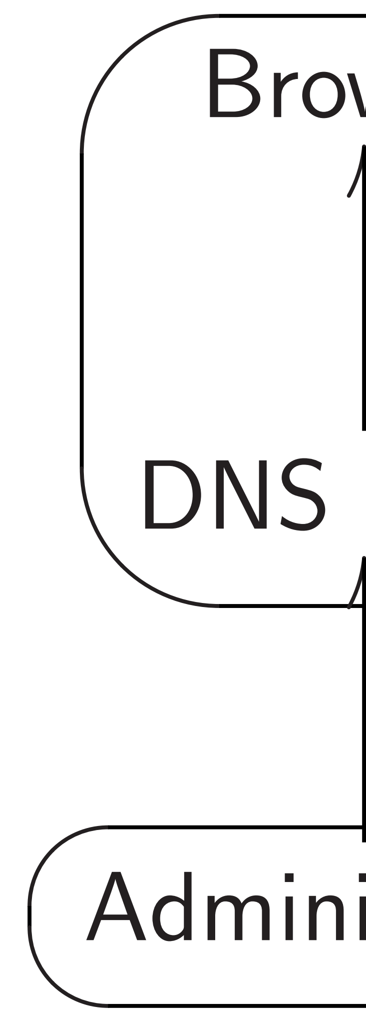

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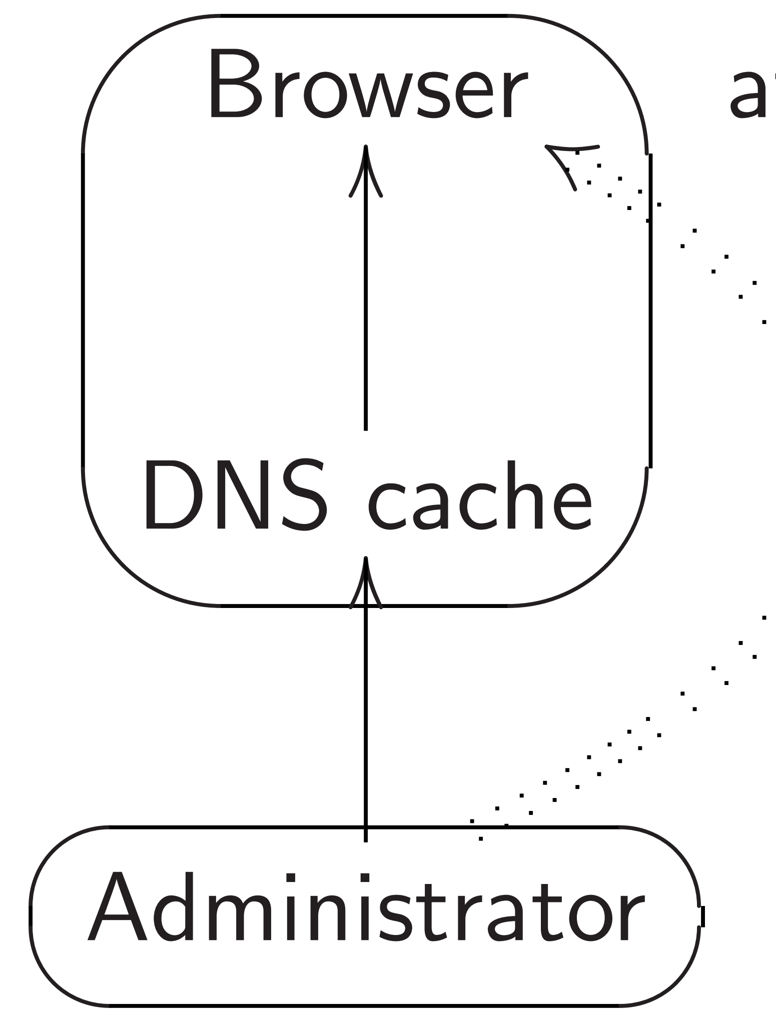

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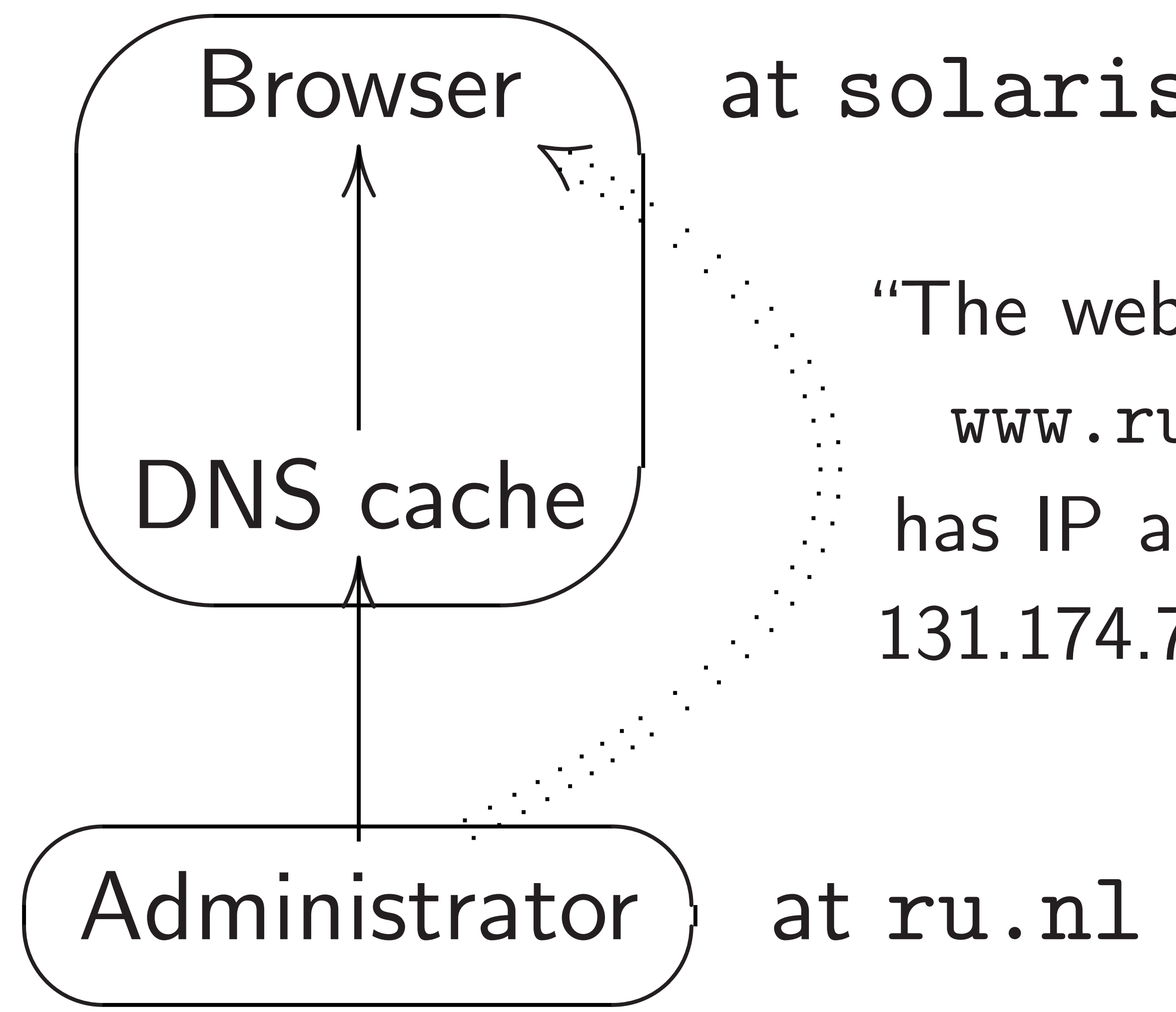

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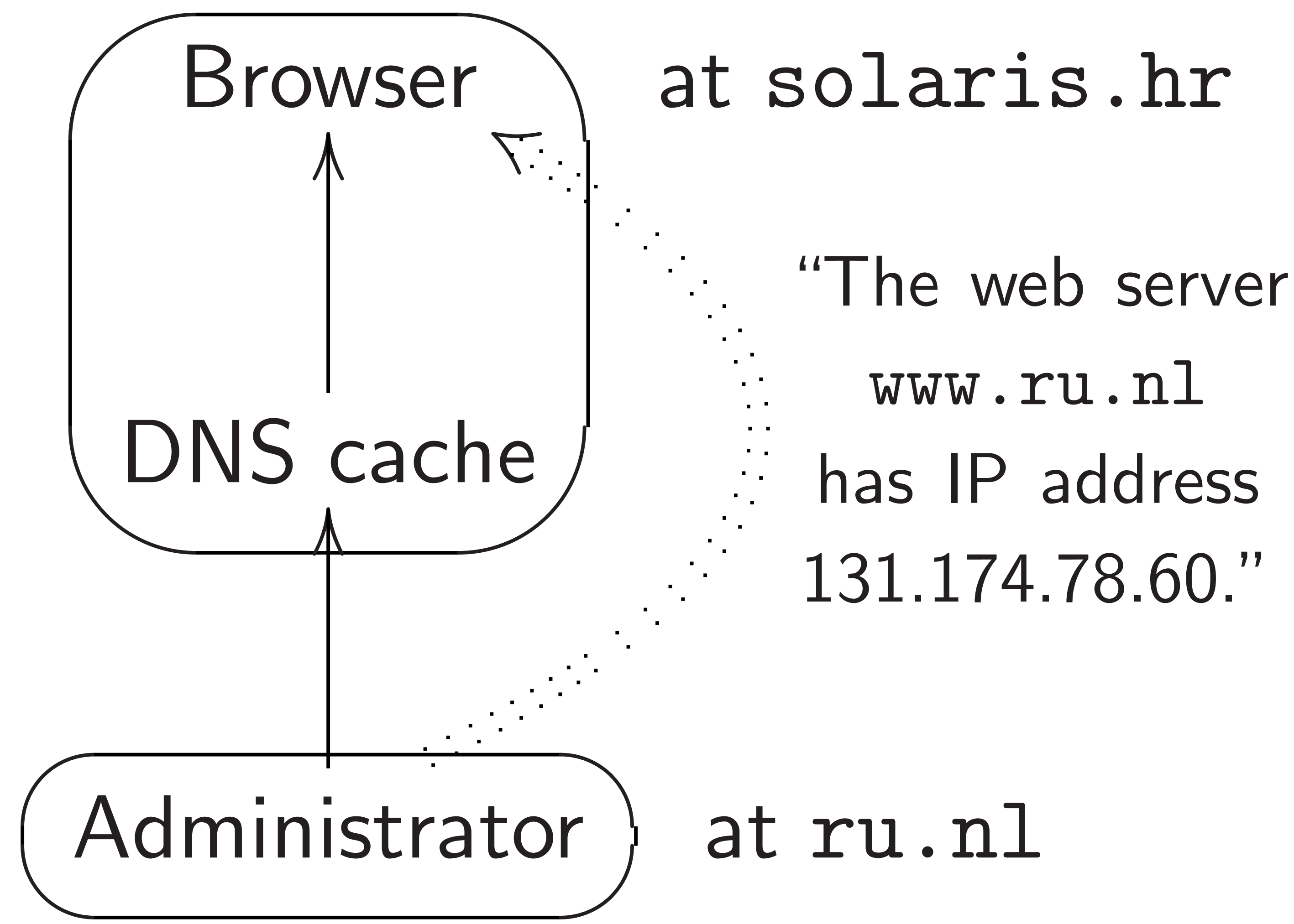

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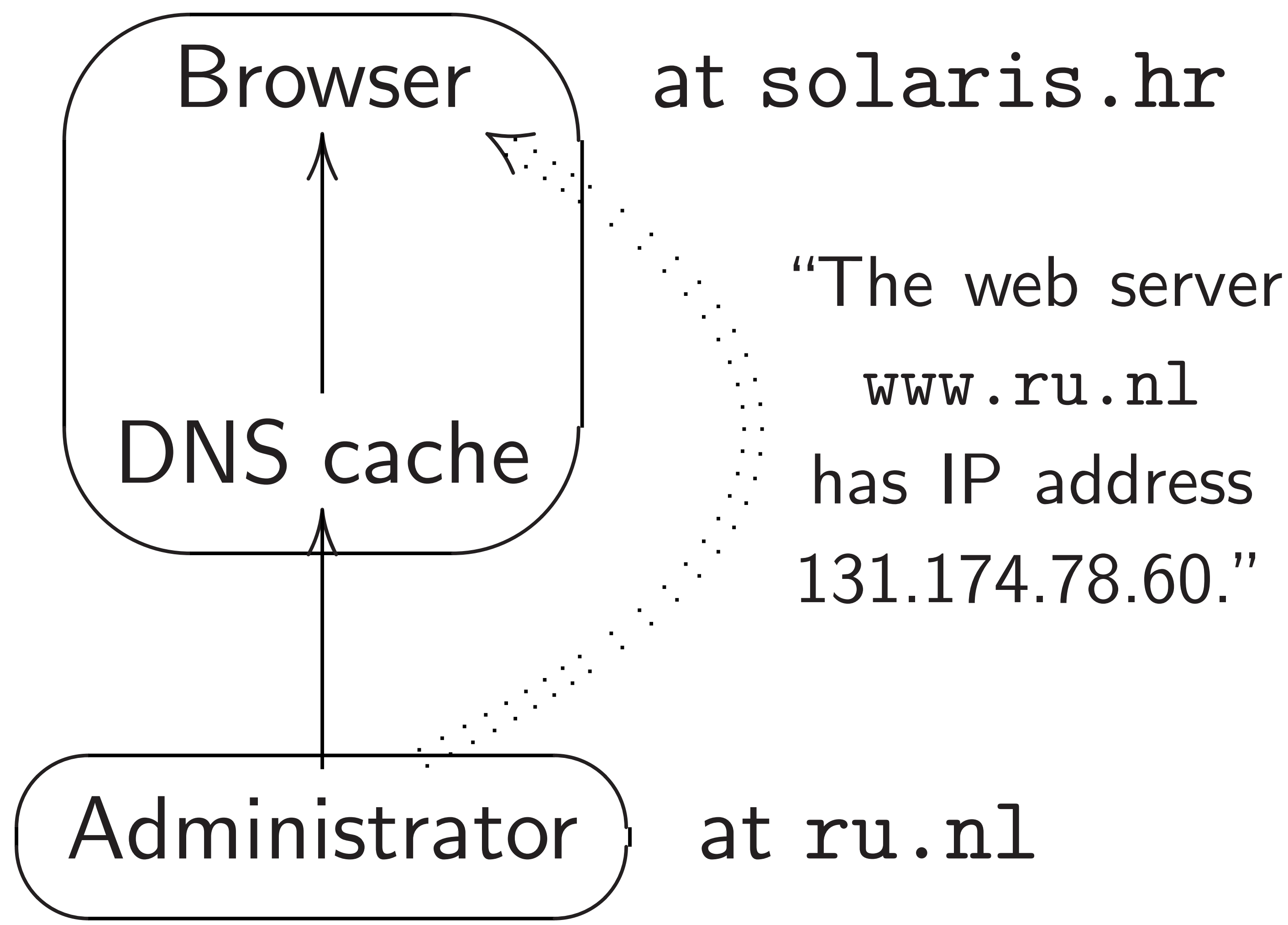

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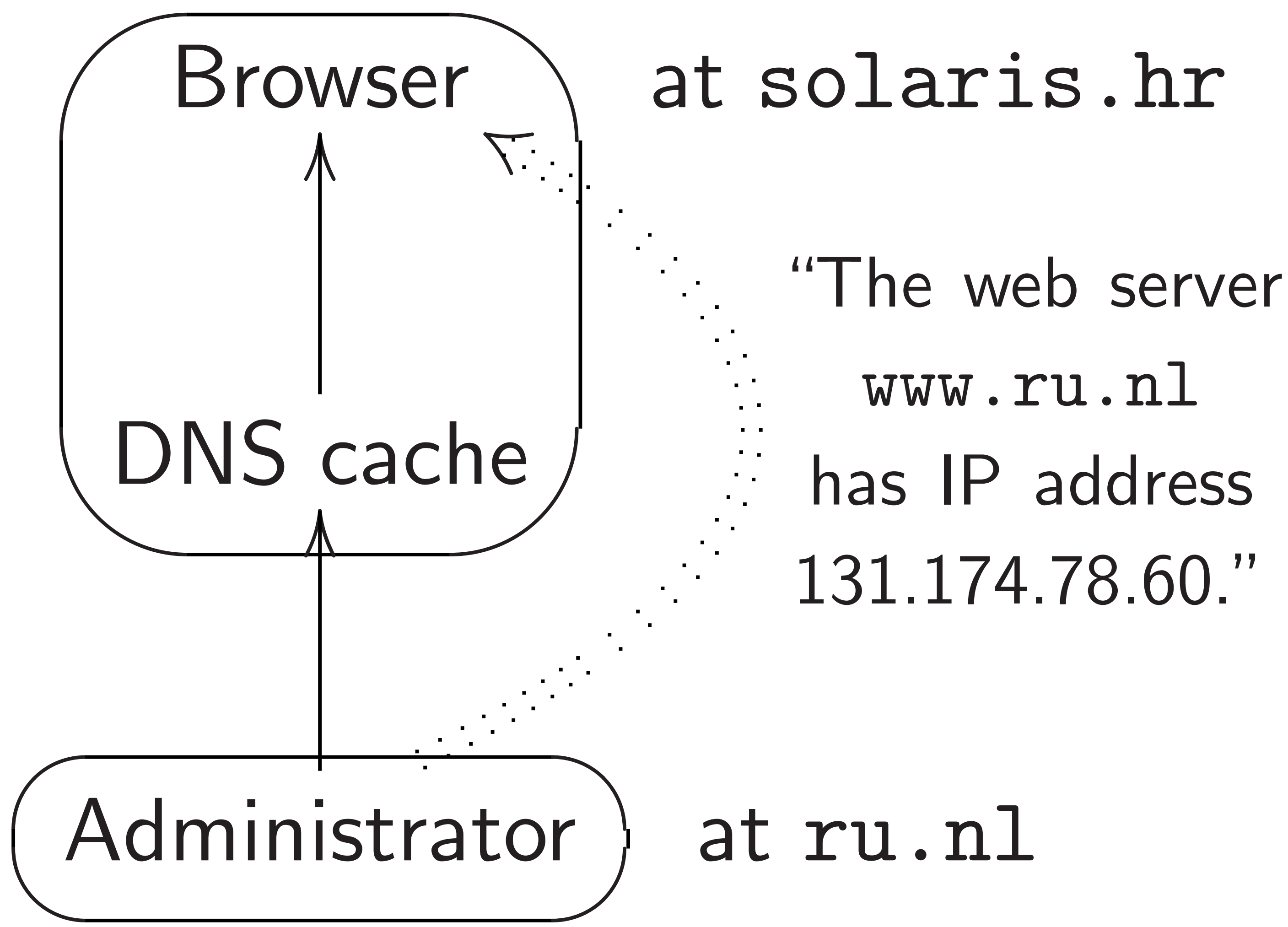

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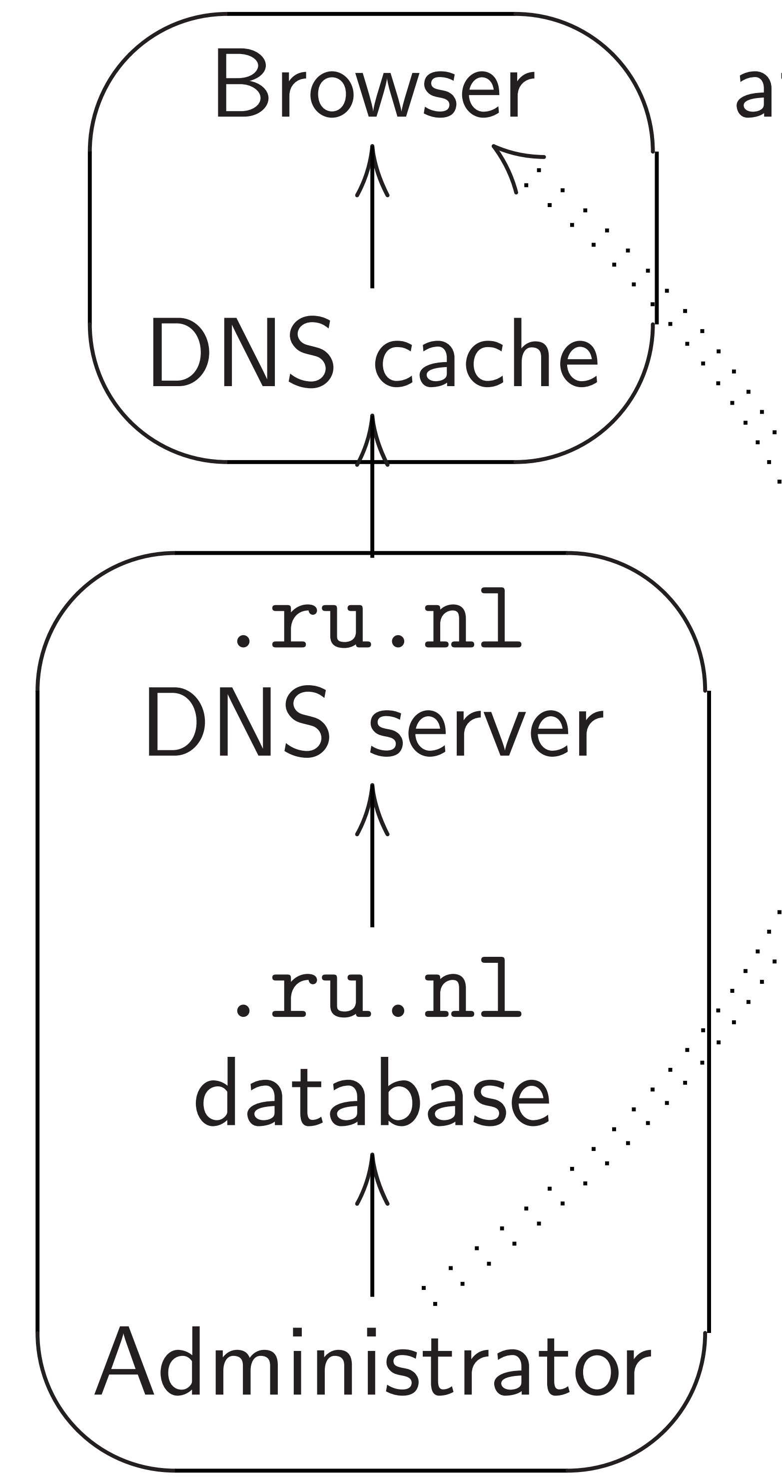

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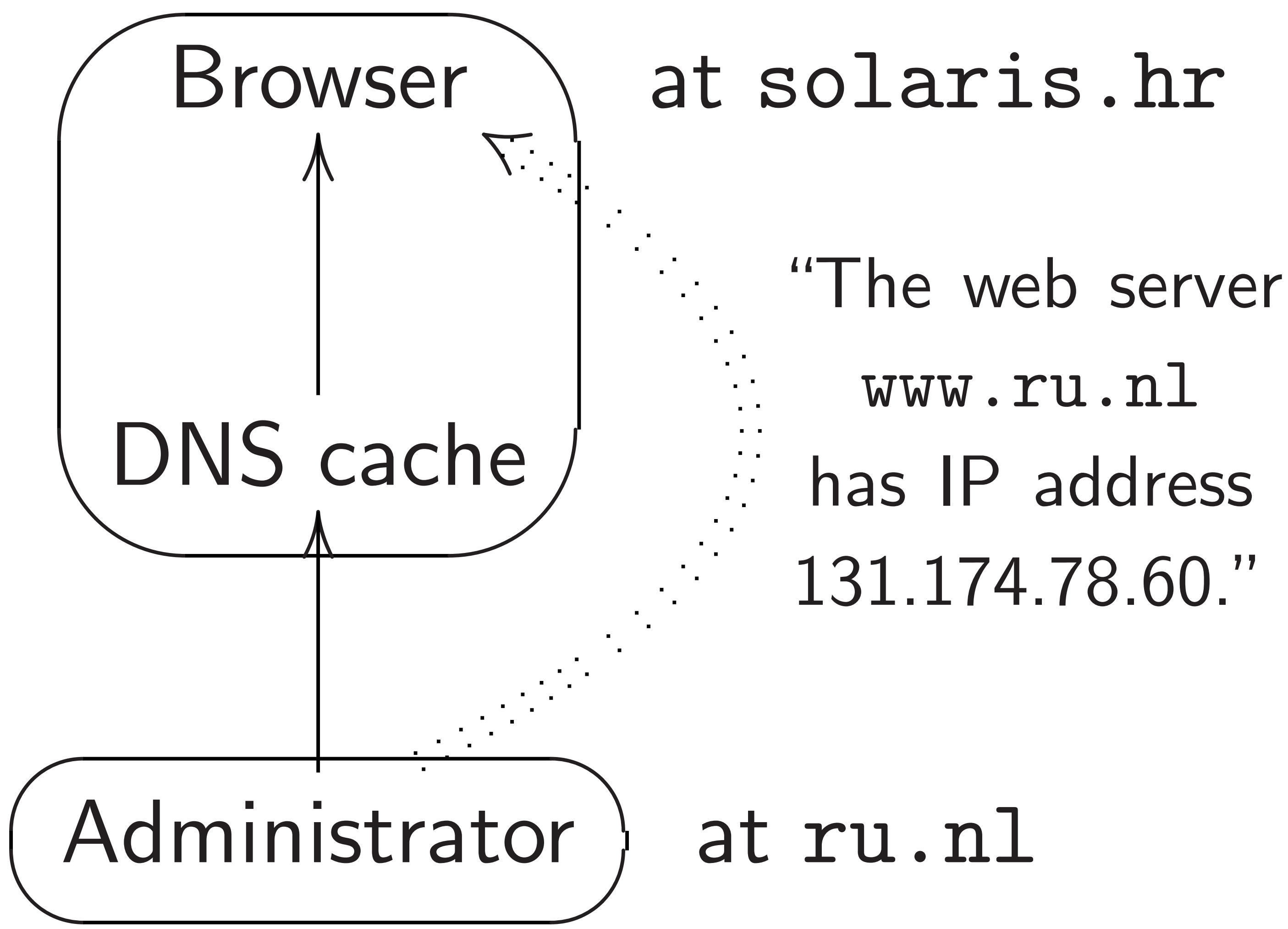

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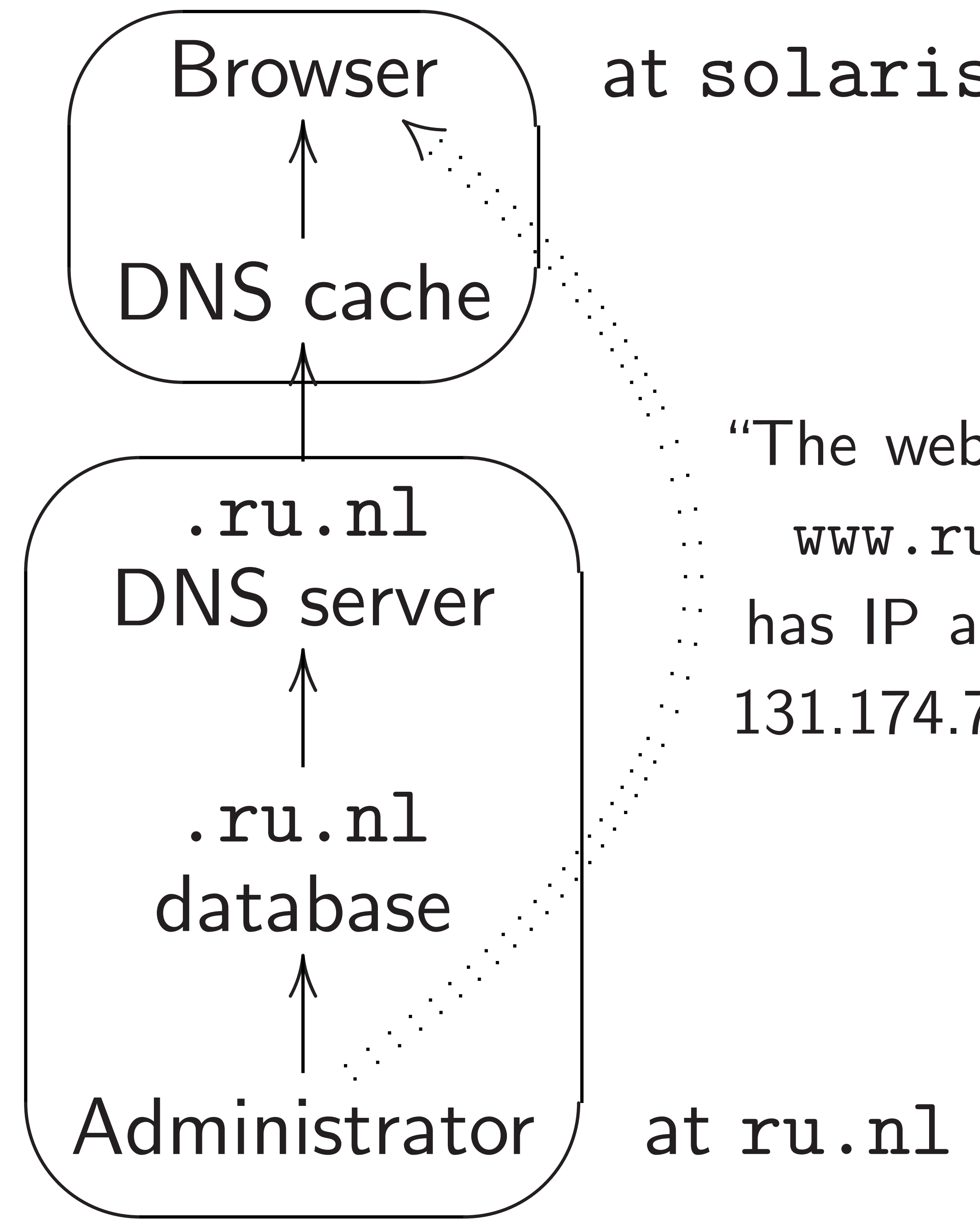

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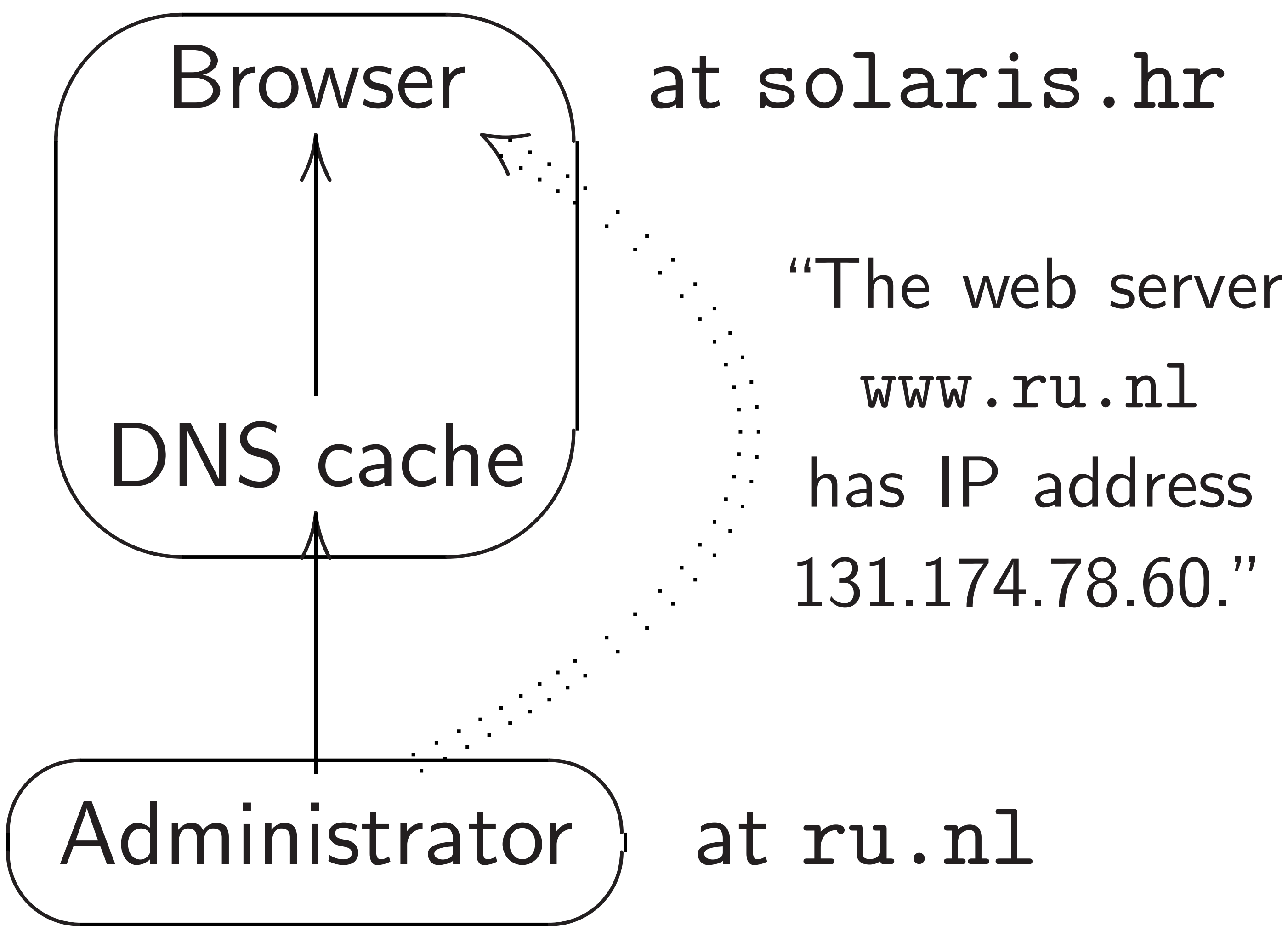

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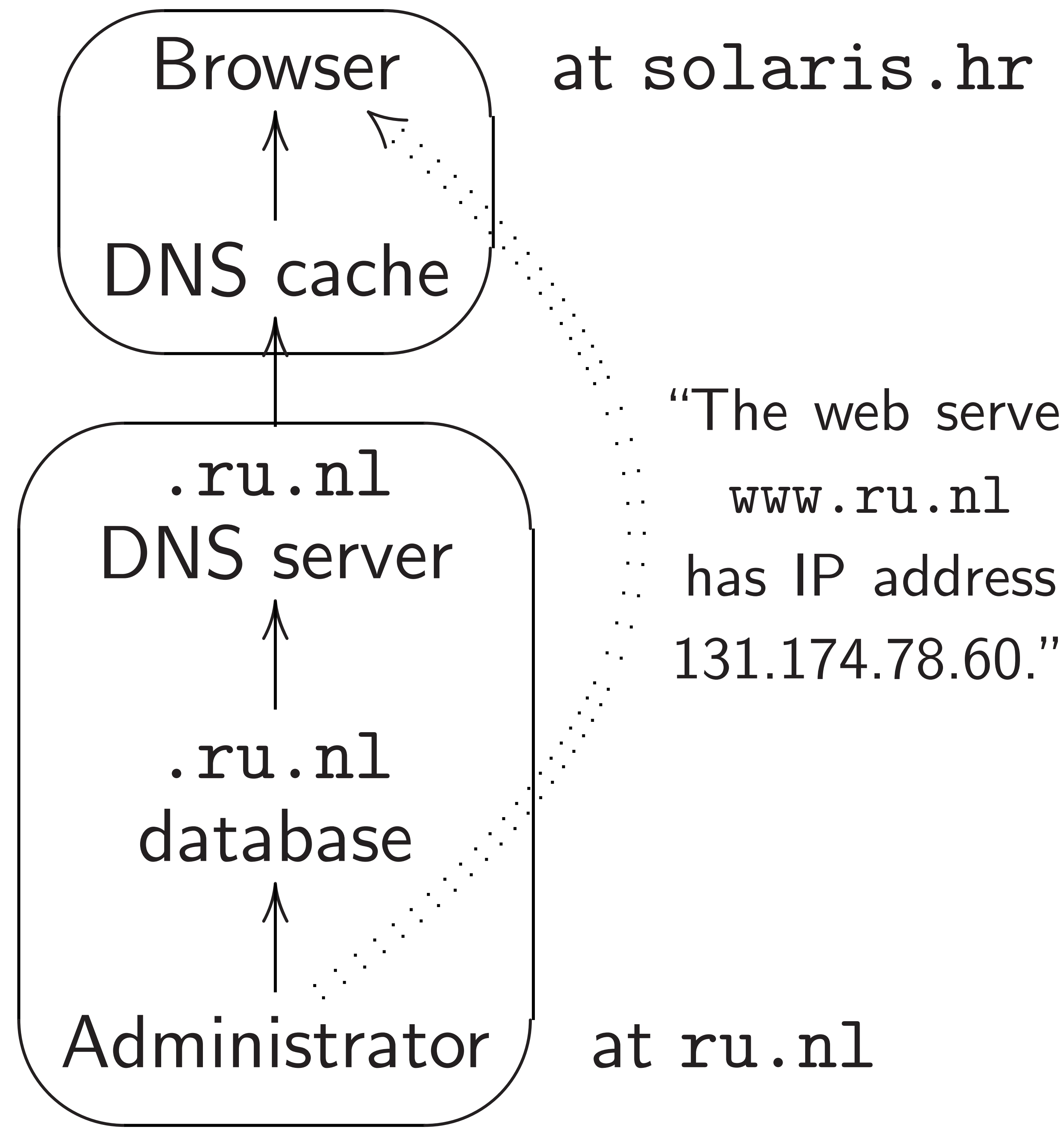

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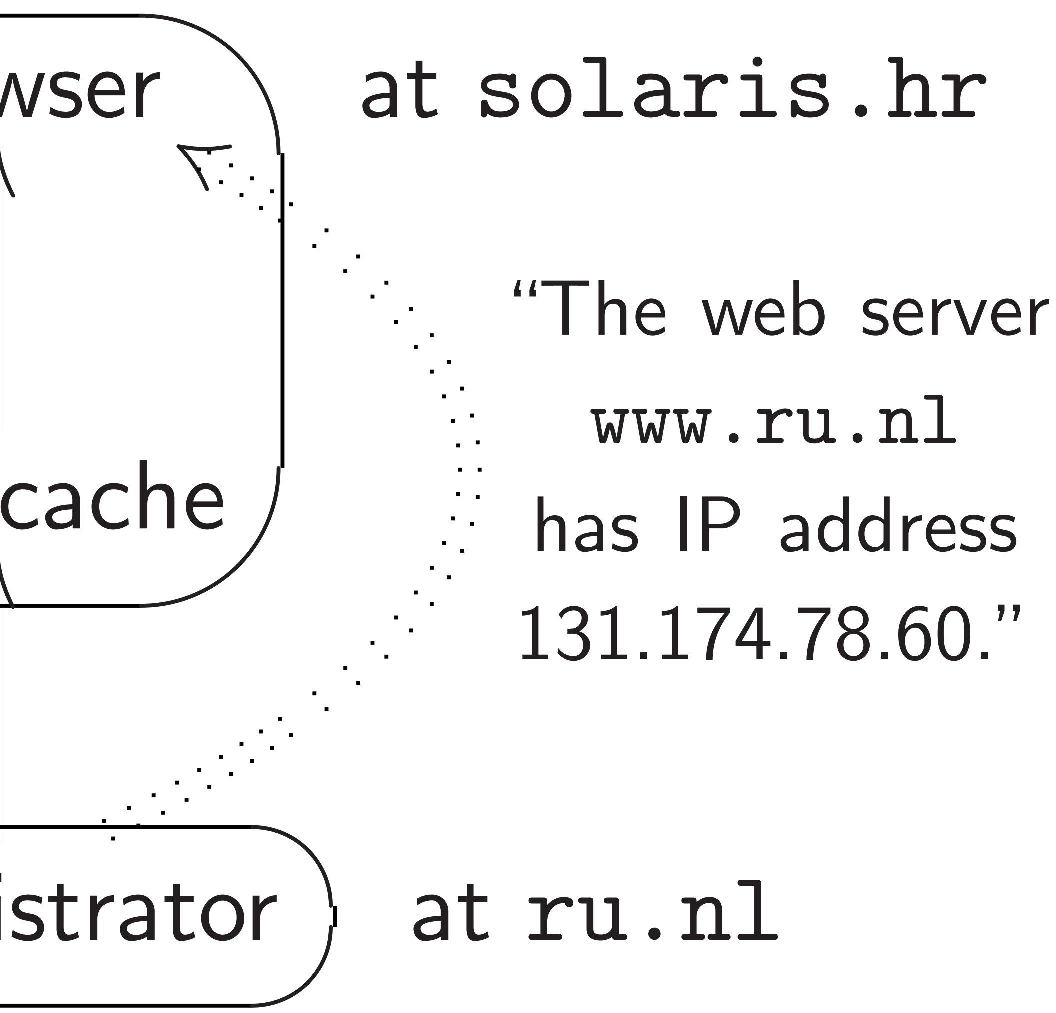

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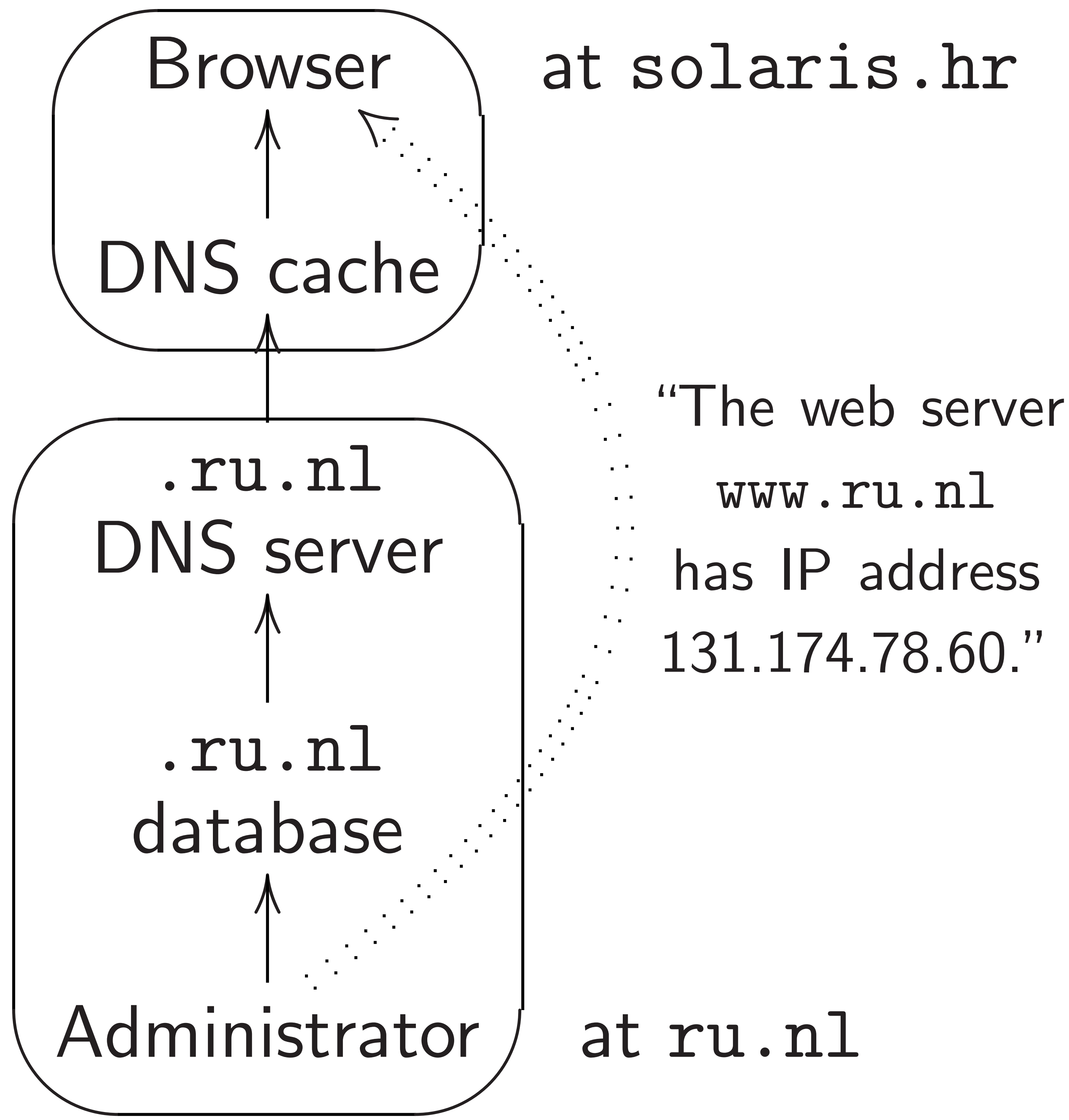

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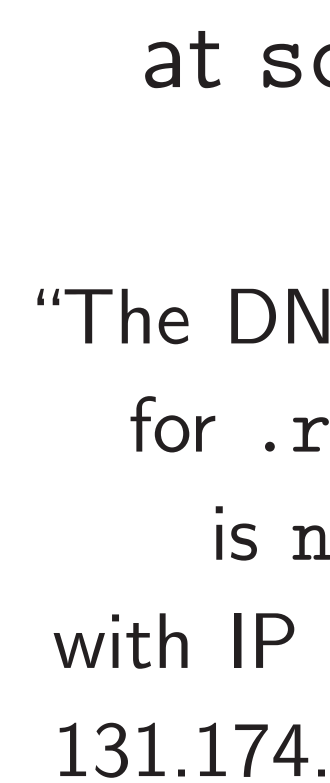

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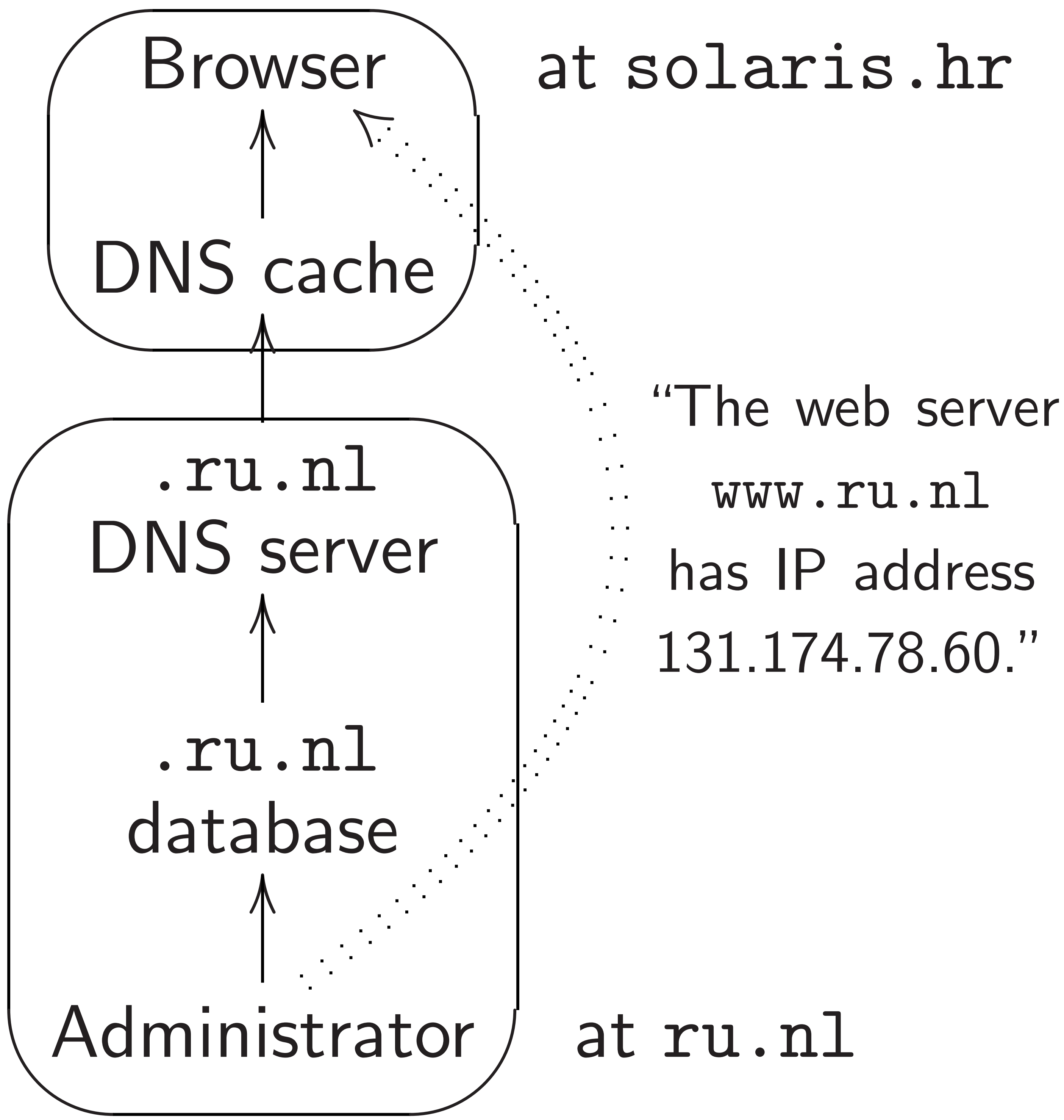

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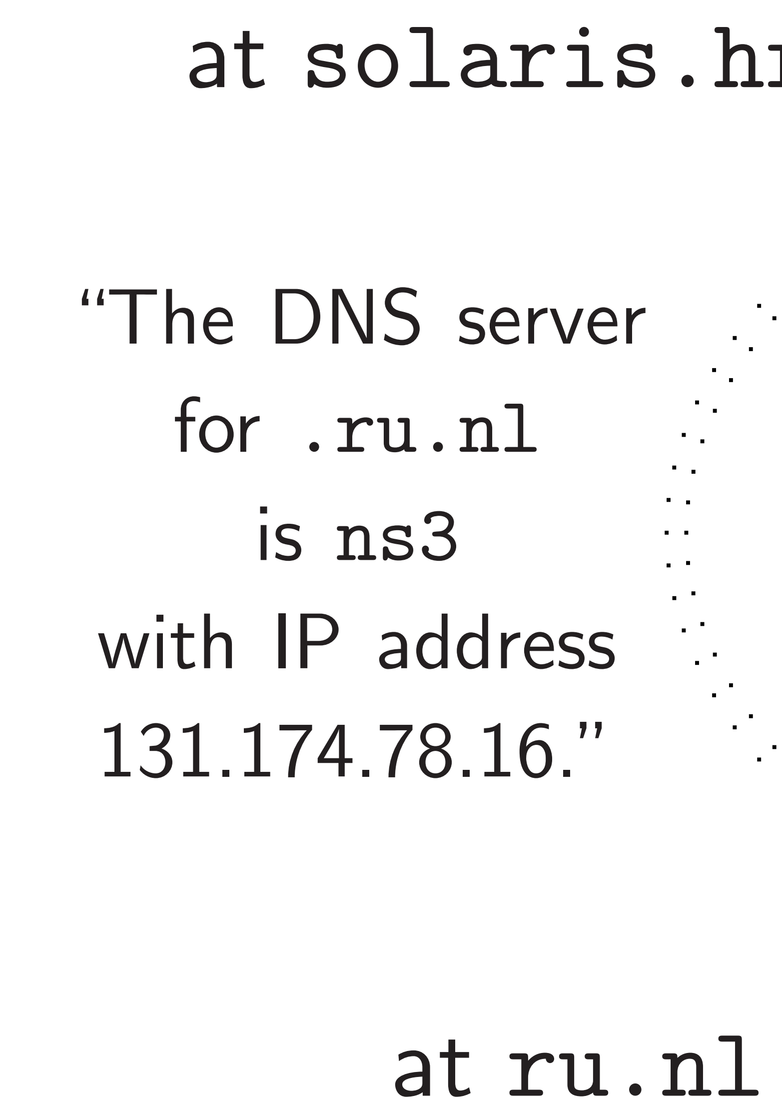

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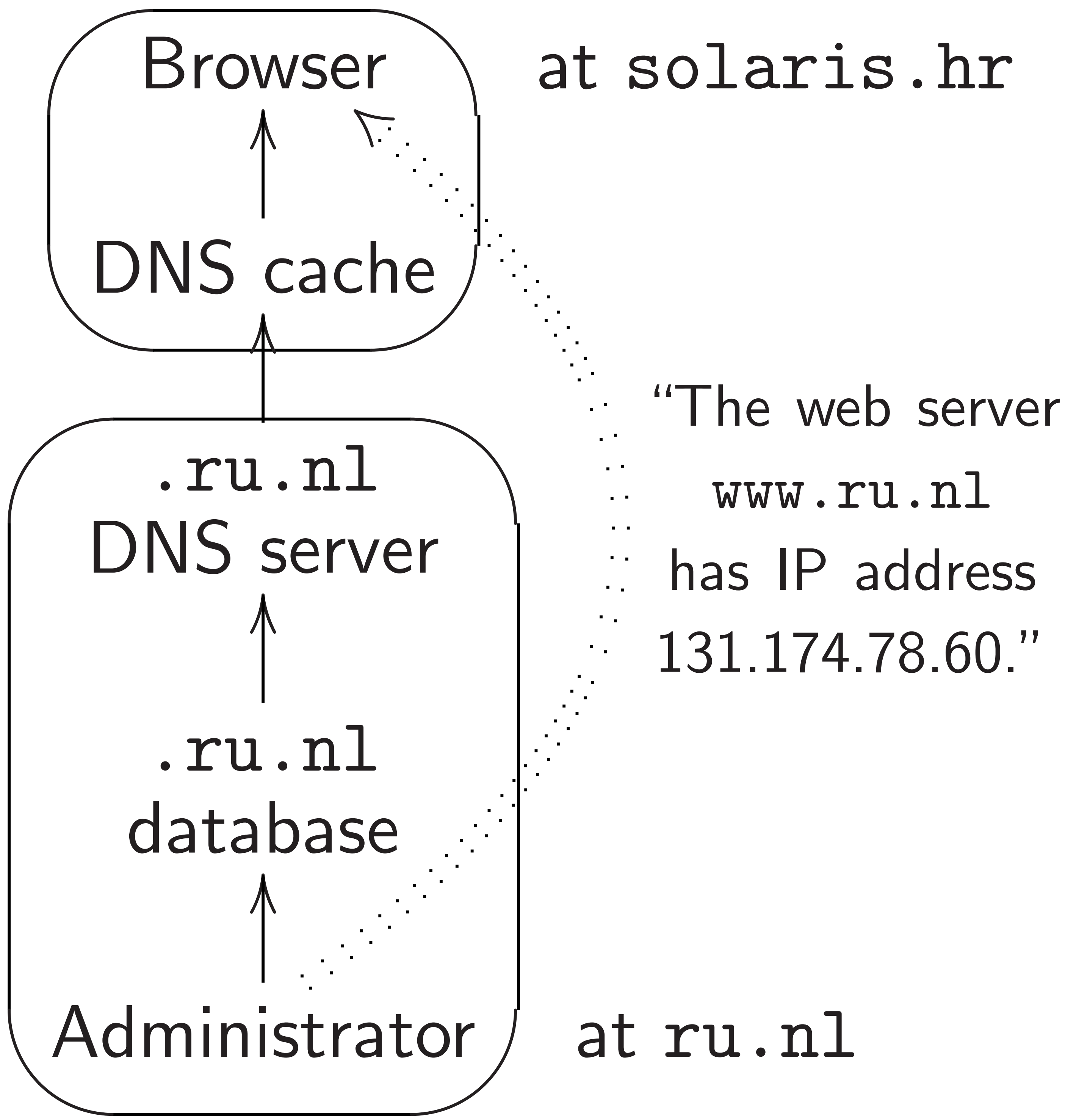

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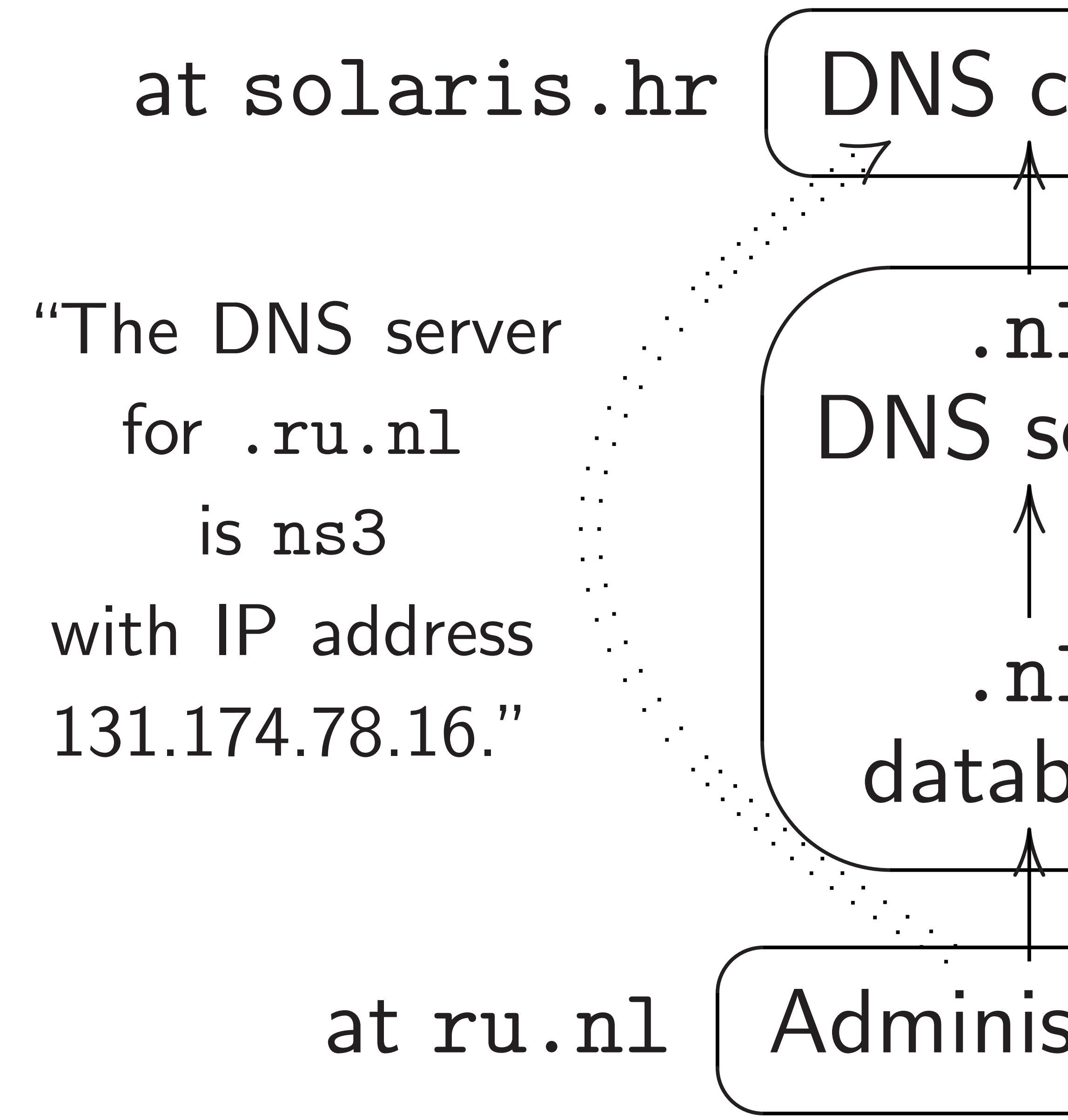

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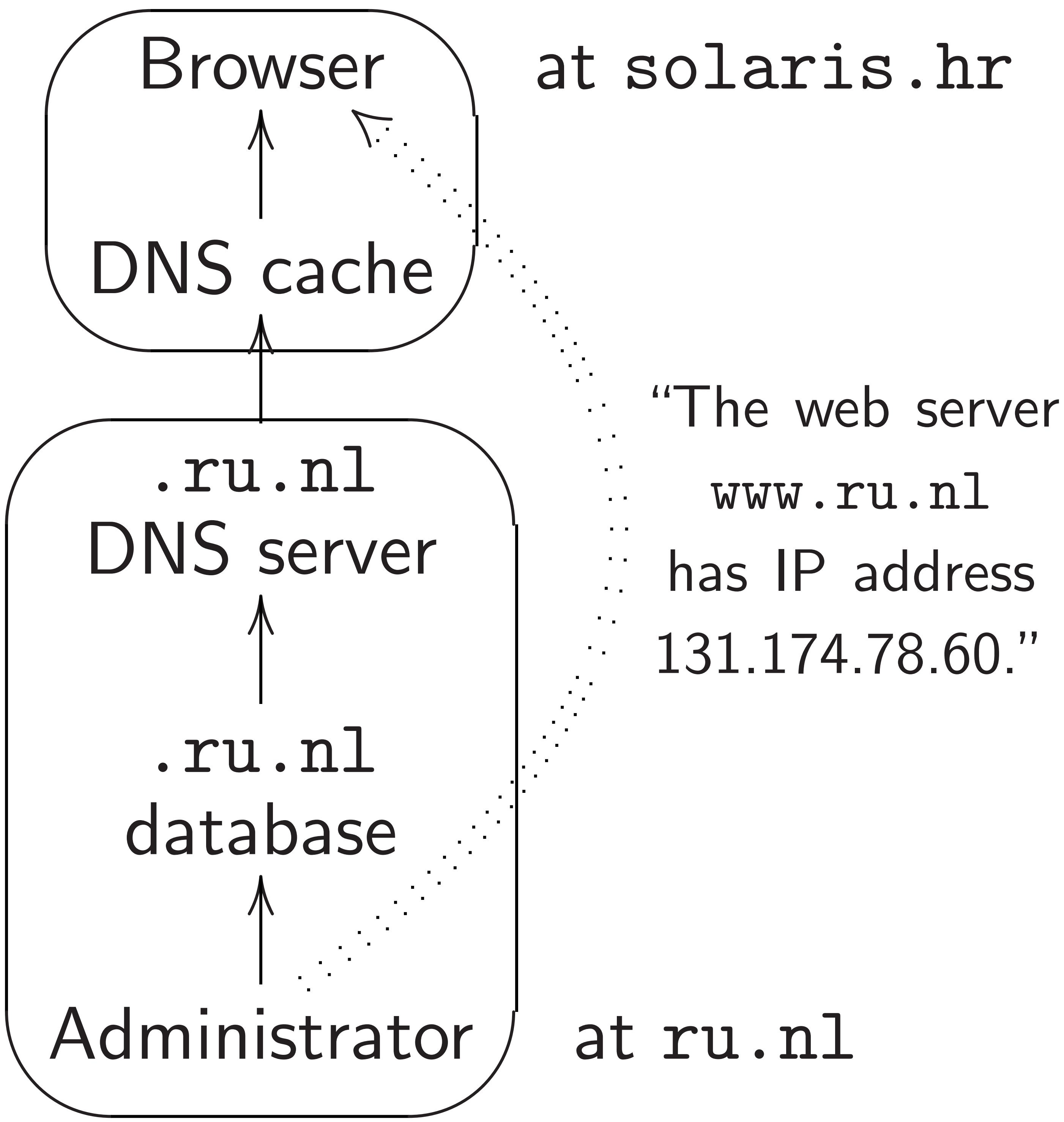

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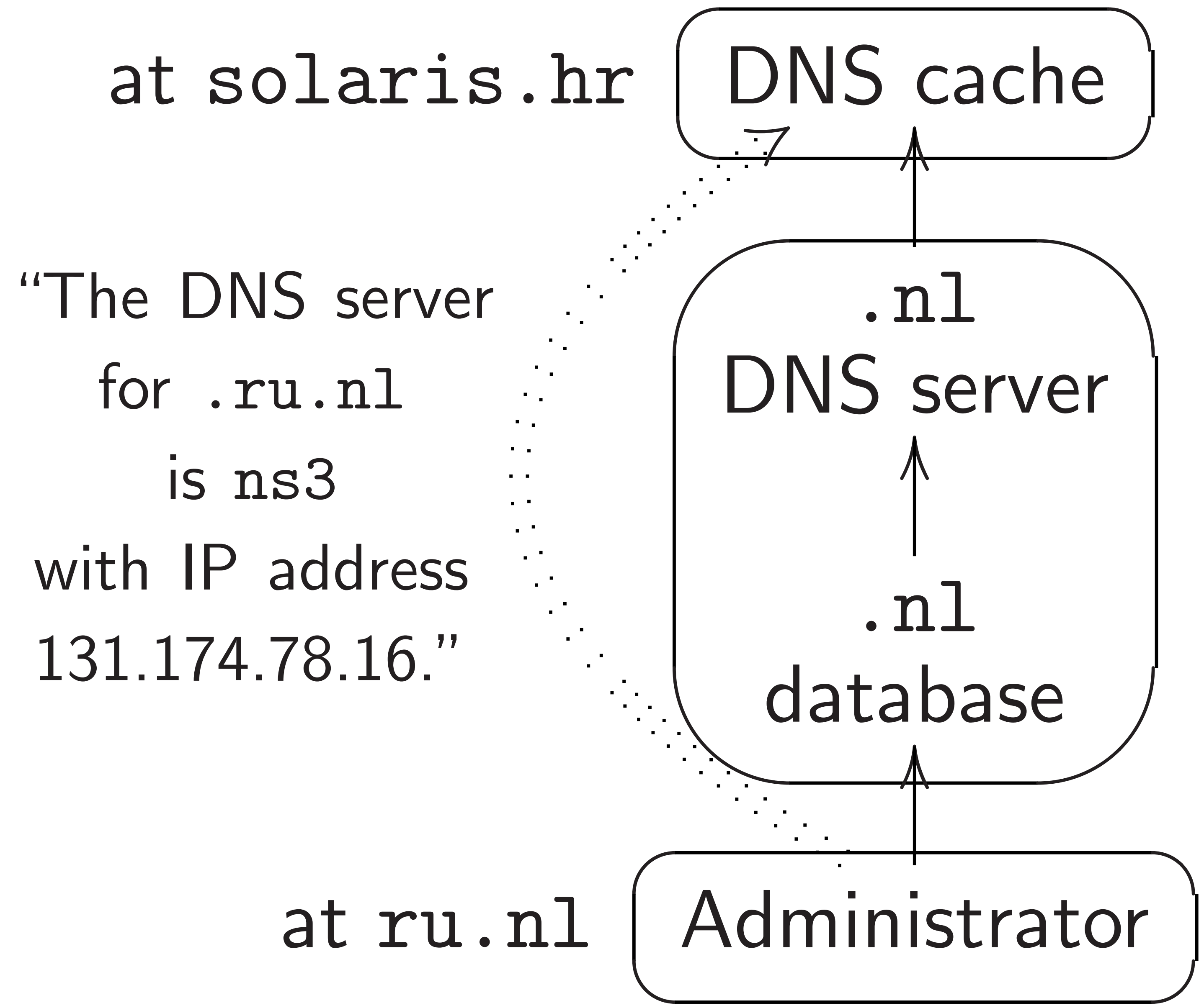

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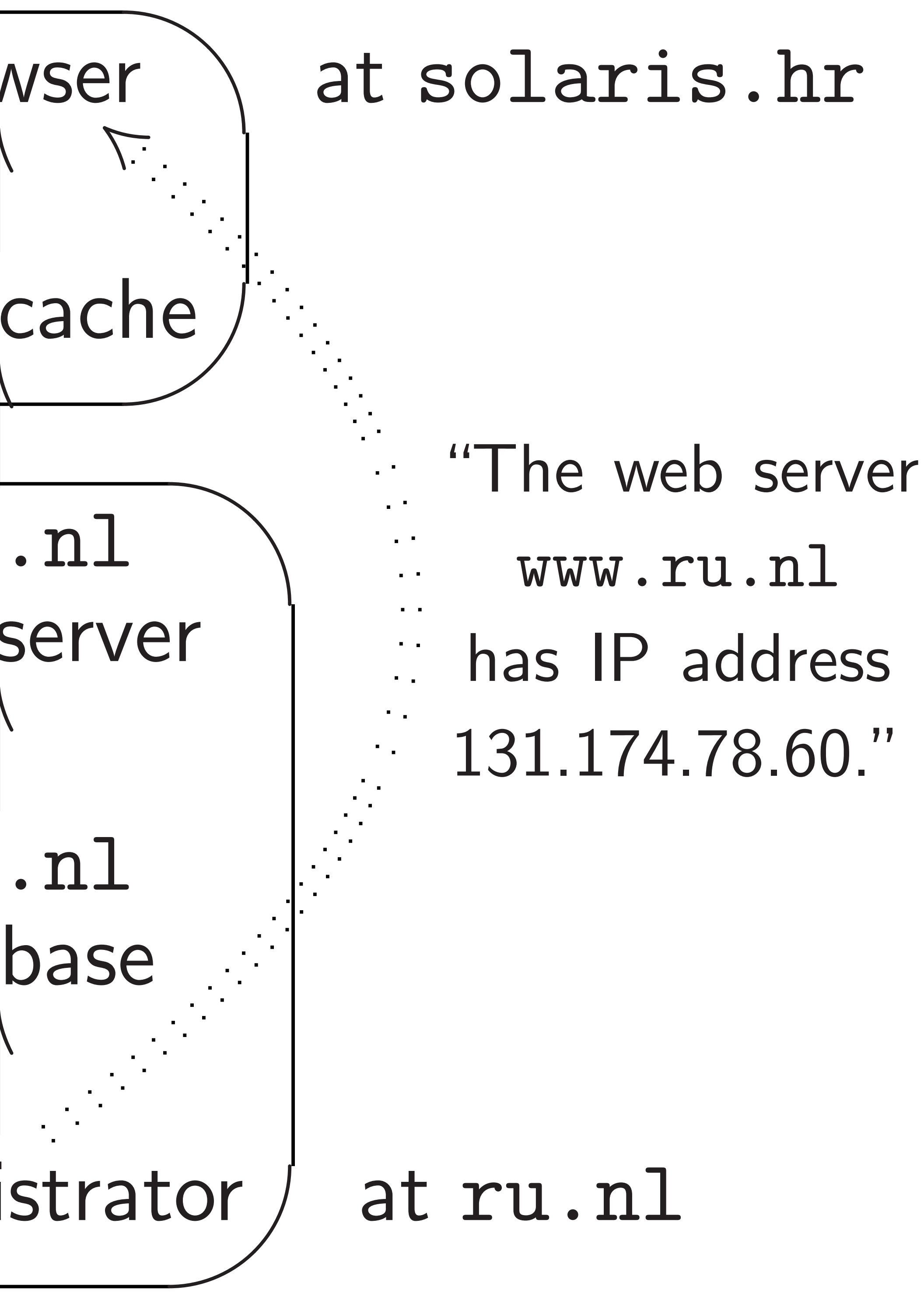

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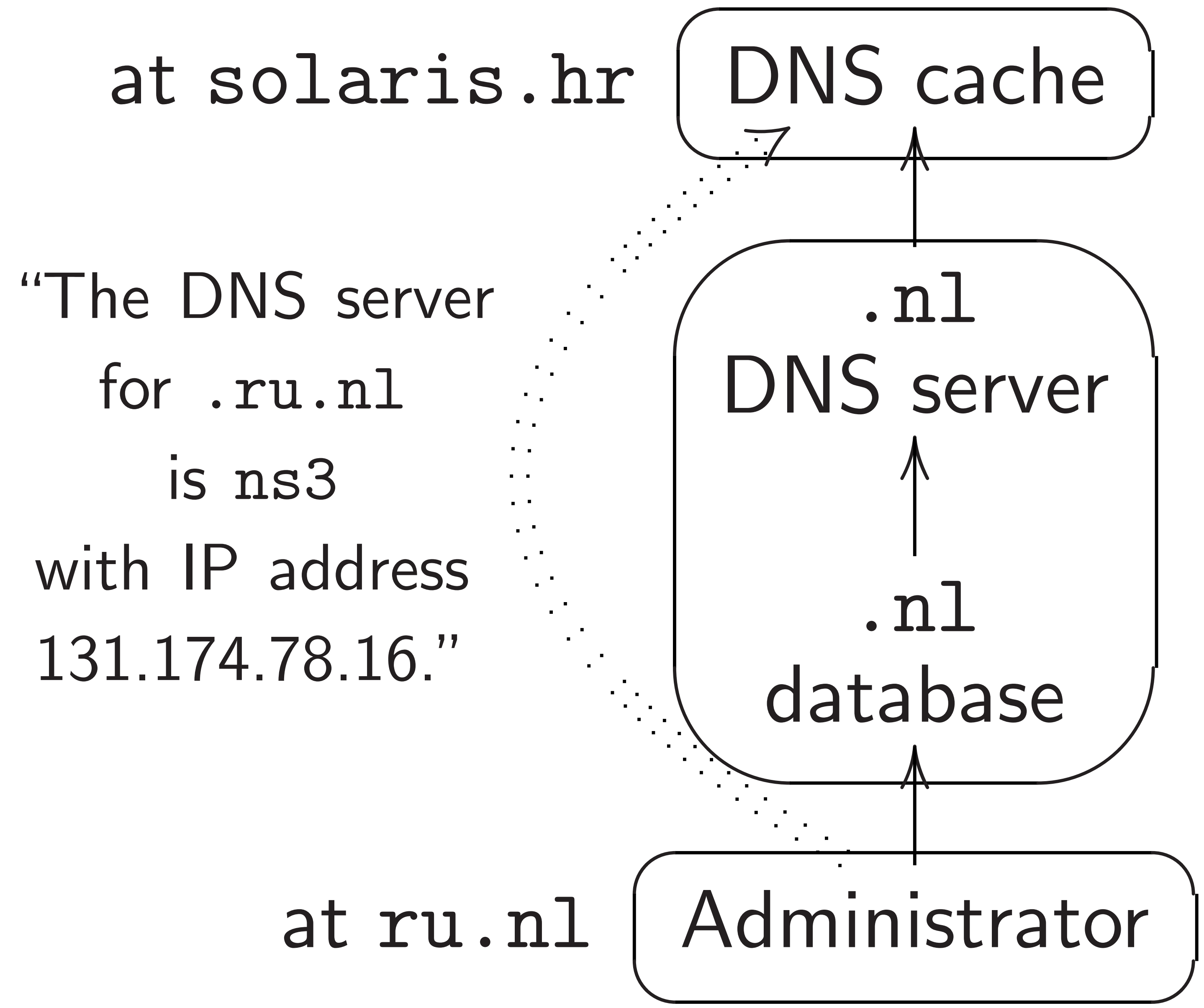

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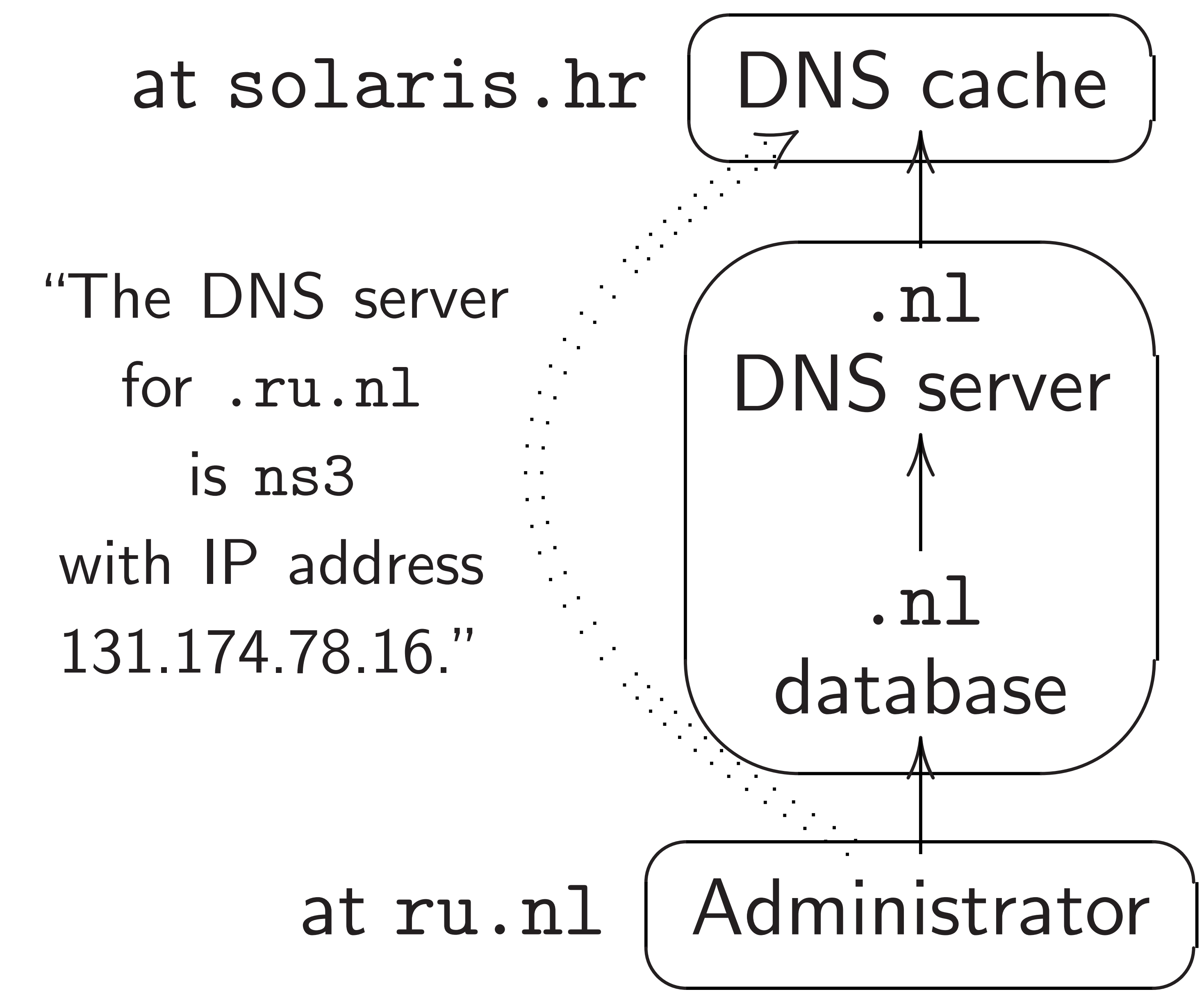

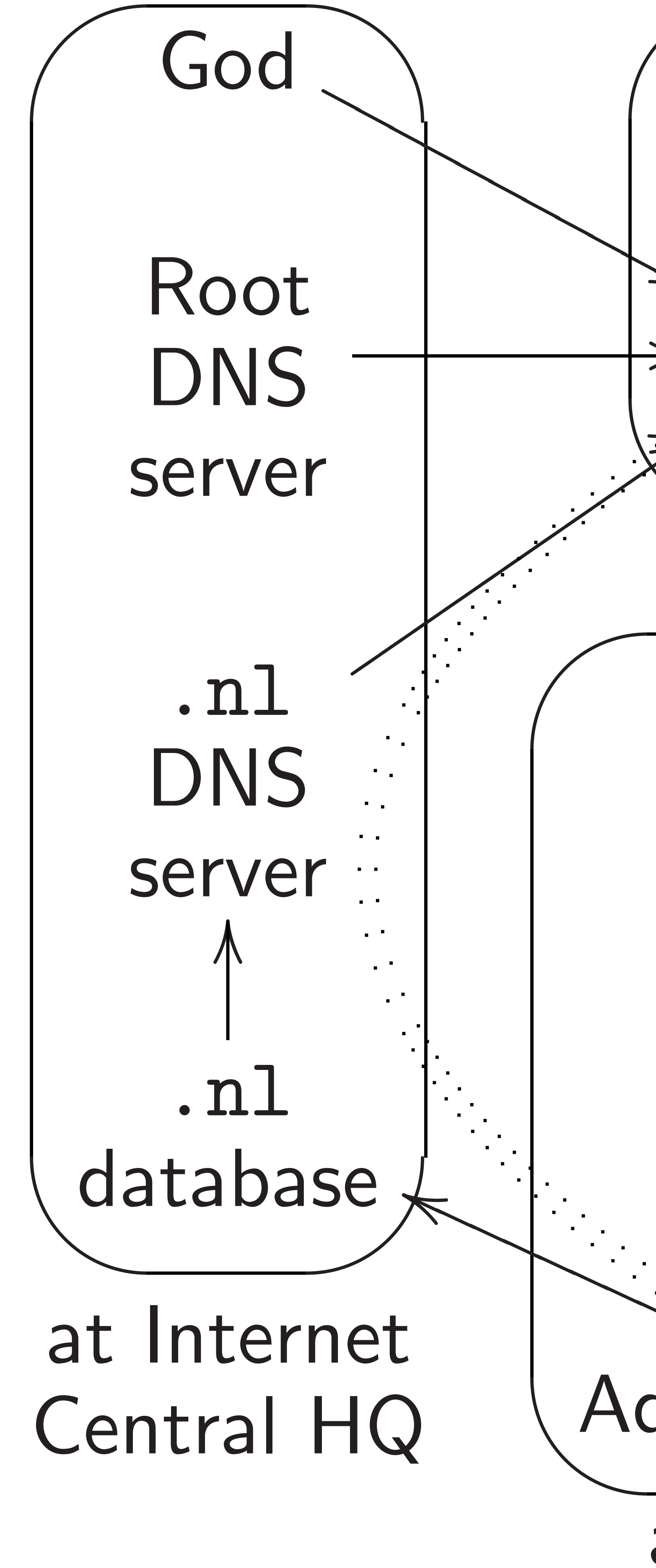

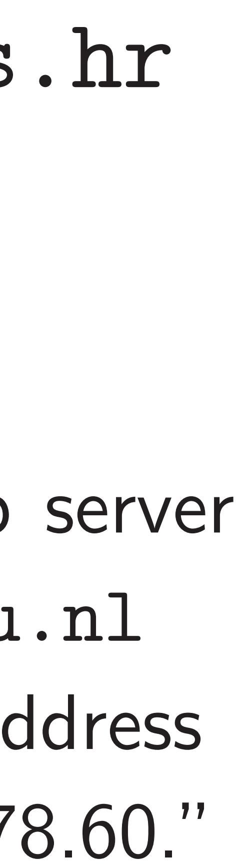

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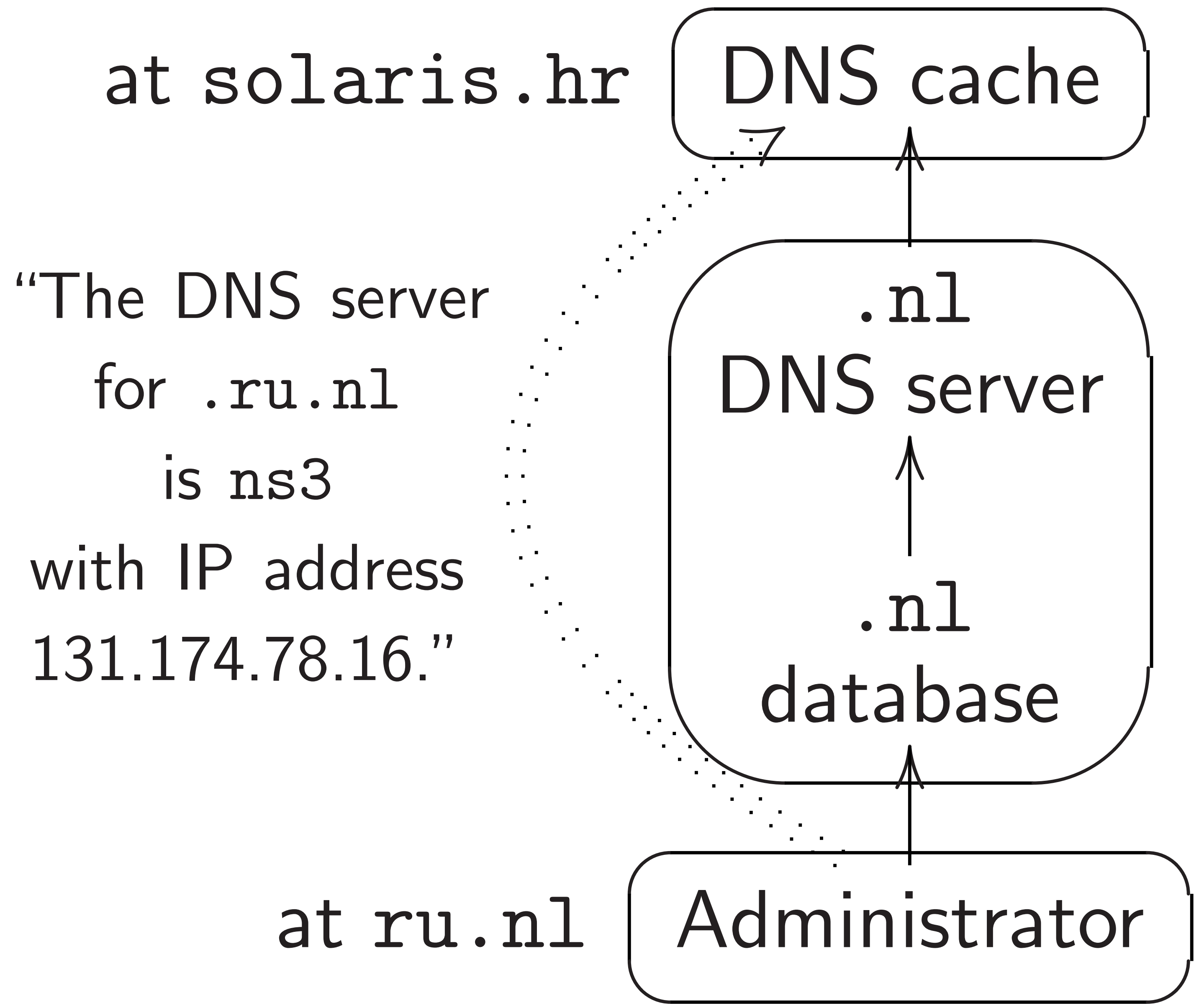

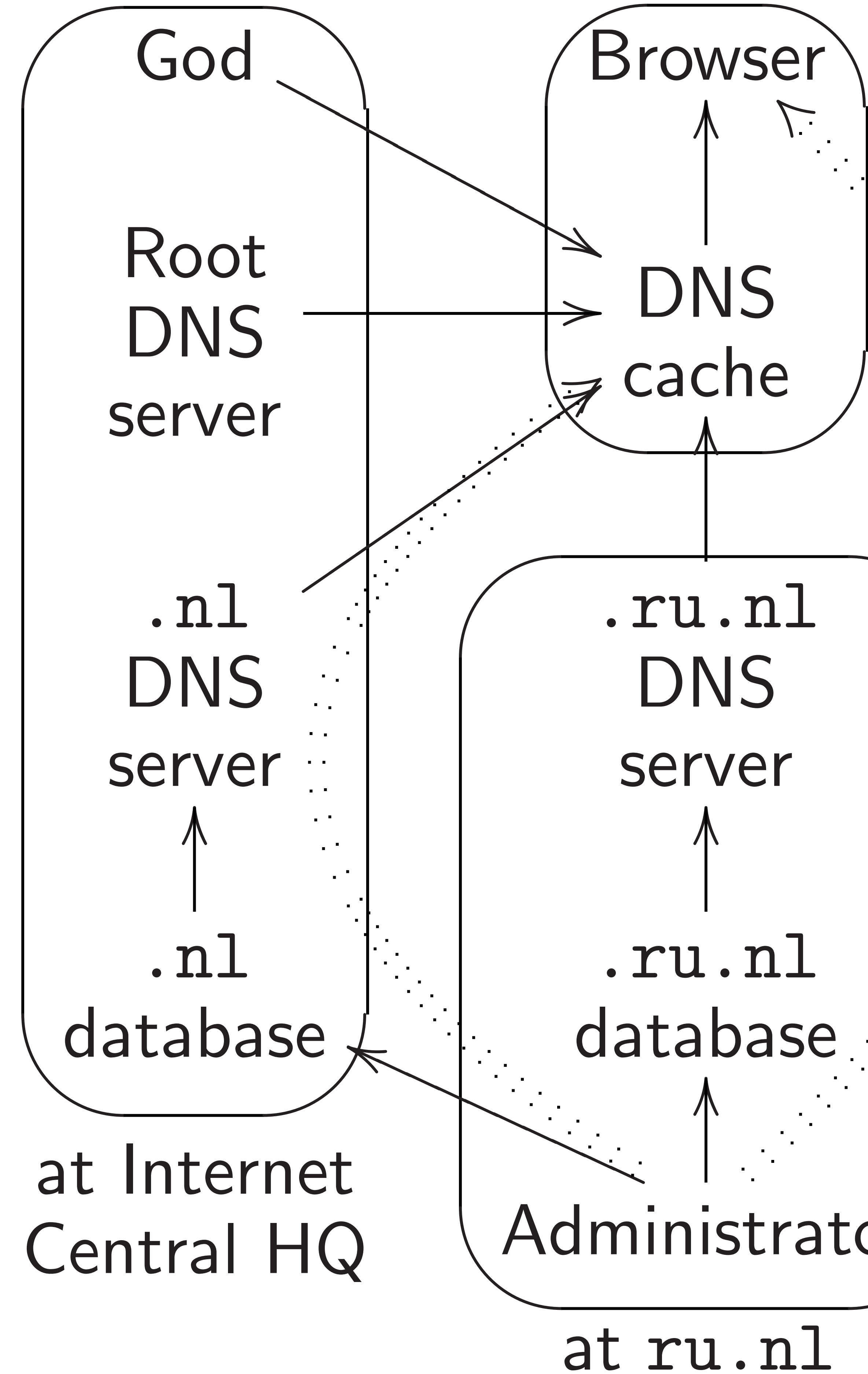

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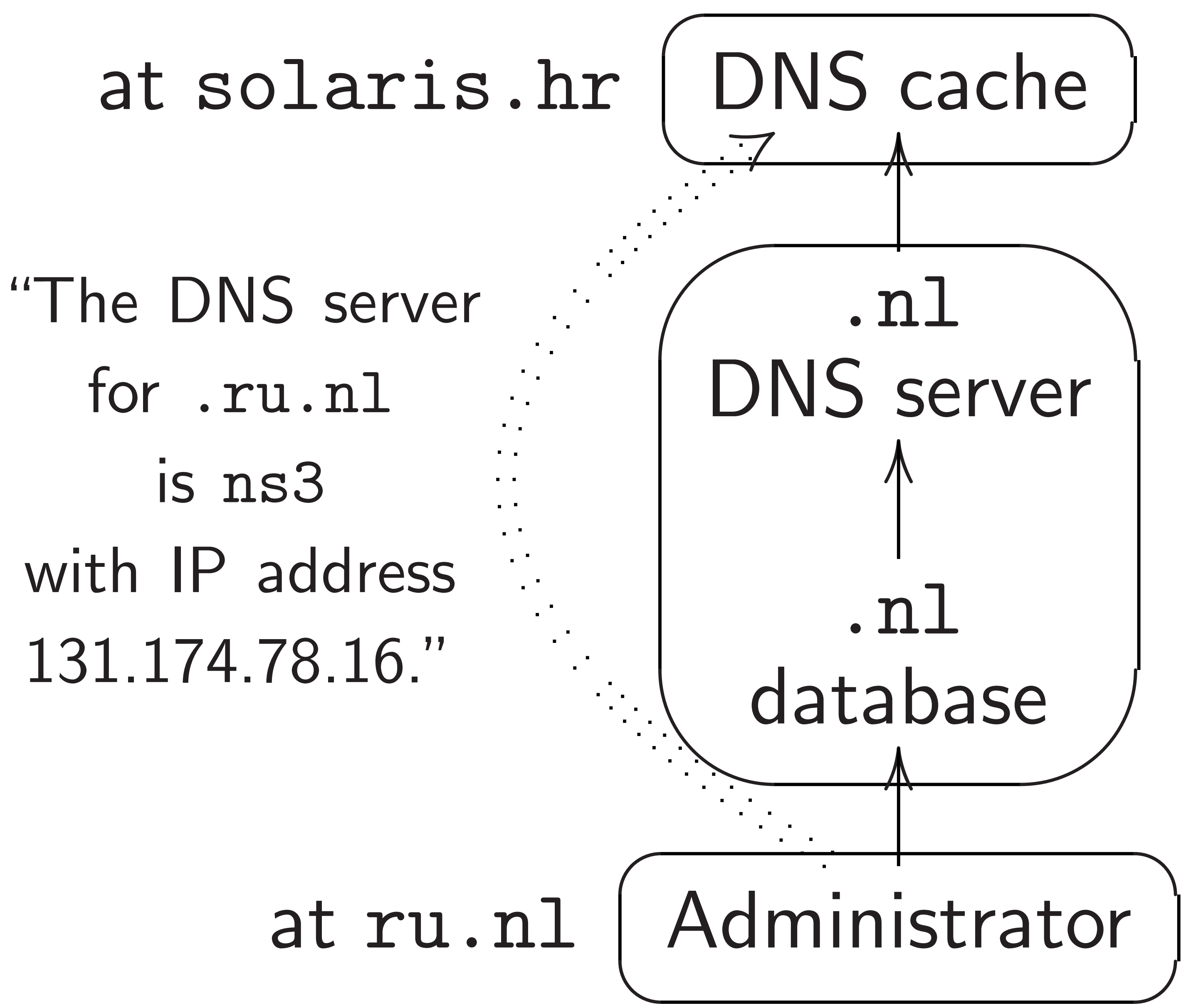

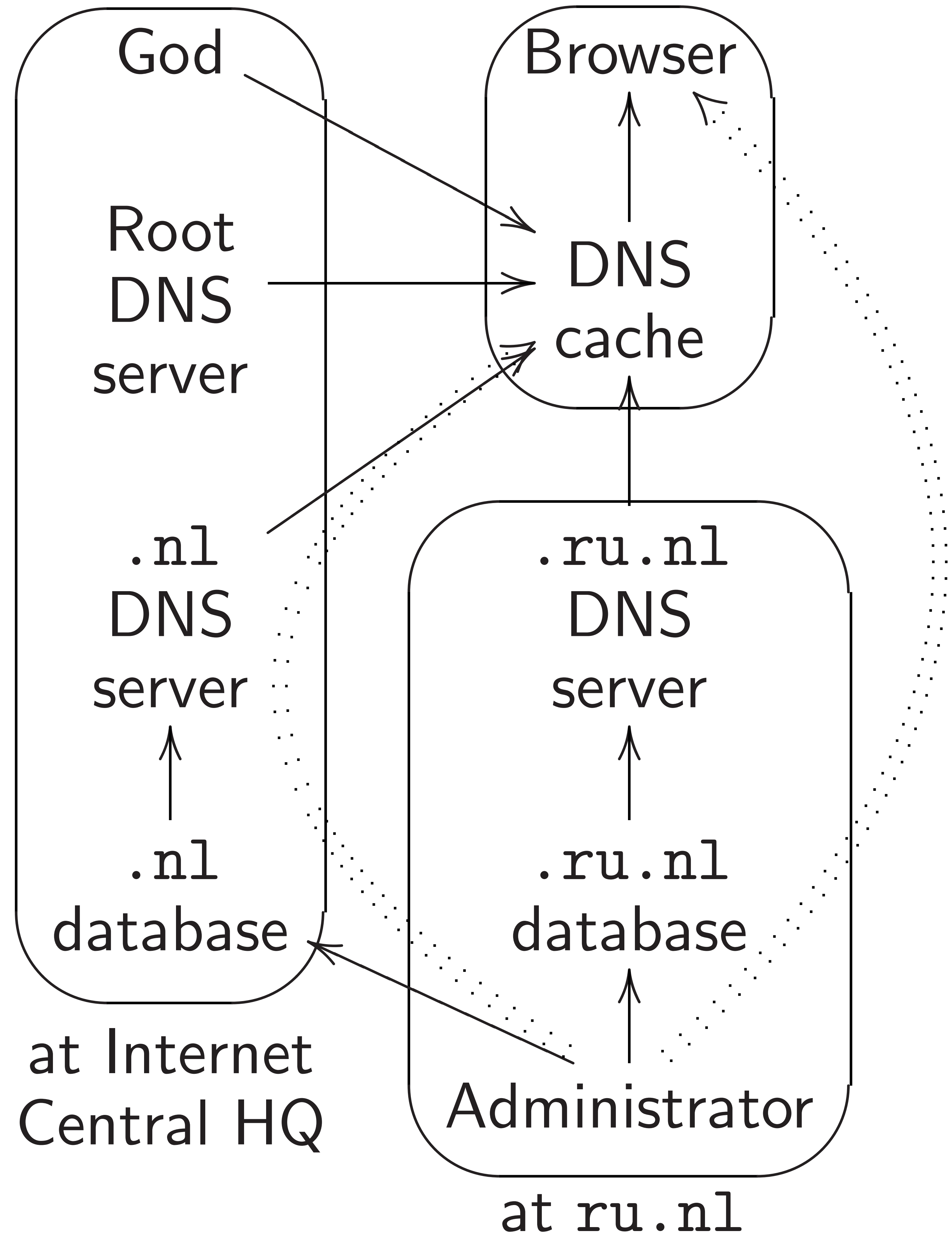

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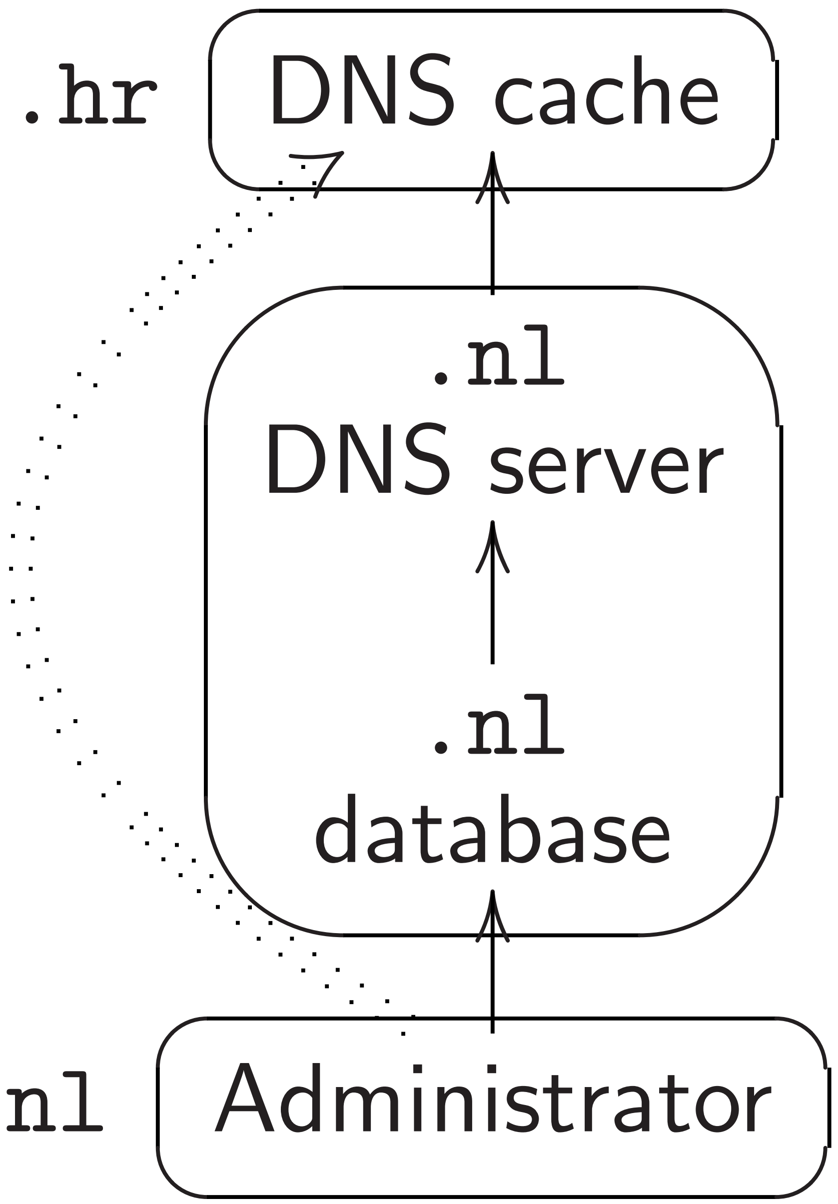

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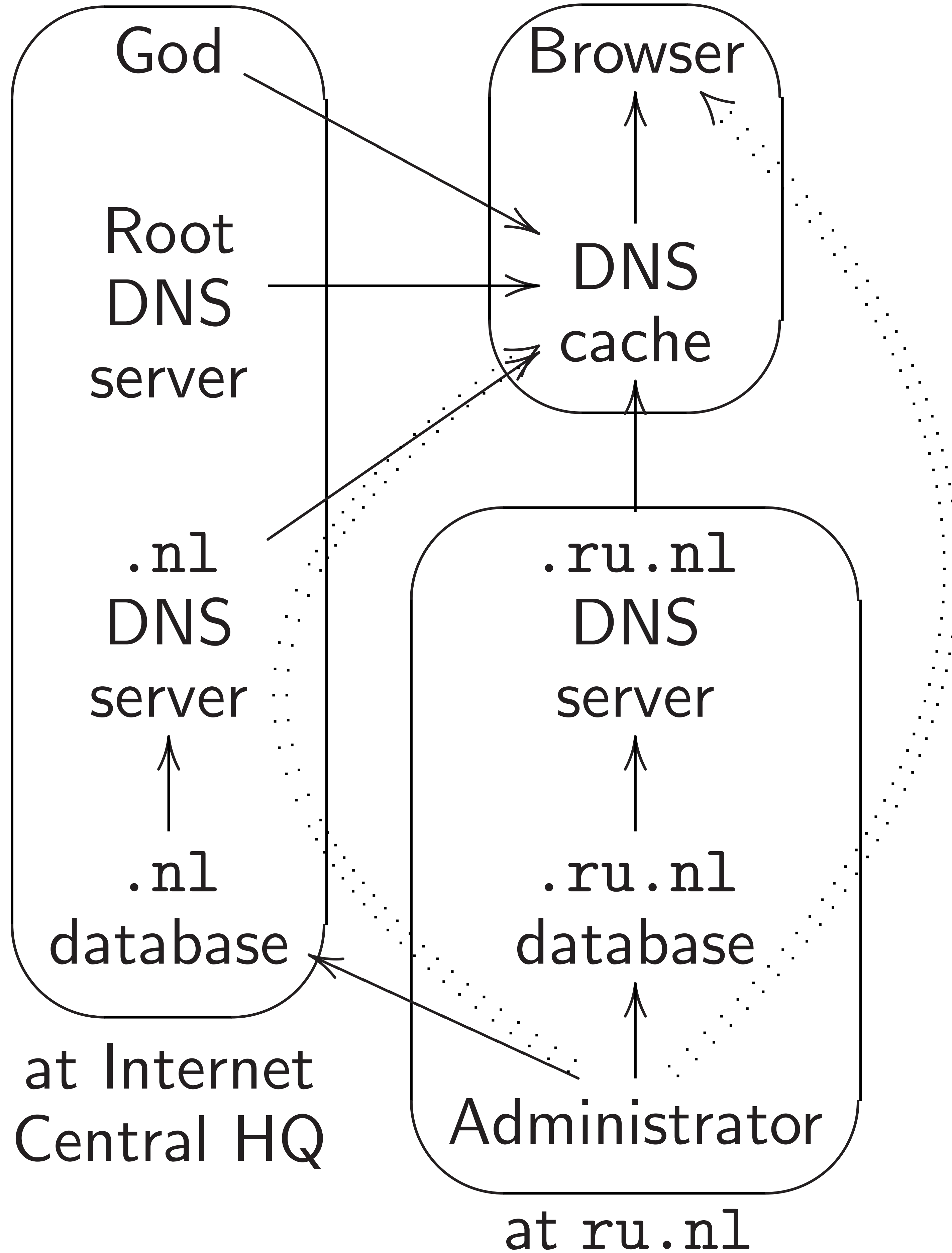

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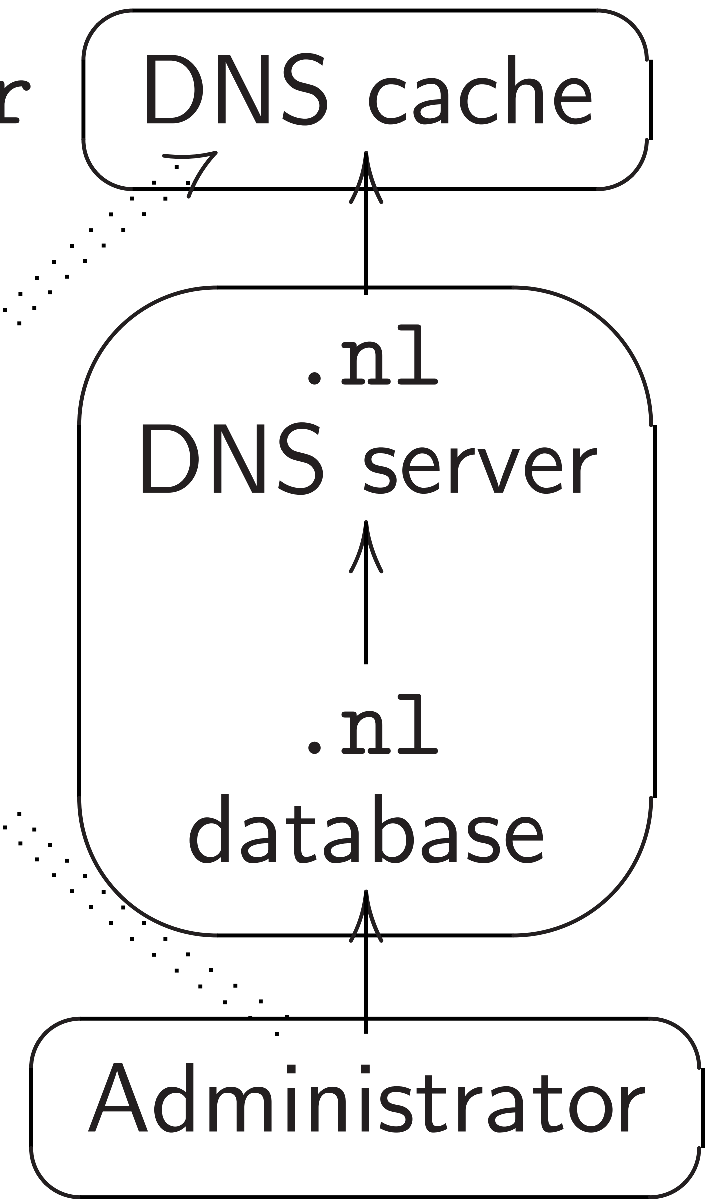

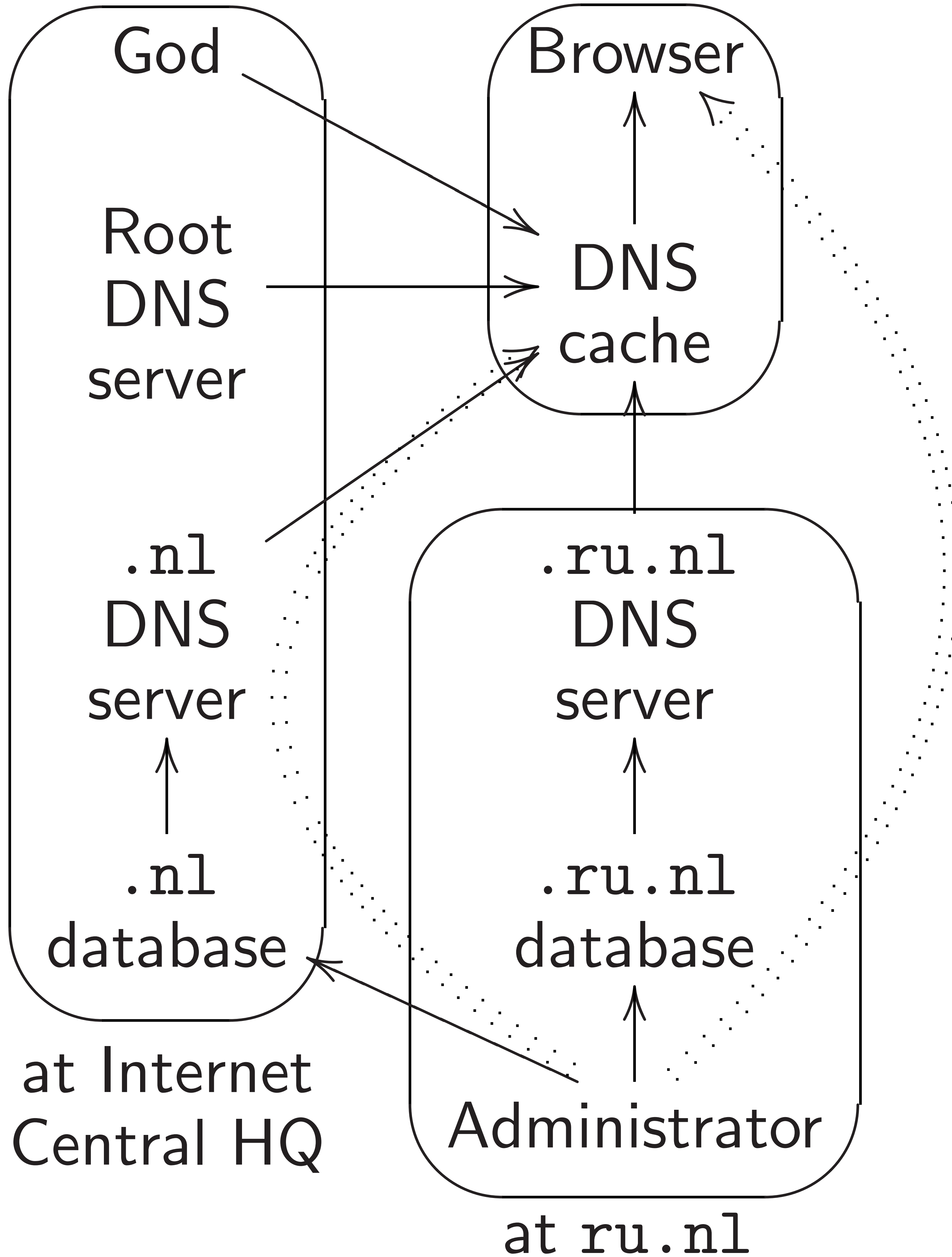

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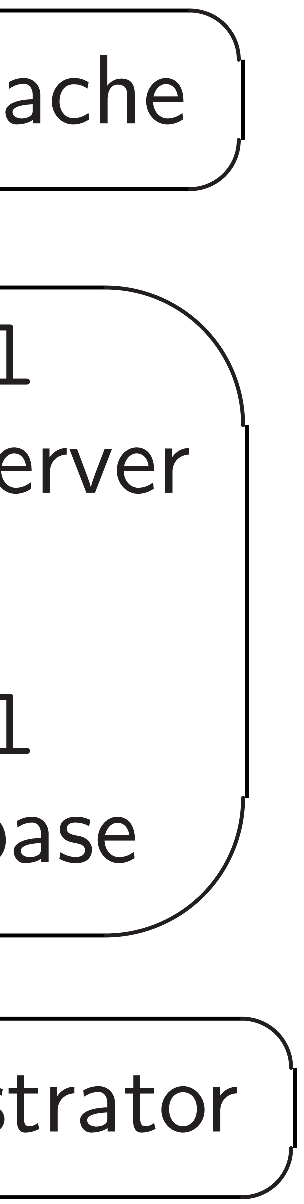

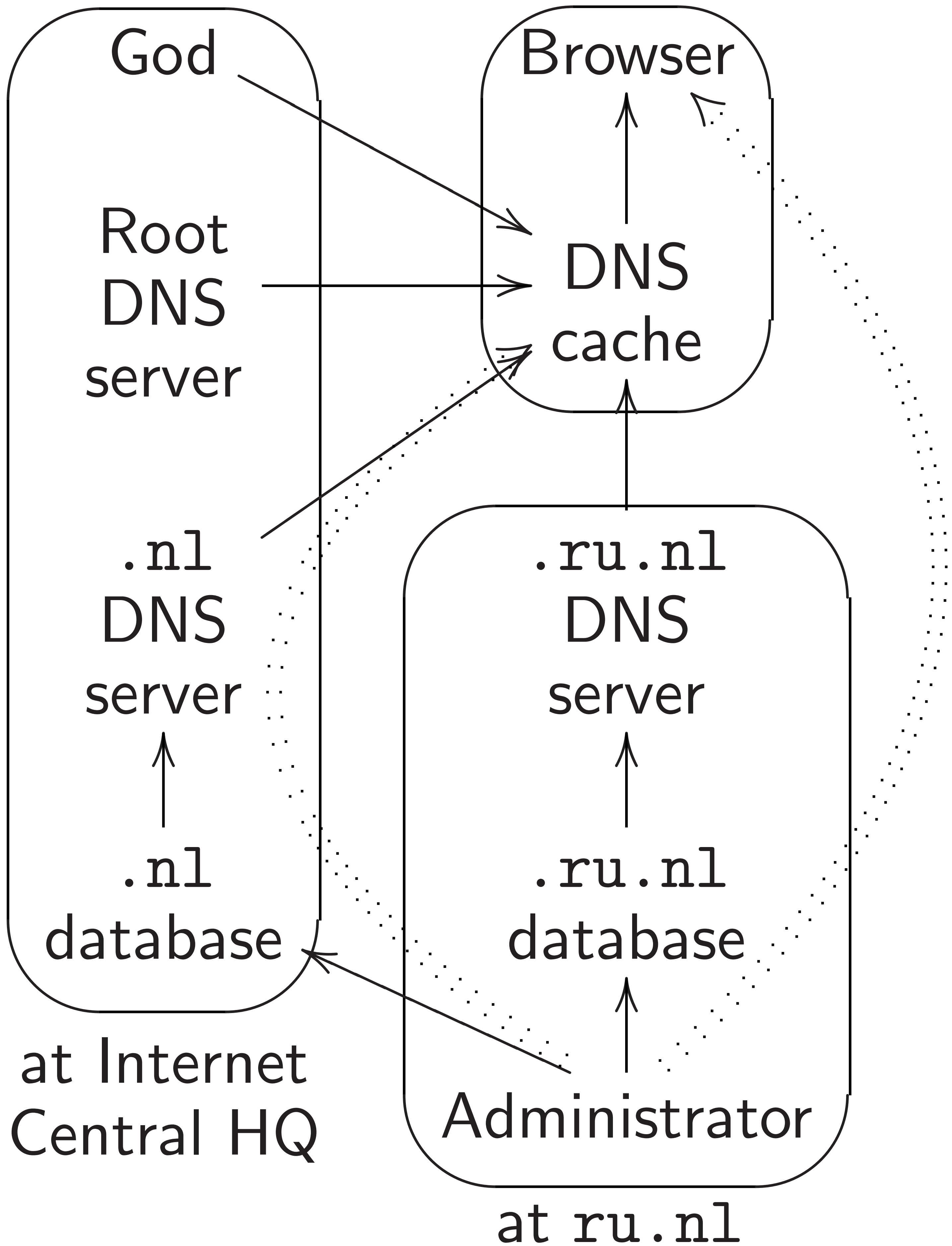

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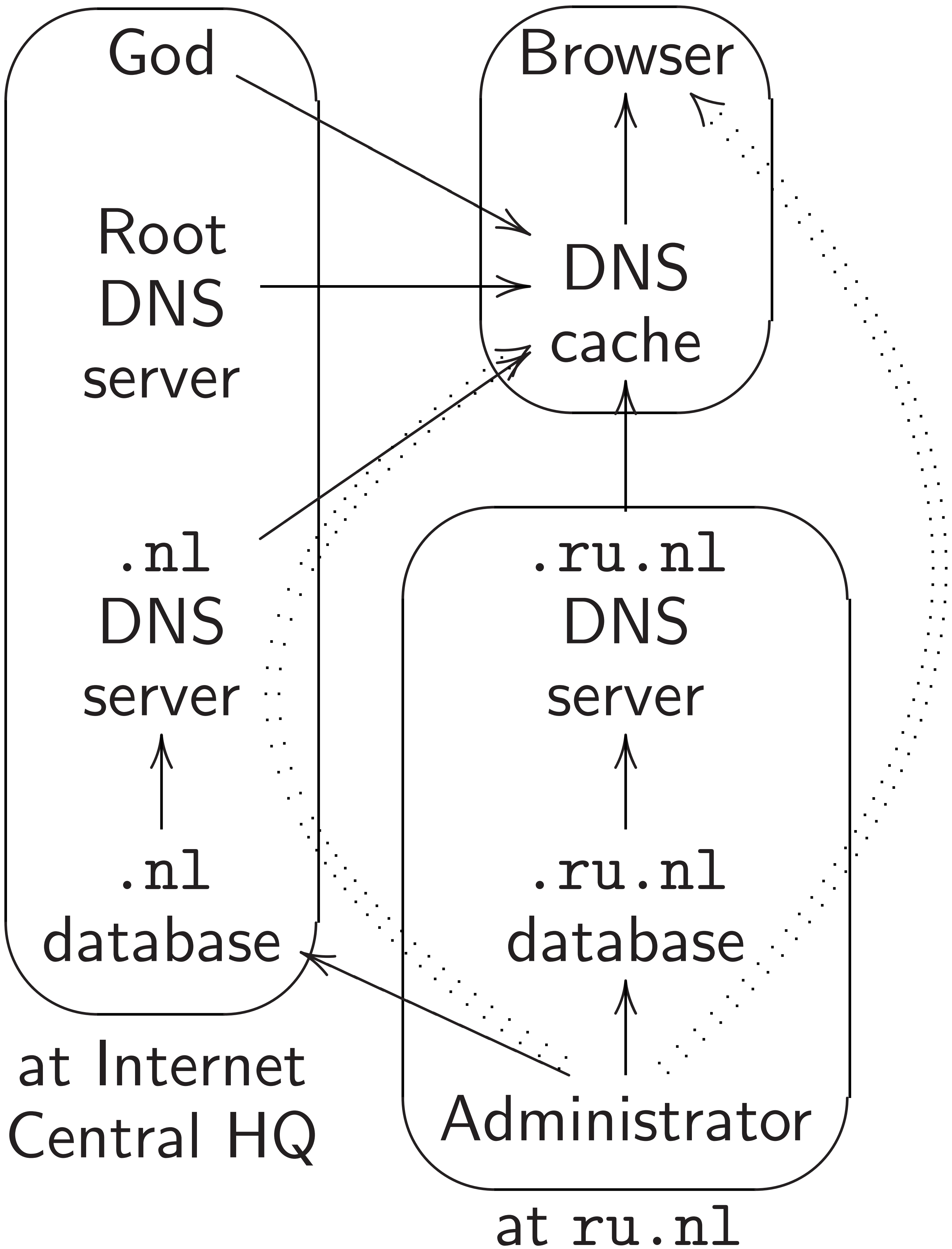

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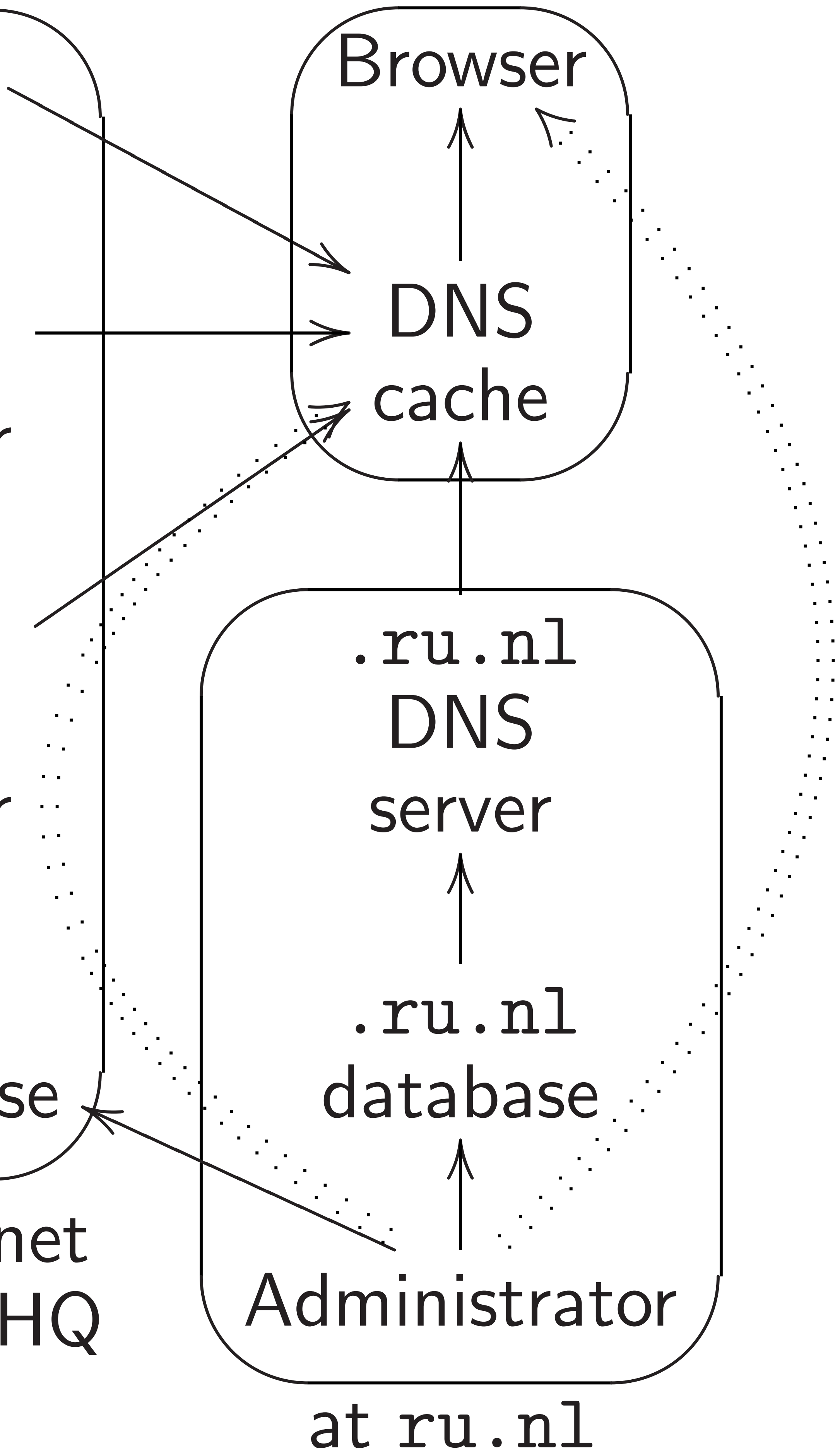

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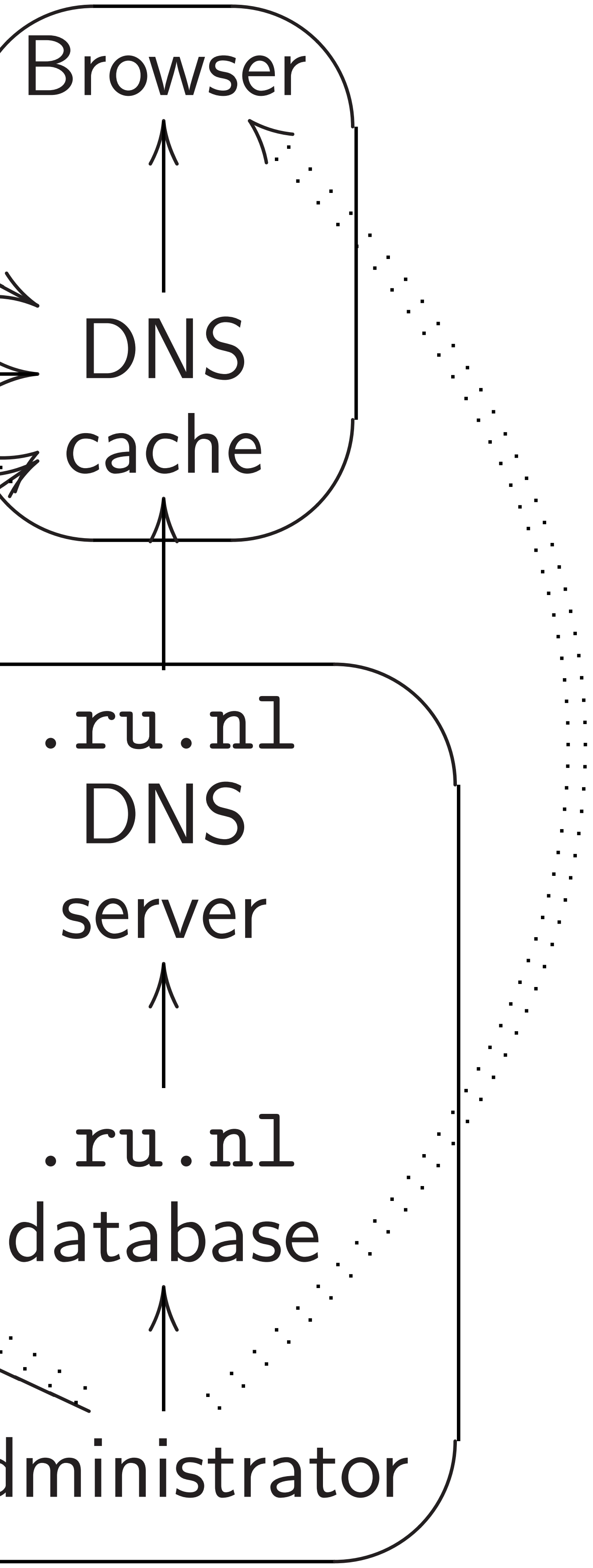

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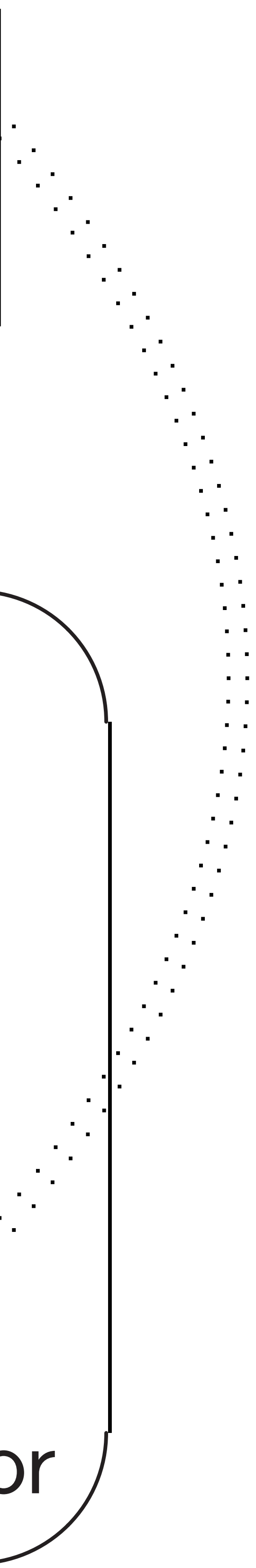

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DNSSEC purists say "Answers should always be static".

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DNSSEC purists disagree:
"It is part of the design philosophy of the DNS that the data in it is public."
But this notion is so extreme that it became a public-relations problem.

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Crypto is at edge of network, handled by simple proxy.

Administrator puts public key into name of server.

Need new DNS cache software but no need to change server software, database-management software, web interfaces, etc.

Easy to implement, easy to deploy.

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ver→cache.

ypt protects
he→client.

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DNSCurve and DNSCrypt and HTTPCurve and SMTP add real security even to PGP-signed web pages, ema

Improved confidentiality: e.g., is the user accessing `firstaid.webmd.com` or `diabetes.webmd.com`?

Improved integrity: e.g., freshness.

Improved availability: attacker forging a packet doesn't break connections.

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