The Root of the Matter: A Discussion of DNS Security

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International Computer Science Institute

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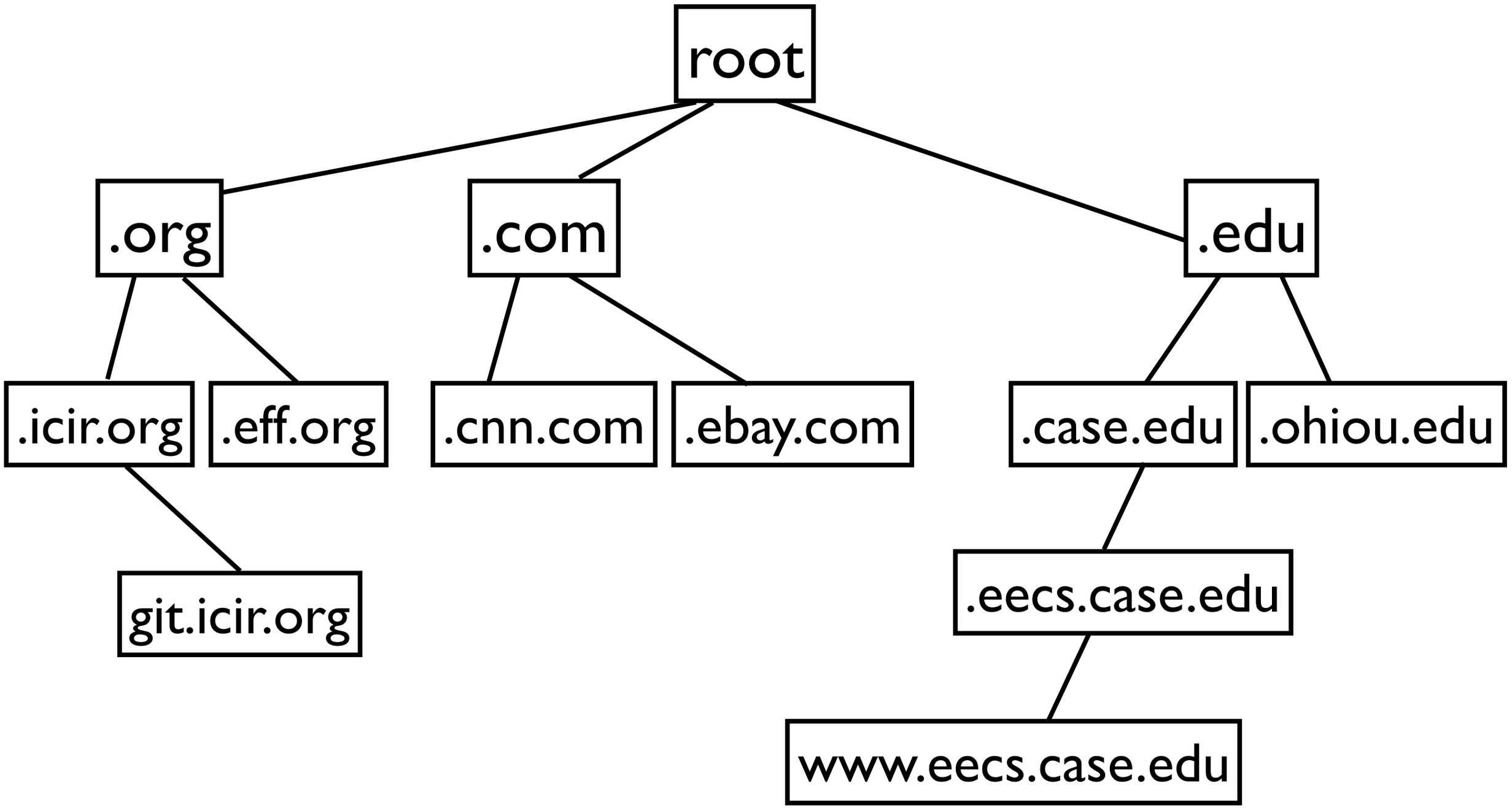
"Like a preacher stealin' hearts in a travelin' show …"

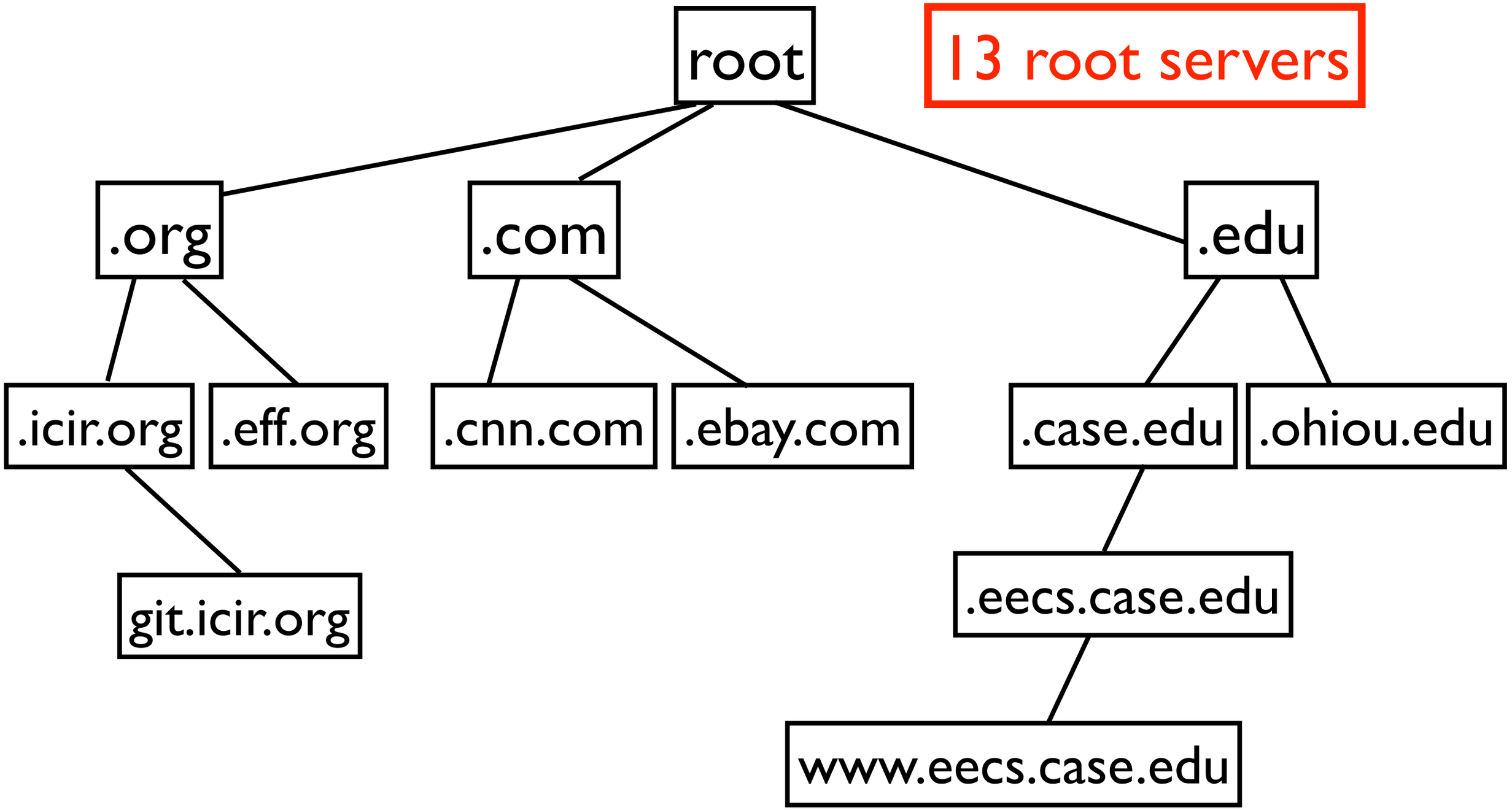
Collaborators

- Michael Bailey, Illinois/UMich
- Owen Bell, Case
- Tom Callahan, Case
- Jake Czyz, UMich
- Nick Feamster, Princeton
- Scott Iekel-Johnson, Arbor
- Ben Jones, Princeton
- Andrew Kalafut, Grand Valley
- Eric Osterweil, Verisign
- Vern Paxson, ICSI & UCB
- Michael Rabinovich, Case
- Kyle Schomp, Case
- Craig Shue, WPI
- Nicholas Weaver, ICSI
- Jing Zhang, UMich

DNS Hierarchy



DNS Hierarchy



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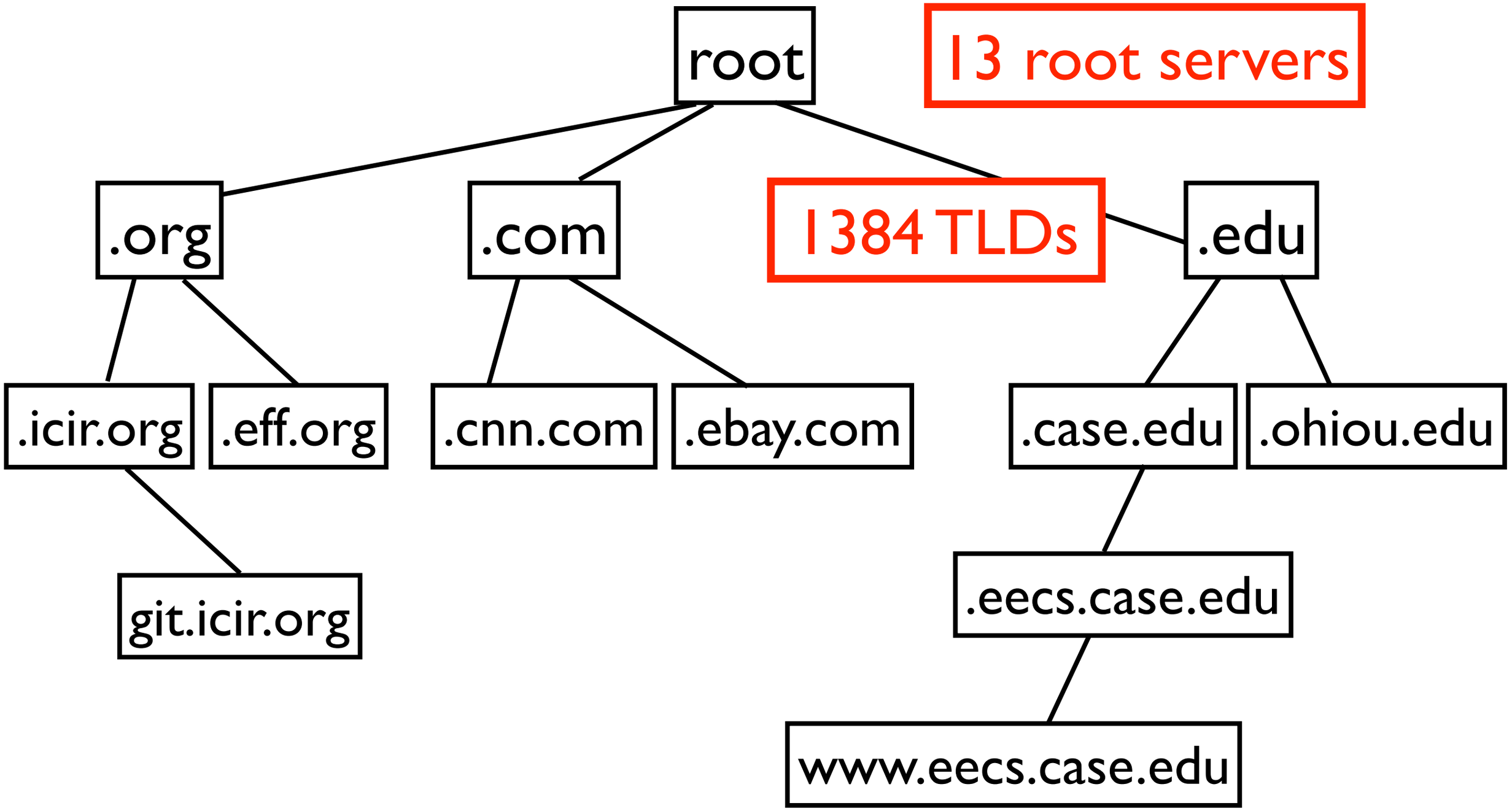
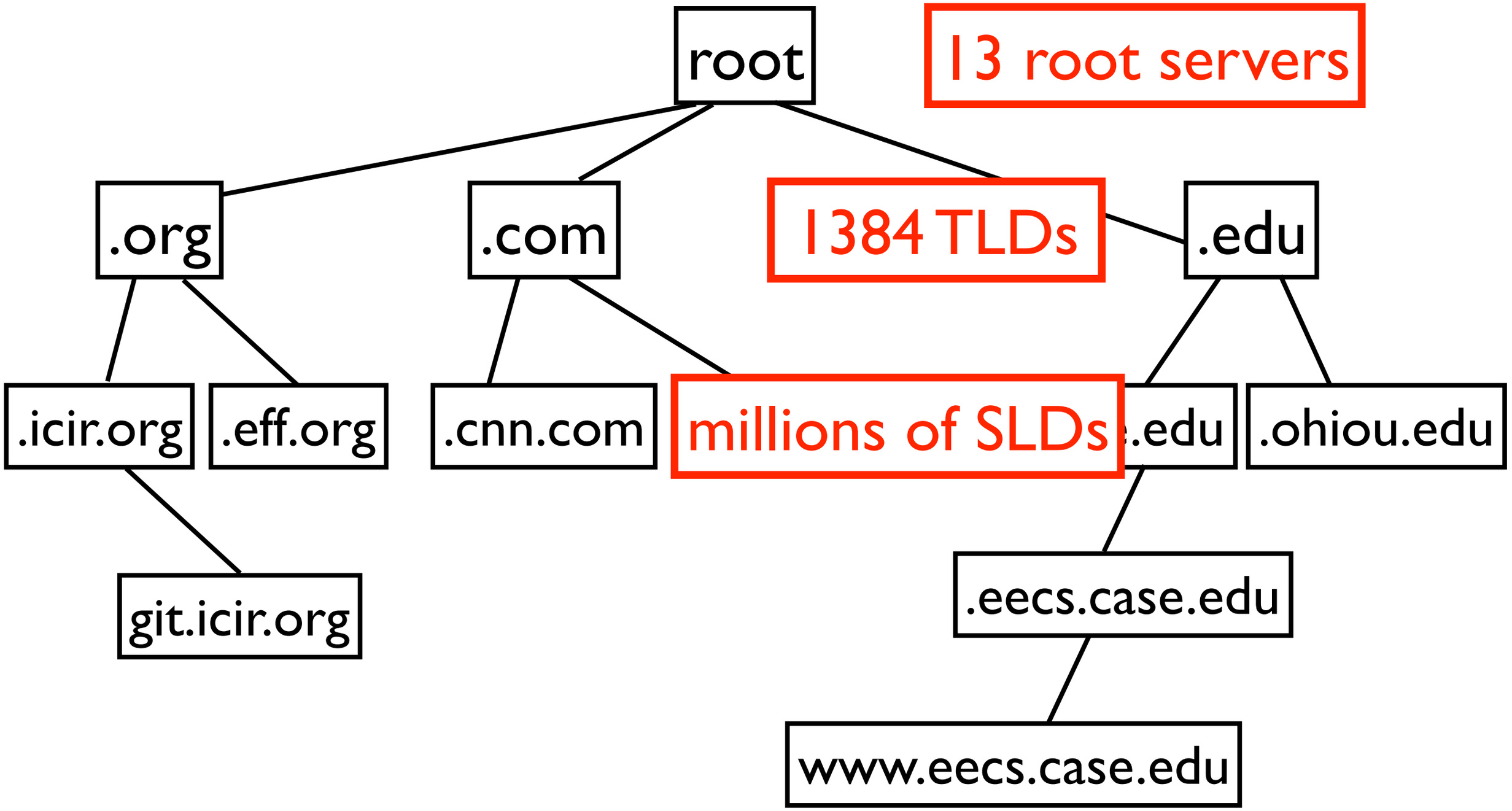


DNS Hierarchy



DNS Protocol

DNS Protocol

- DNS, as we use it:
  - connectionless UDP transport
  - single packet request
  - single packet response

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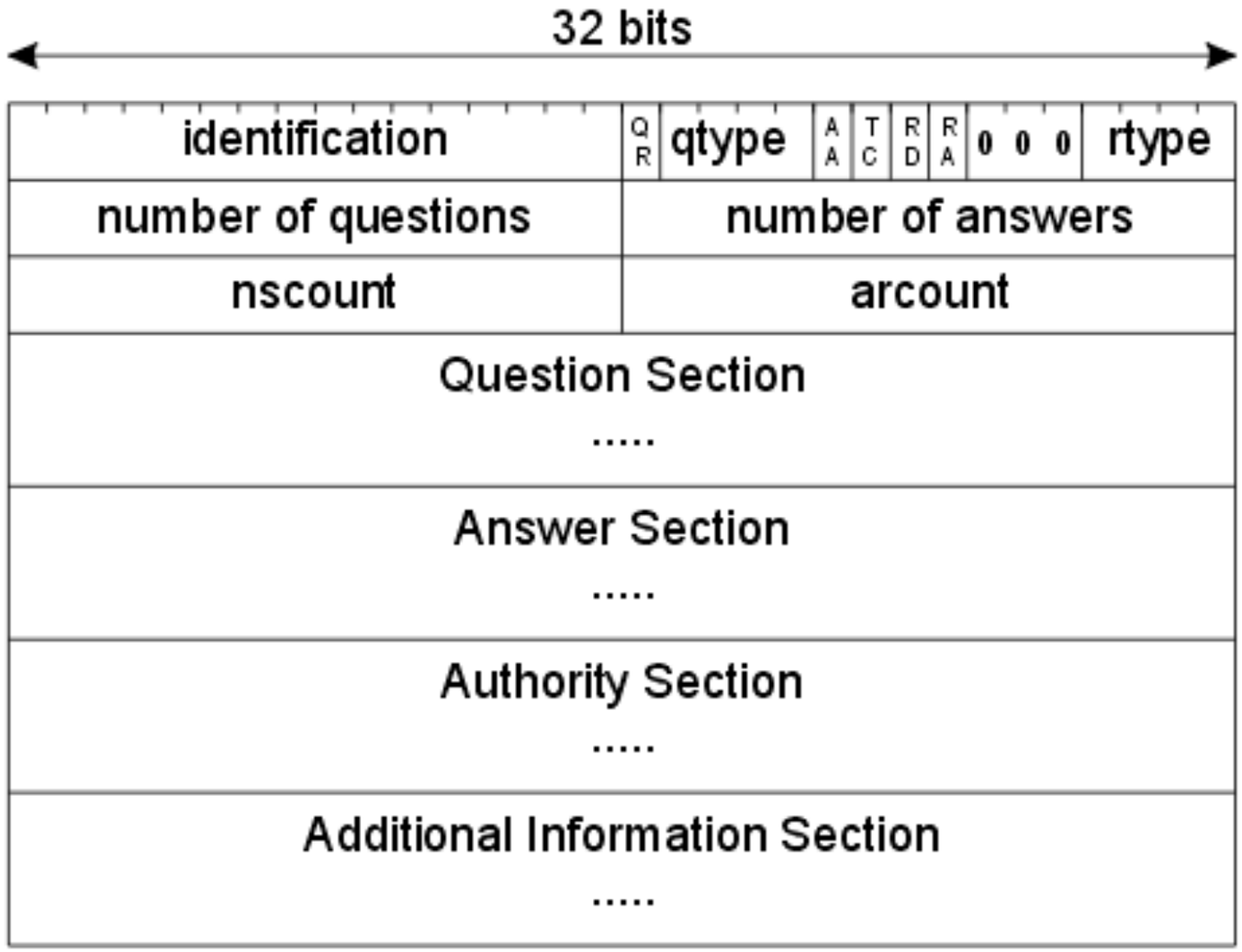
- However, name resolution is structurally *complex and mysterious* with many hidden components

DNS Protocol

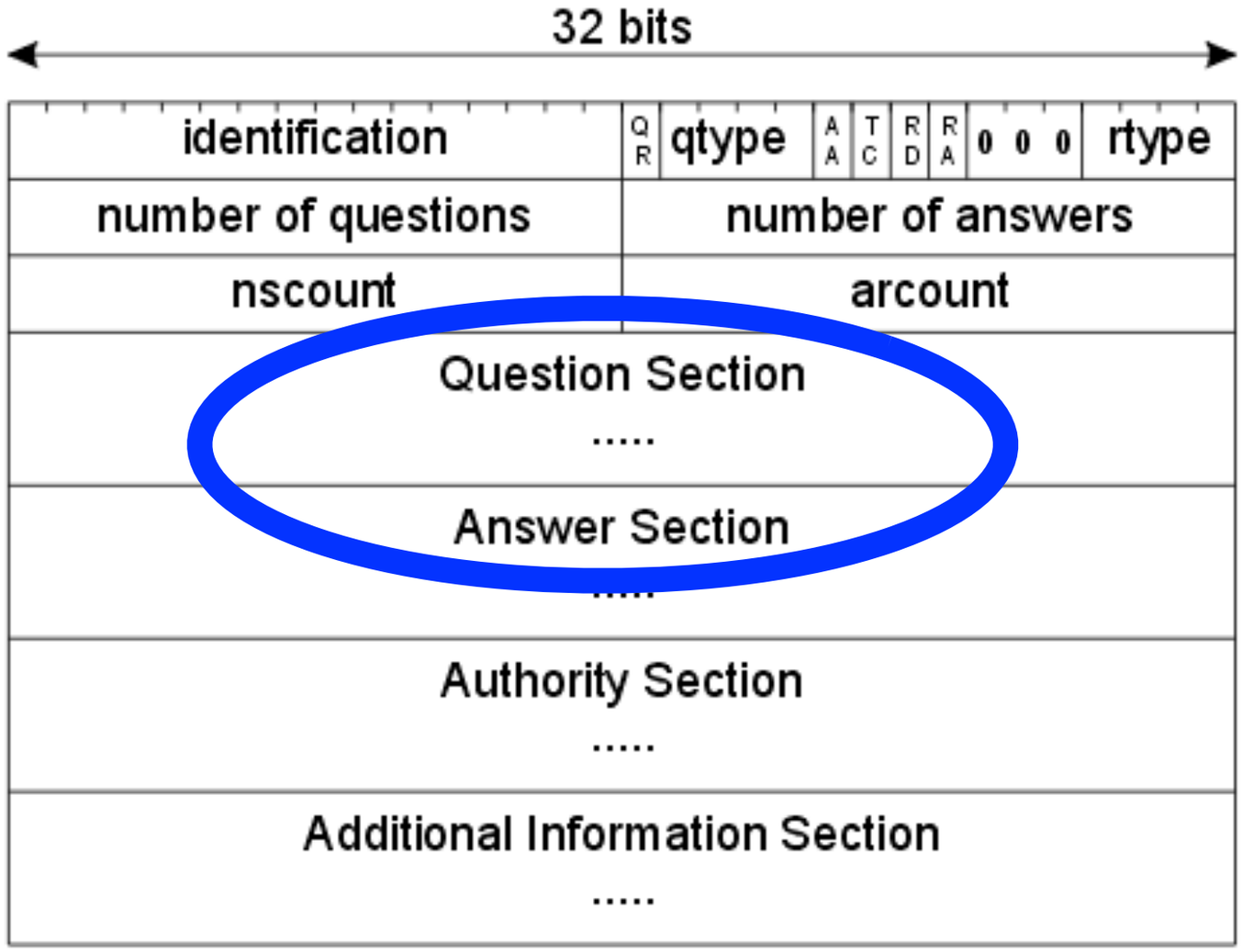
DNS Protocol

DNS server message format

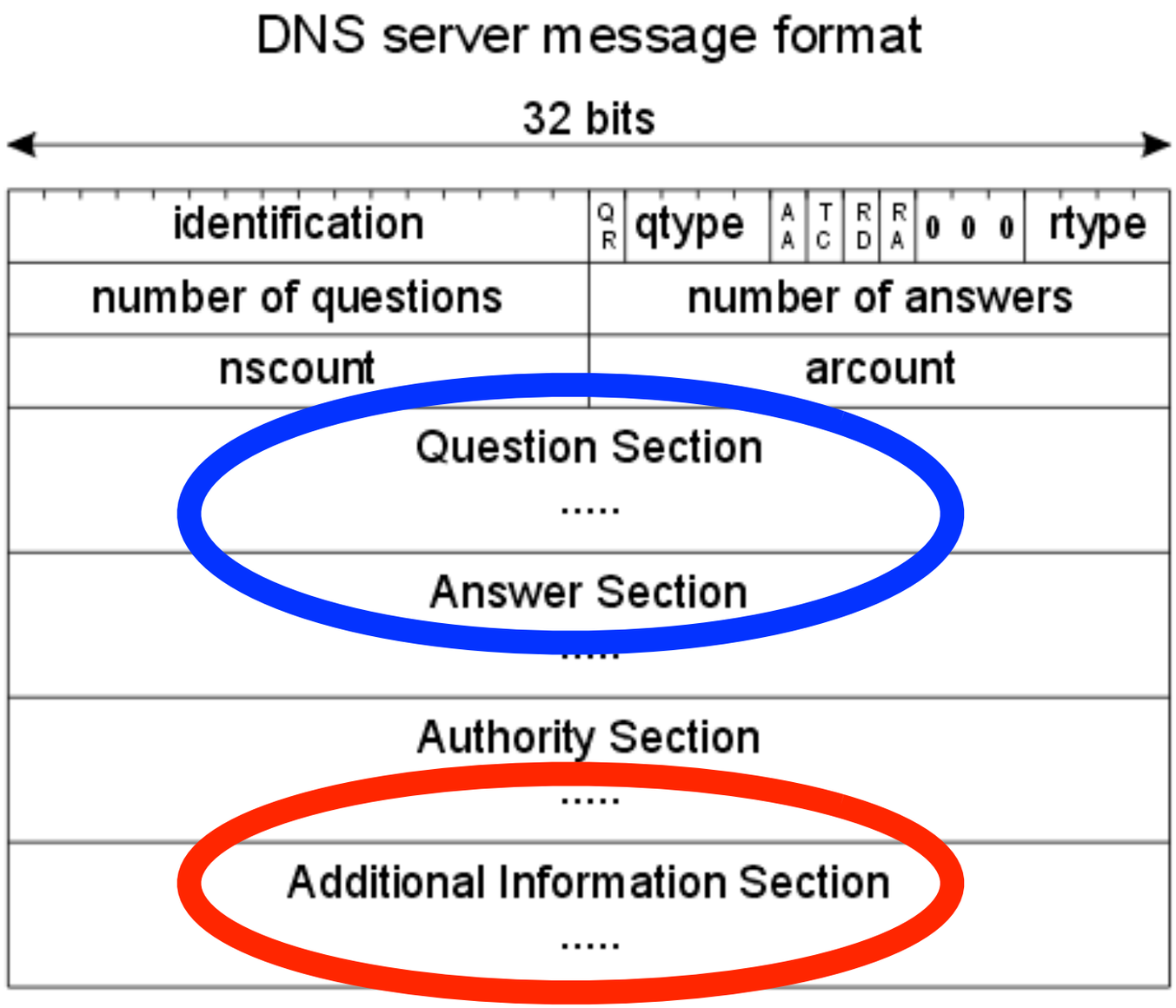


DNS Protocol

DNS server message format



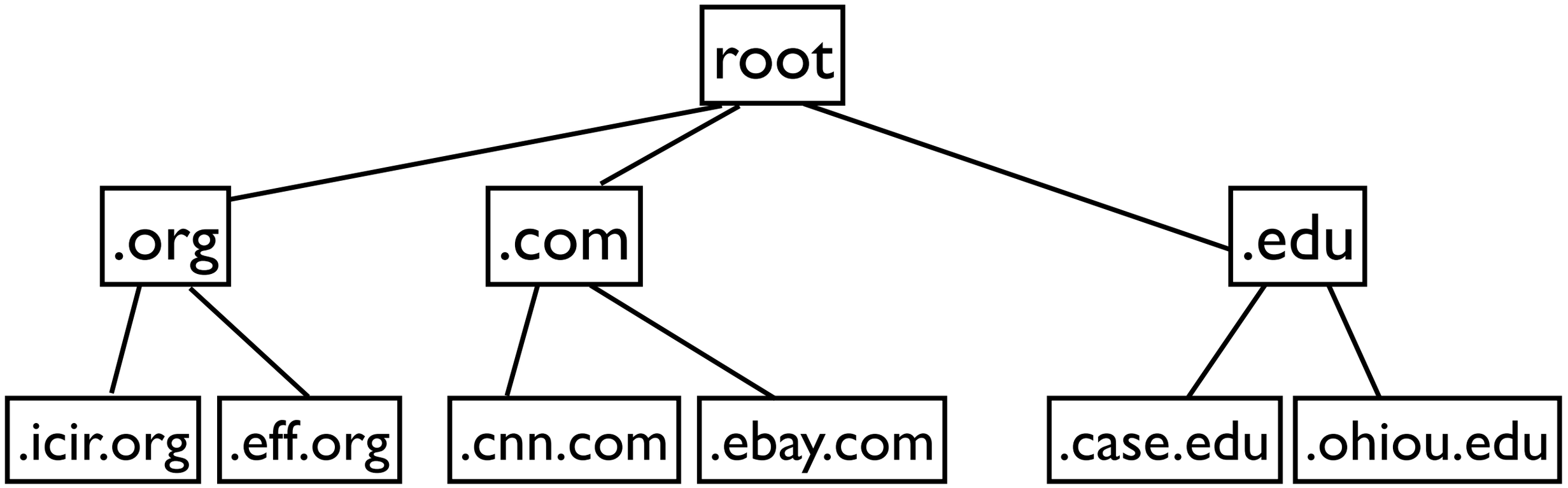
DNS Protocol



DNS Refresher

Goal:

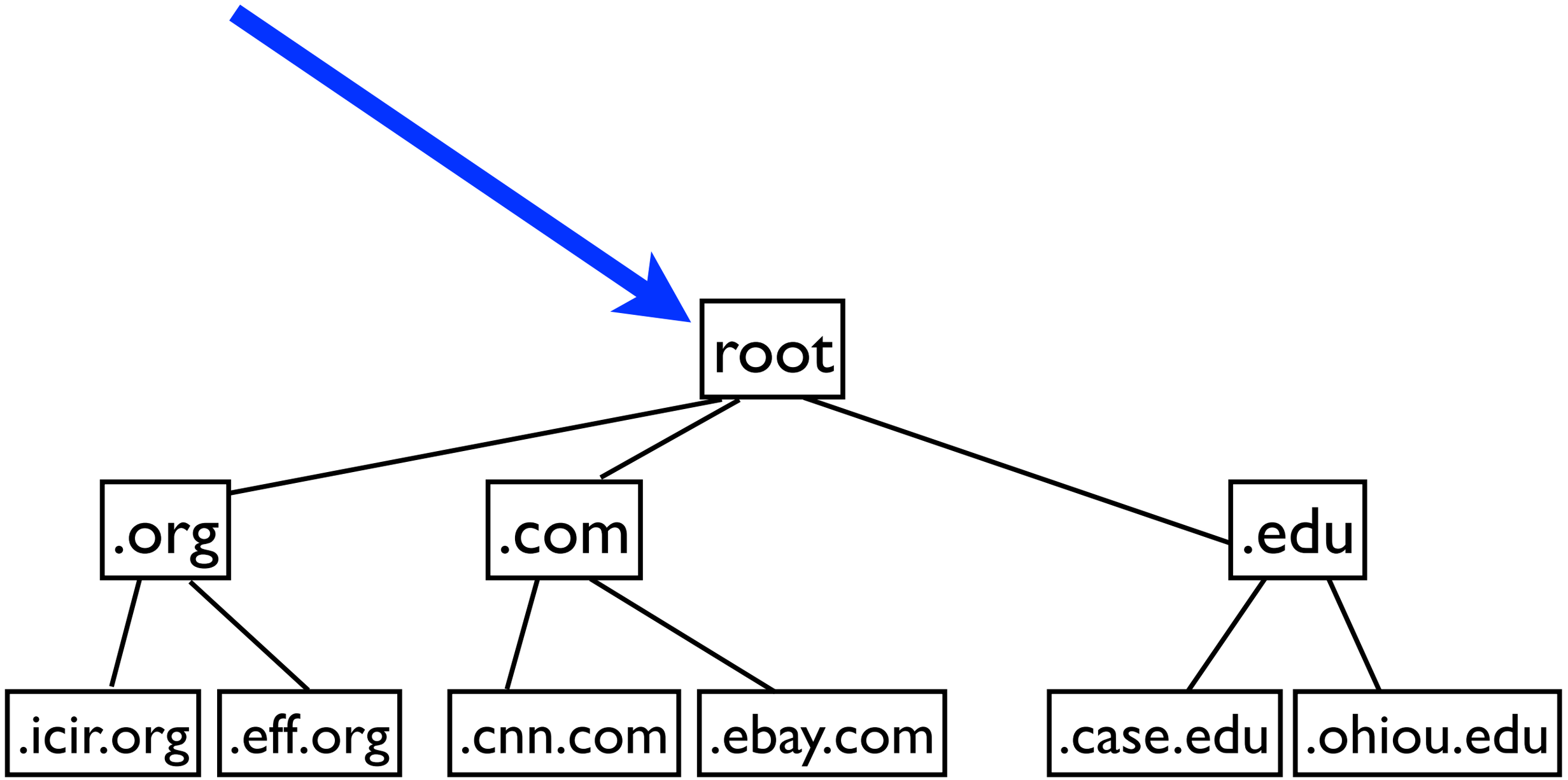
`www.icir.org`



DNS Refresher

Goal:
`www.icir.org`

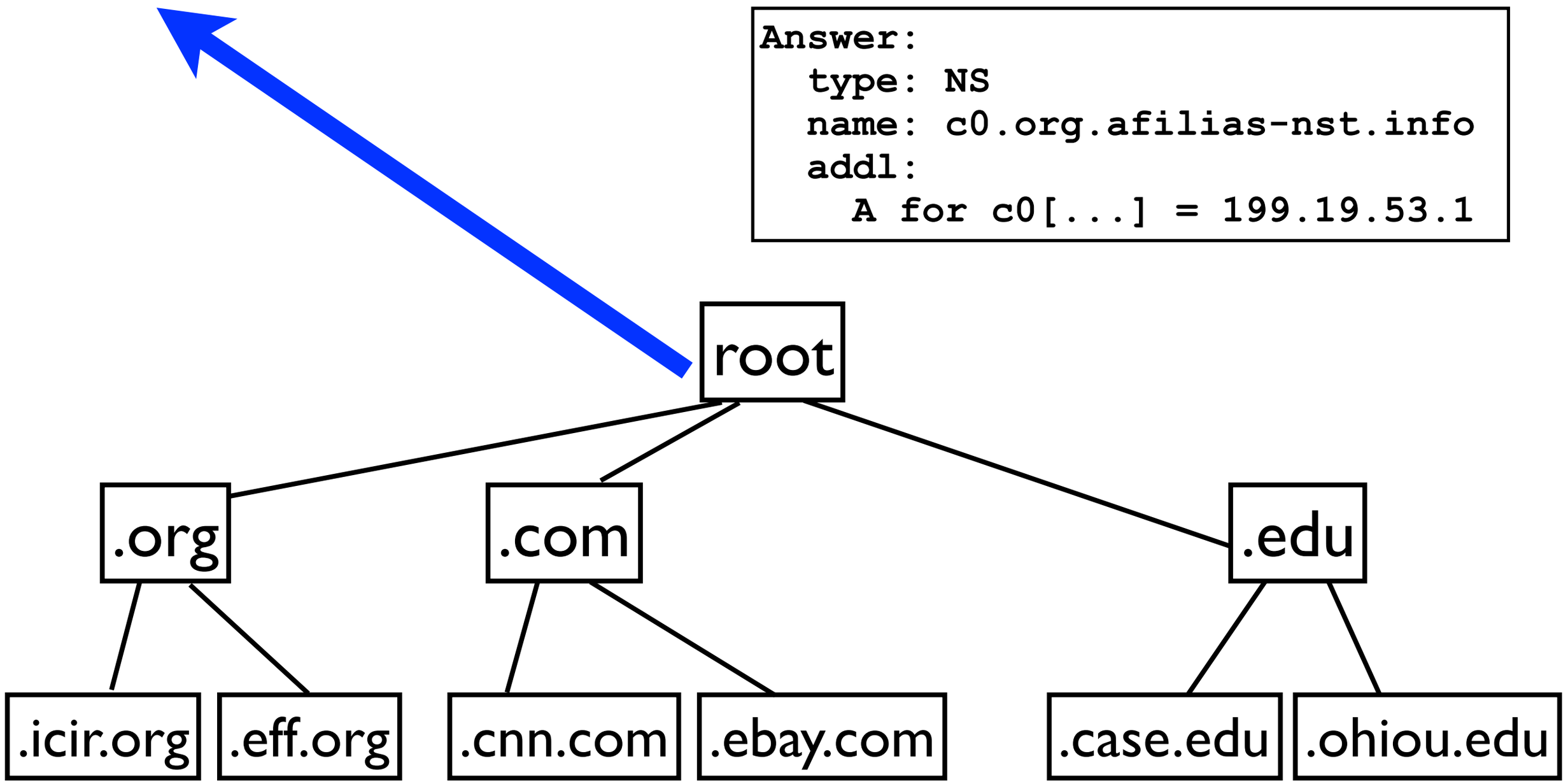
```
Question:
  type: A
  name: www.icir.org
```



DNS Refresher

Goal:
`www.icir.org`

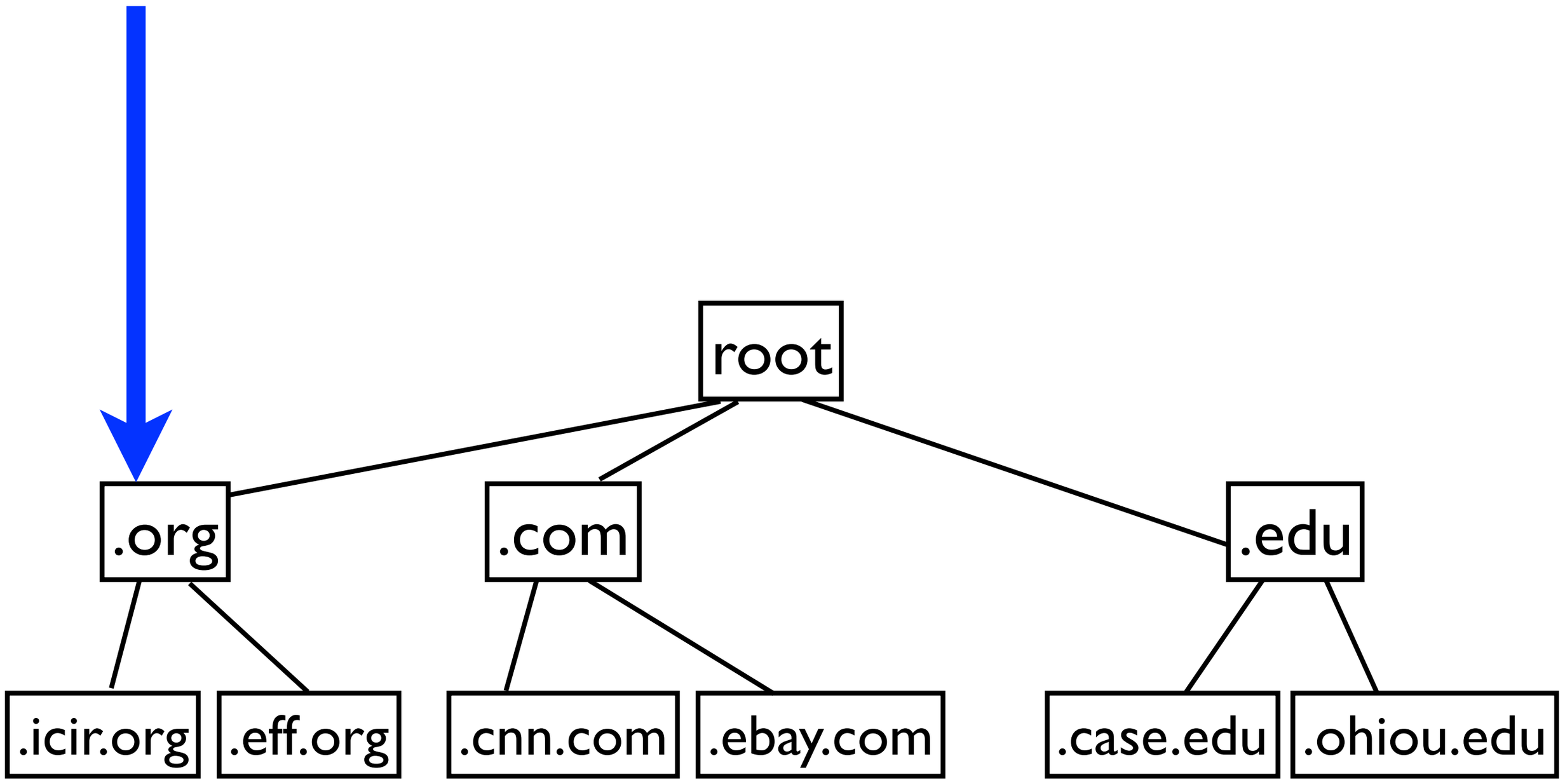
```
Answer:
  type: NS
  name: c0.org.afilias-nst.info
  addl:
    A for c0[...] = 199.19.53.1
```



DNS Refresher

Goal:
`www.icir.org`

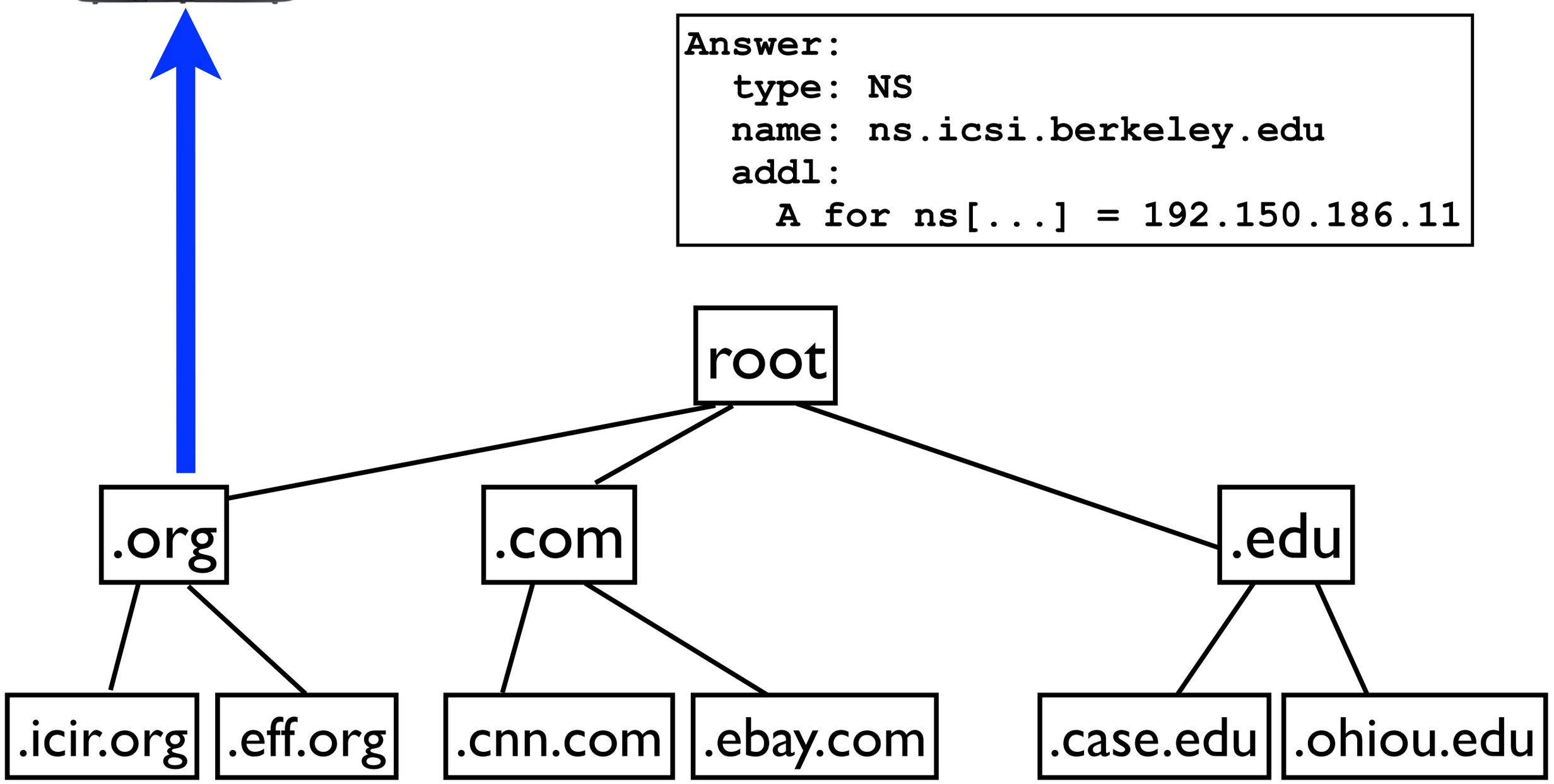
```
Question:
  type: A
  name: www.icir.org
```



DNS Refresher

Goal:
`www.icir.org`

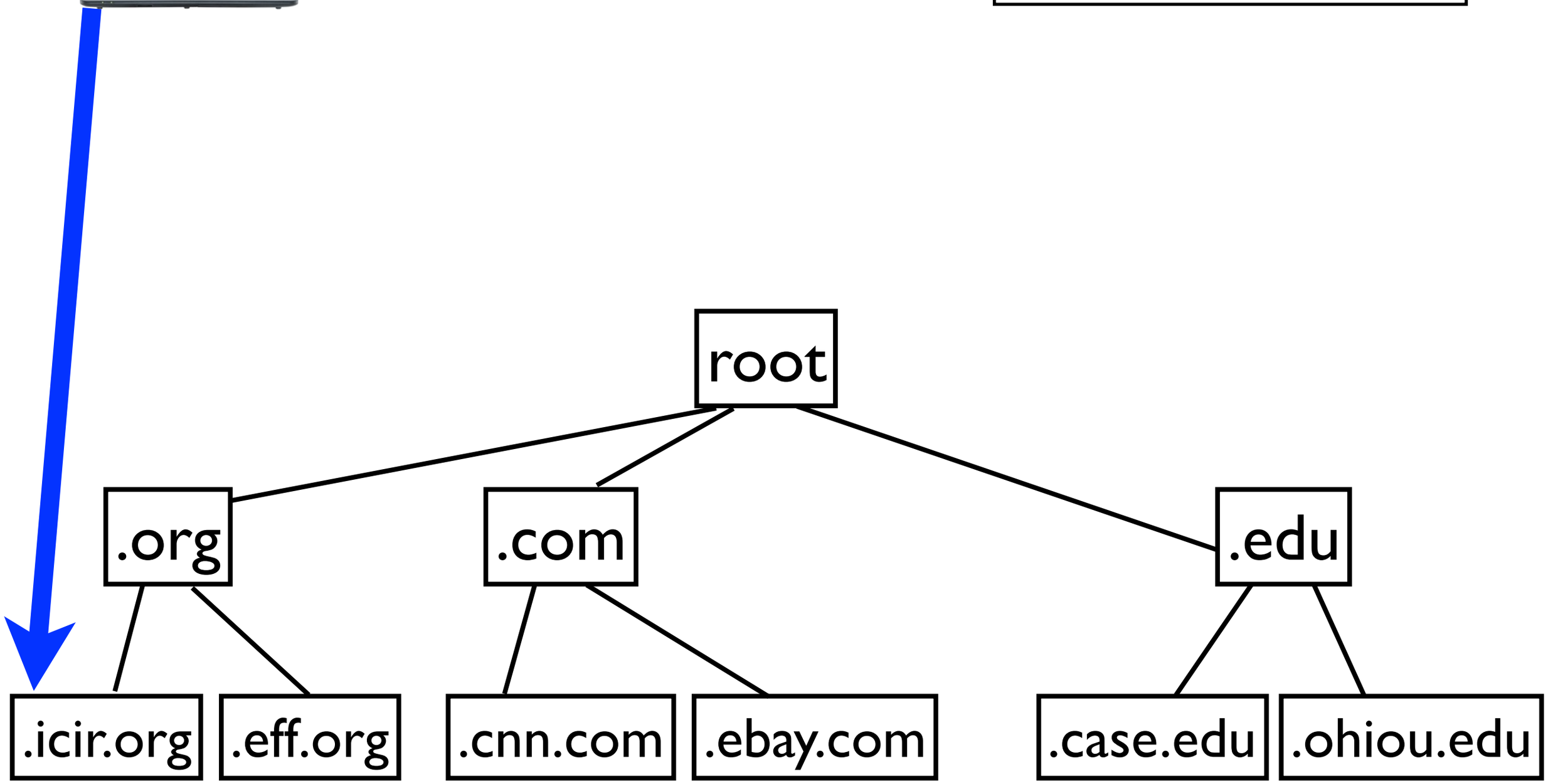
```
Answer:
  type: NS
  name: ns.icsi.berkeley.edu
  addl:
    A for ns[...] = 192.150.186.11
```



DNS Refresher

Goal:
`www.icir.org`

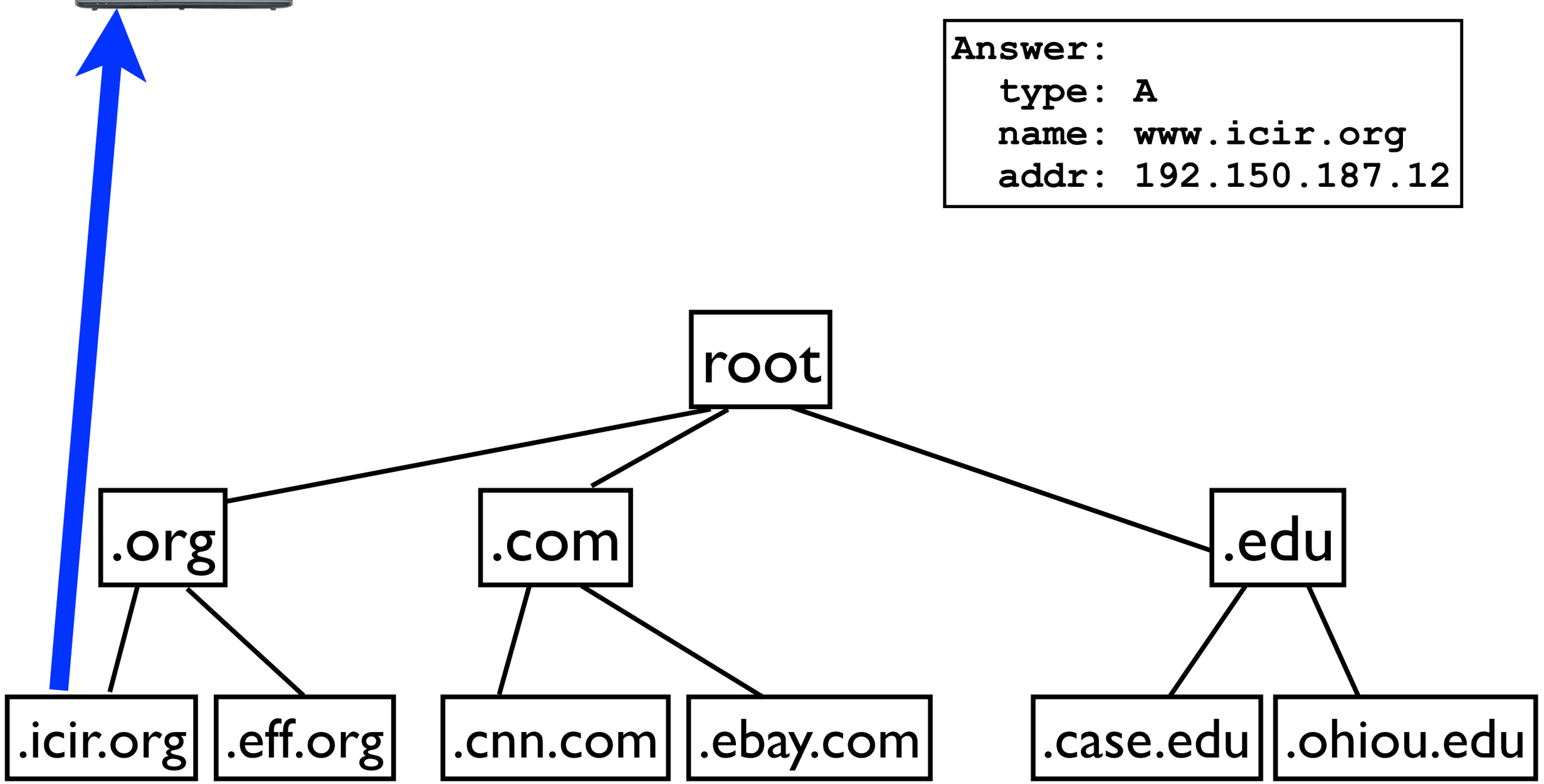
```
Question:
  type: A
  name: www.icir.org
```



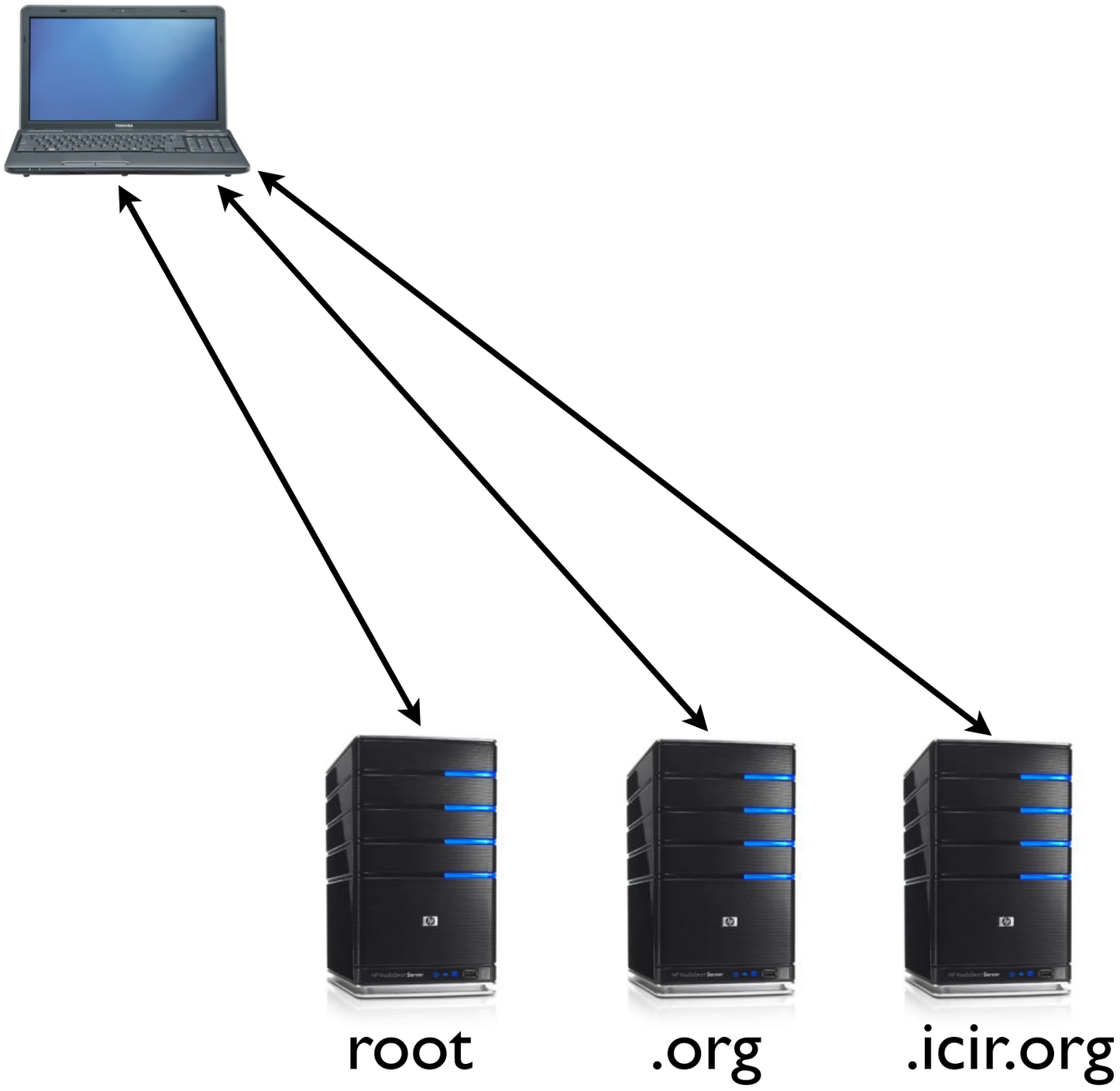
DNS Refresher

Goal:
`www.icir.org`

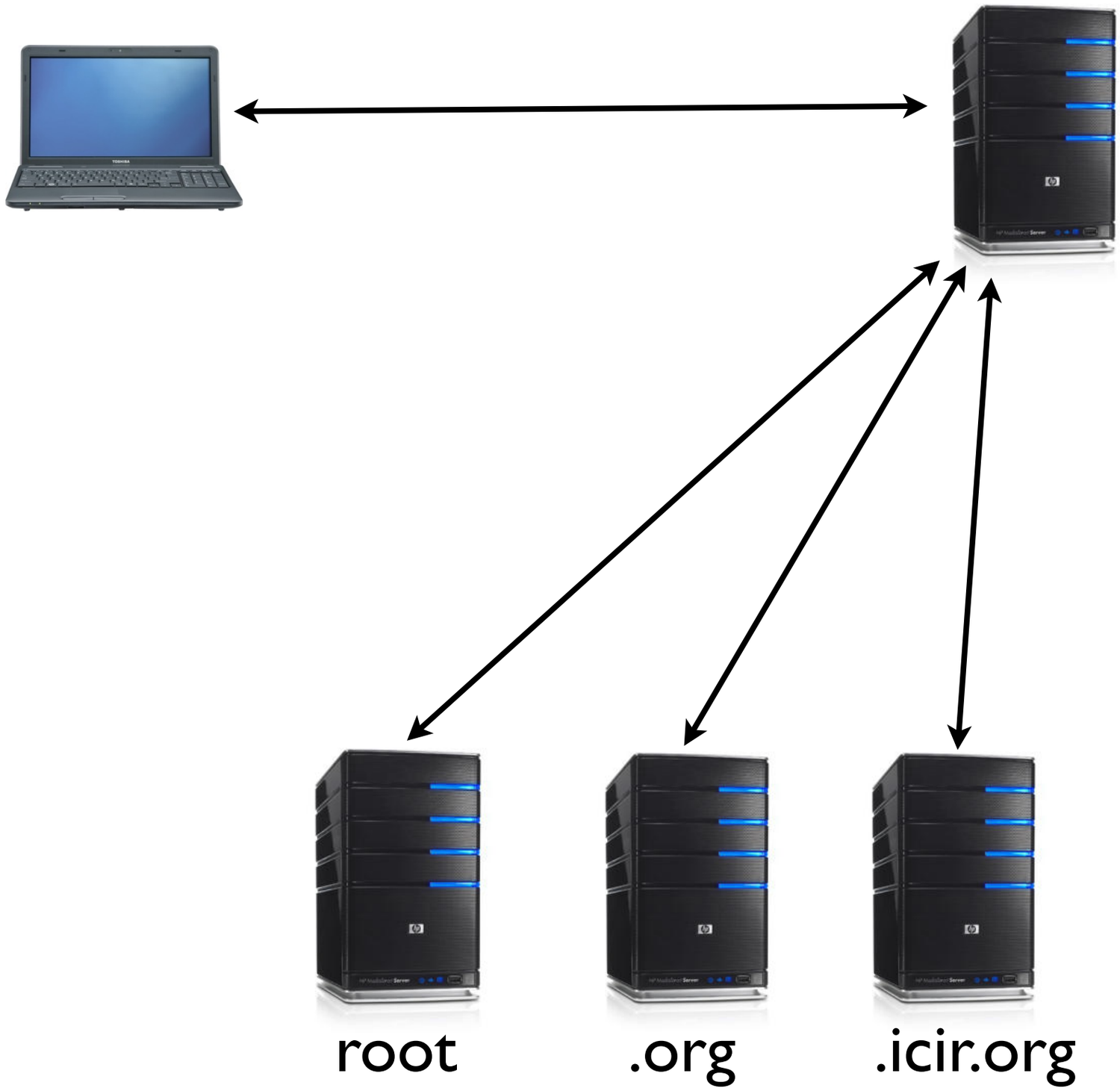
```
Answer:
   type: A
   name: www.icir.org
   addr: 192.150.187.12
```



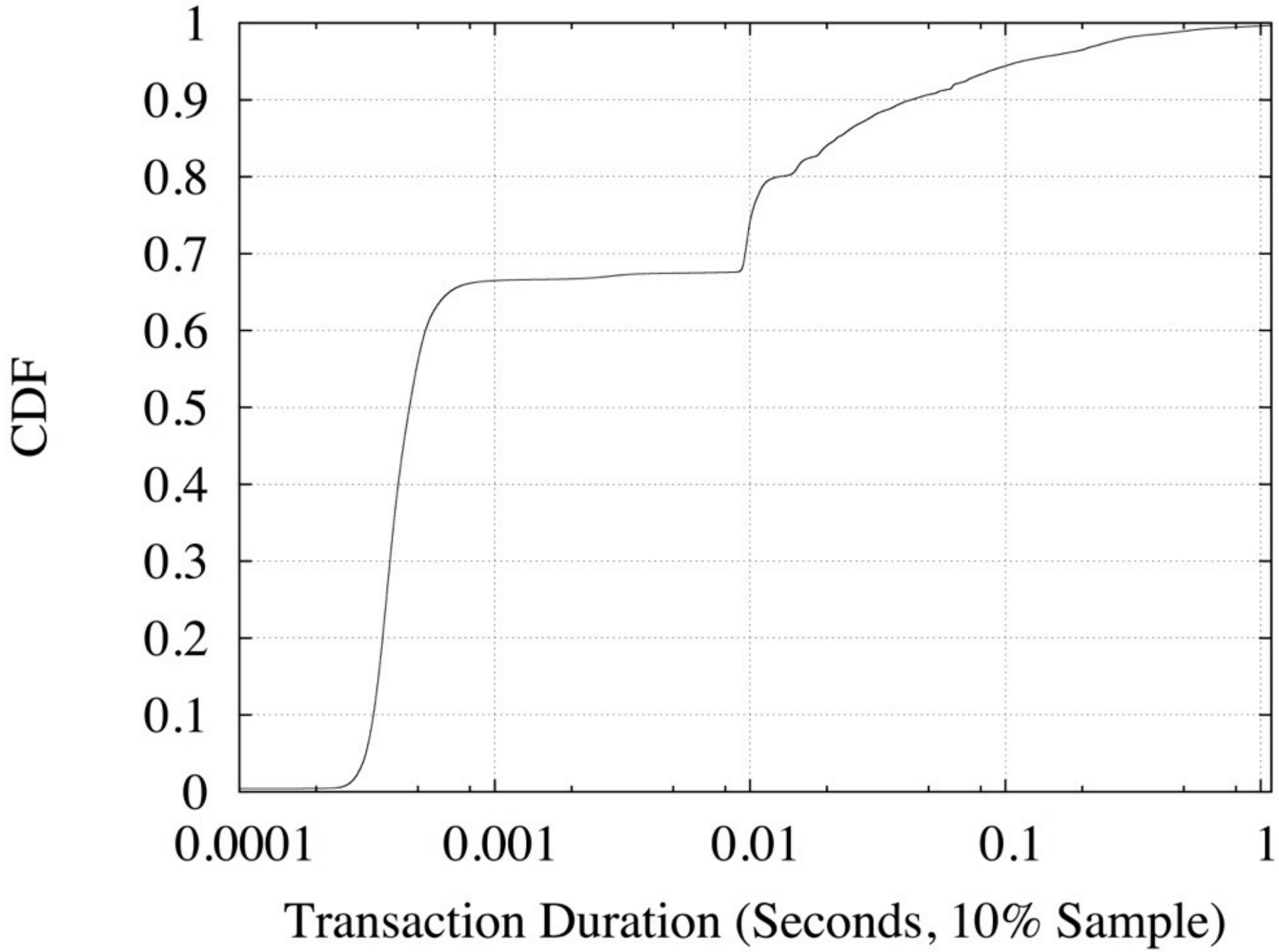
Basic Structure



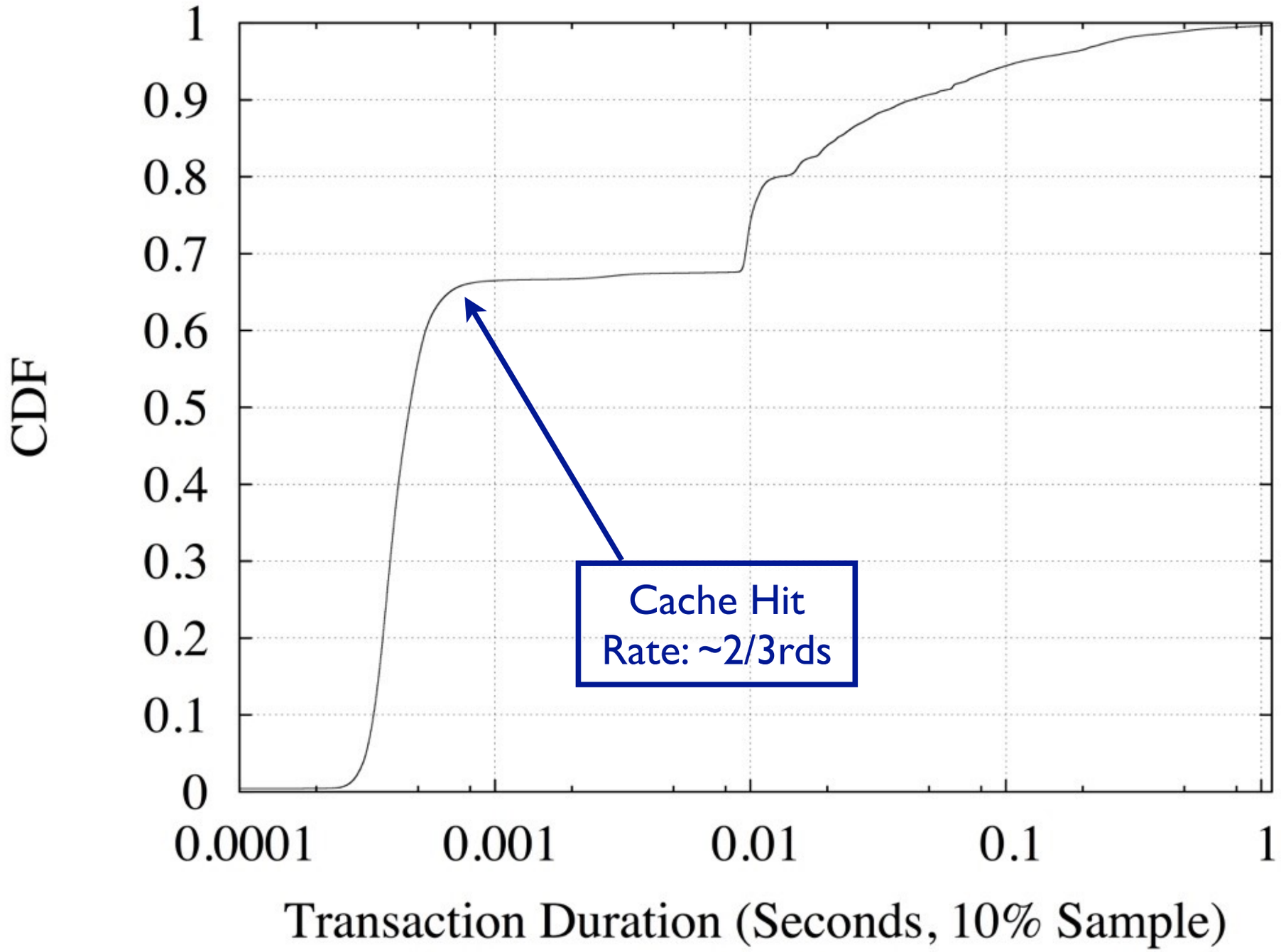
Delegating Resolution



Caching Efficacy



Caching Efficacy



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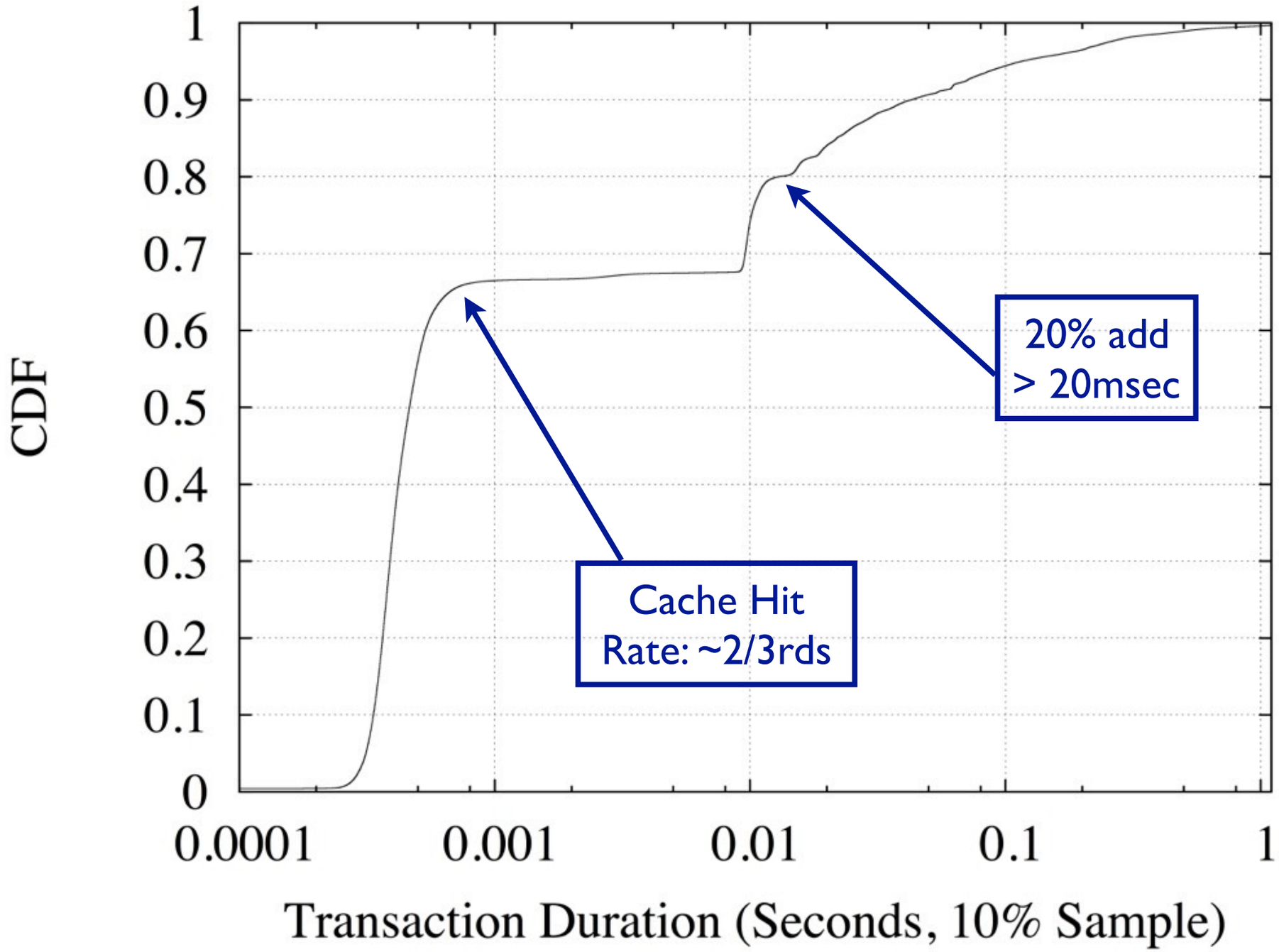
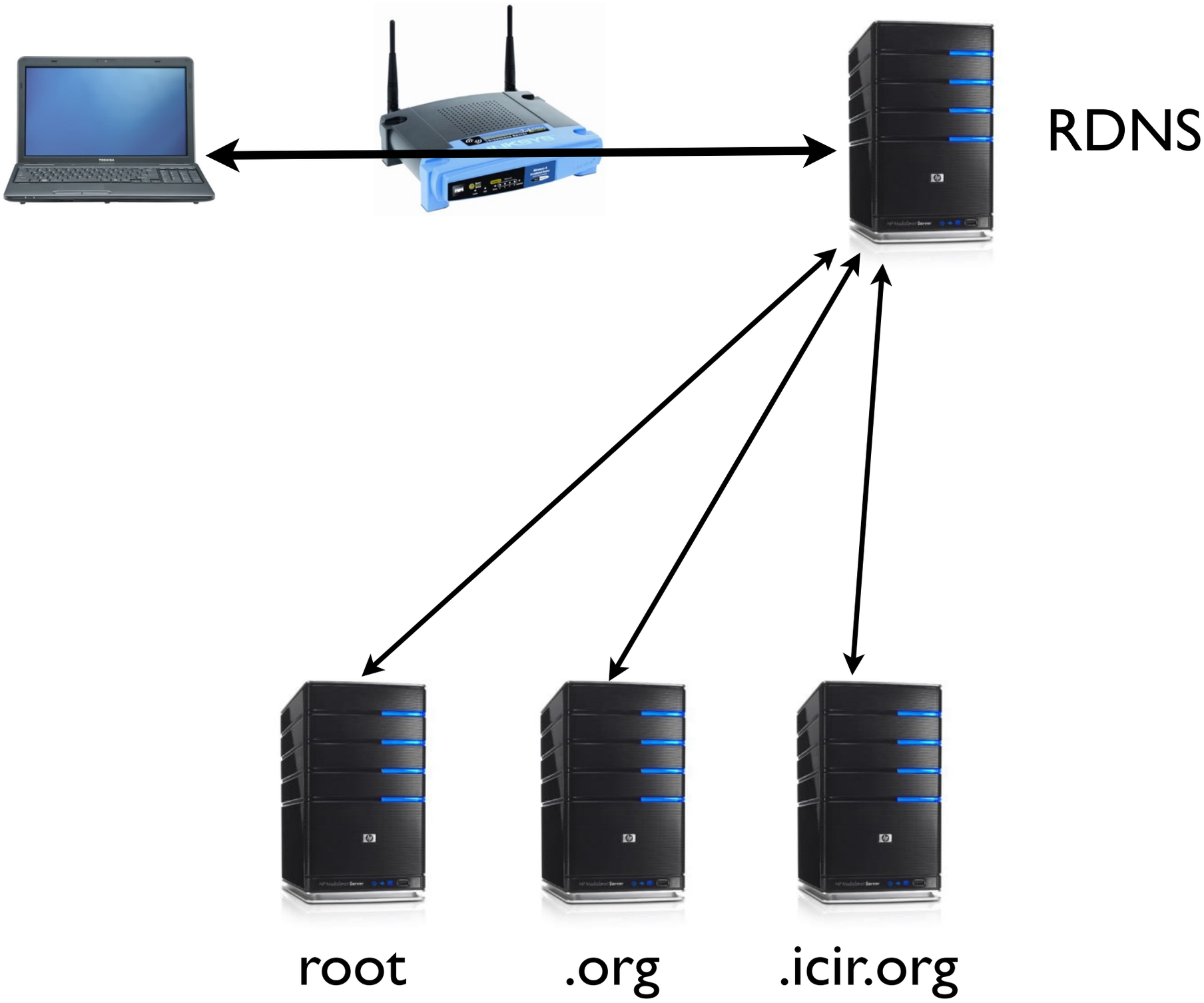


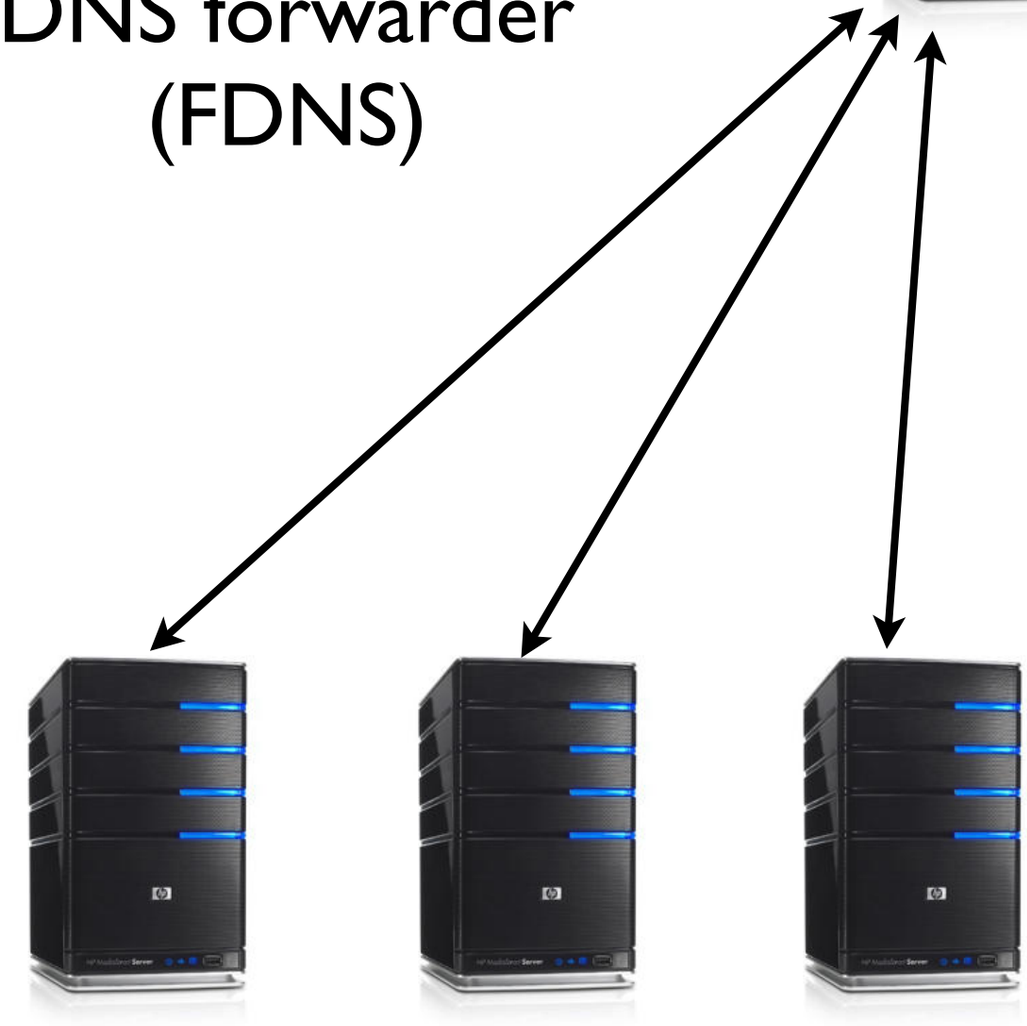
More Delegation!



More Delegation!

DNS forwarder
(FDNS)

RDNS



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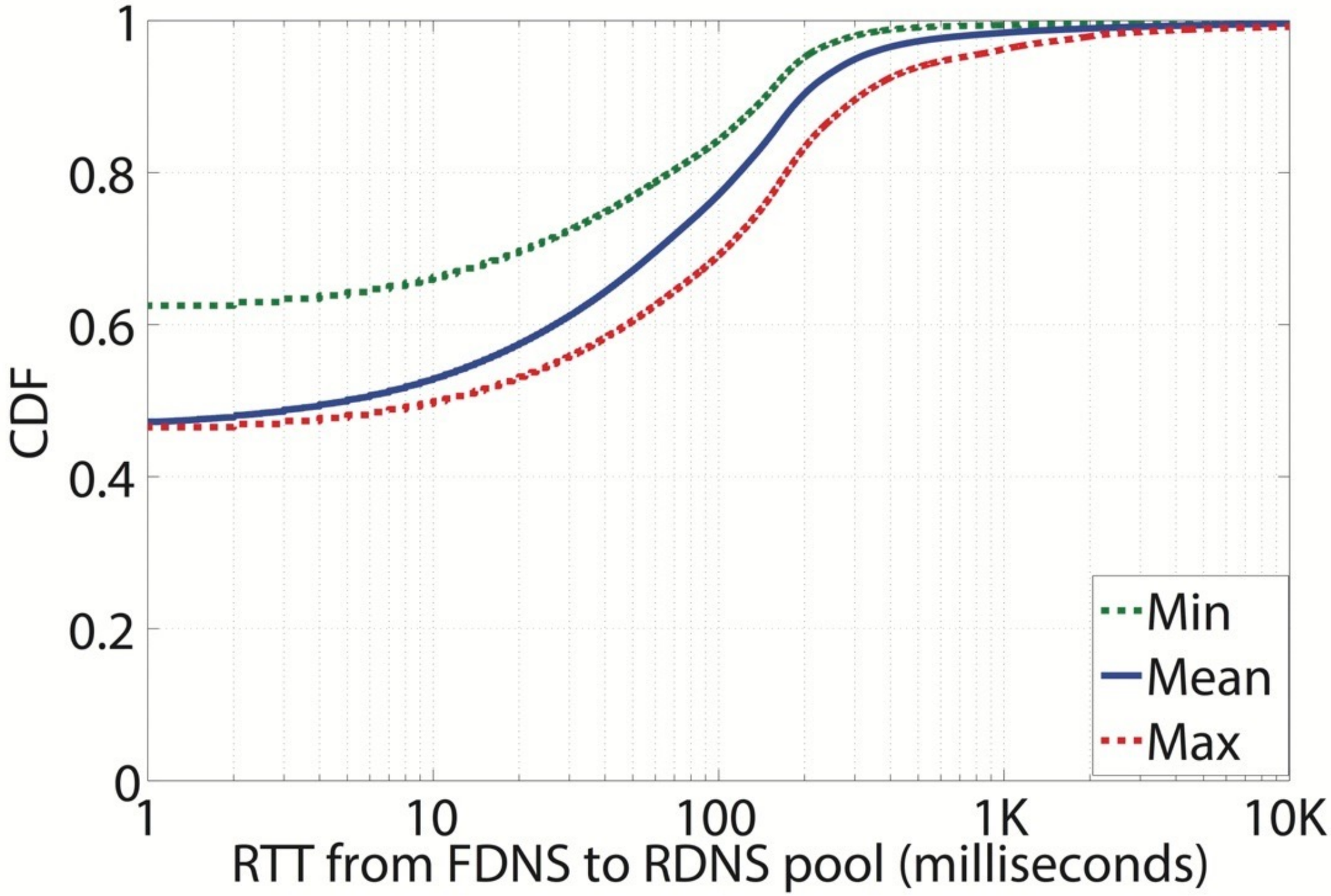
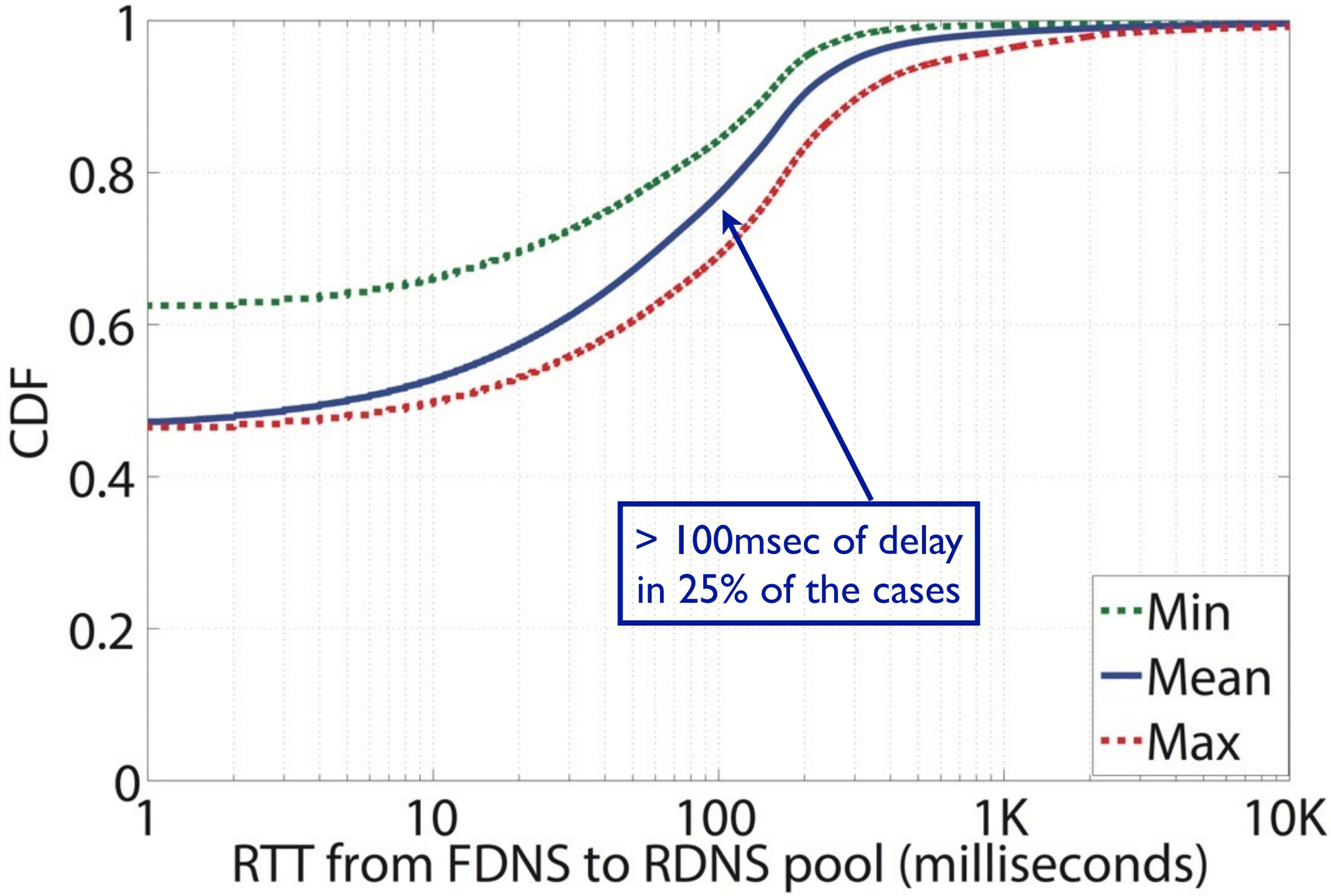
FDNS-to-RDNS Delay



FDNS-to-RDNS Delay



Implementation Diversity

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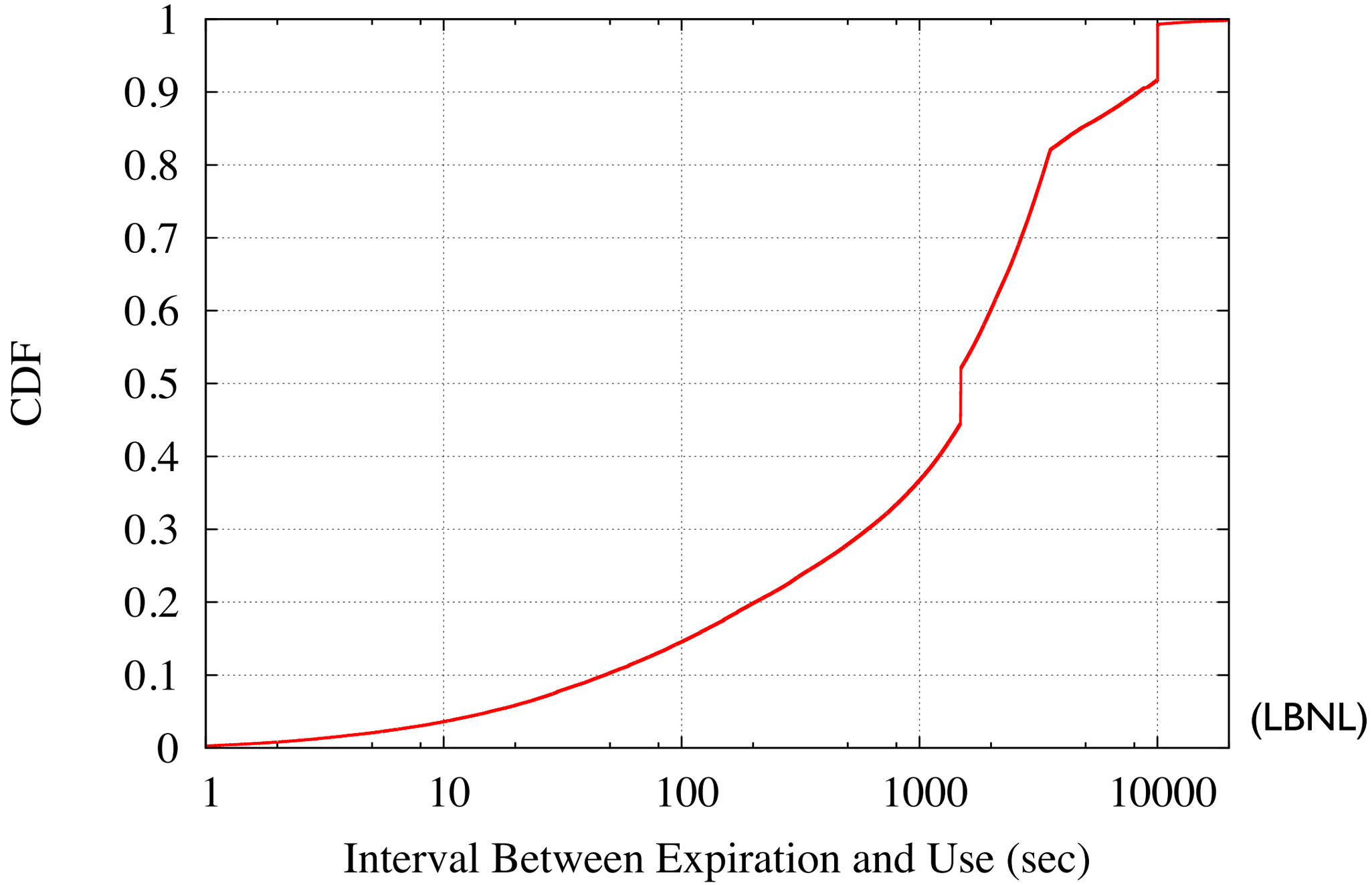
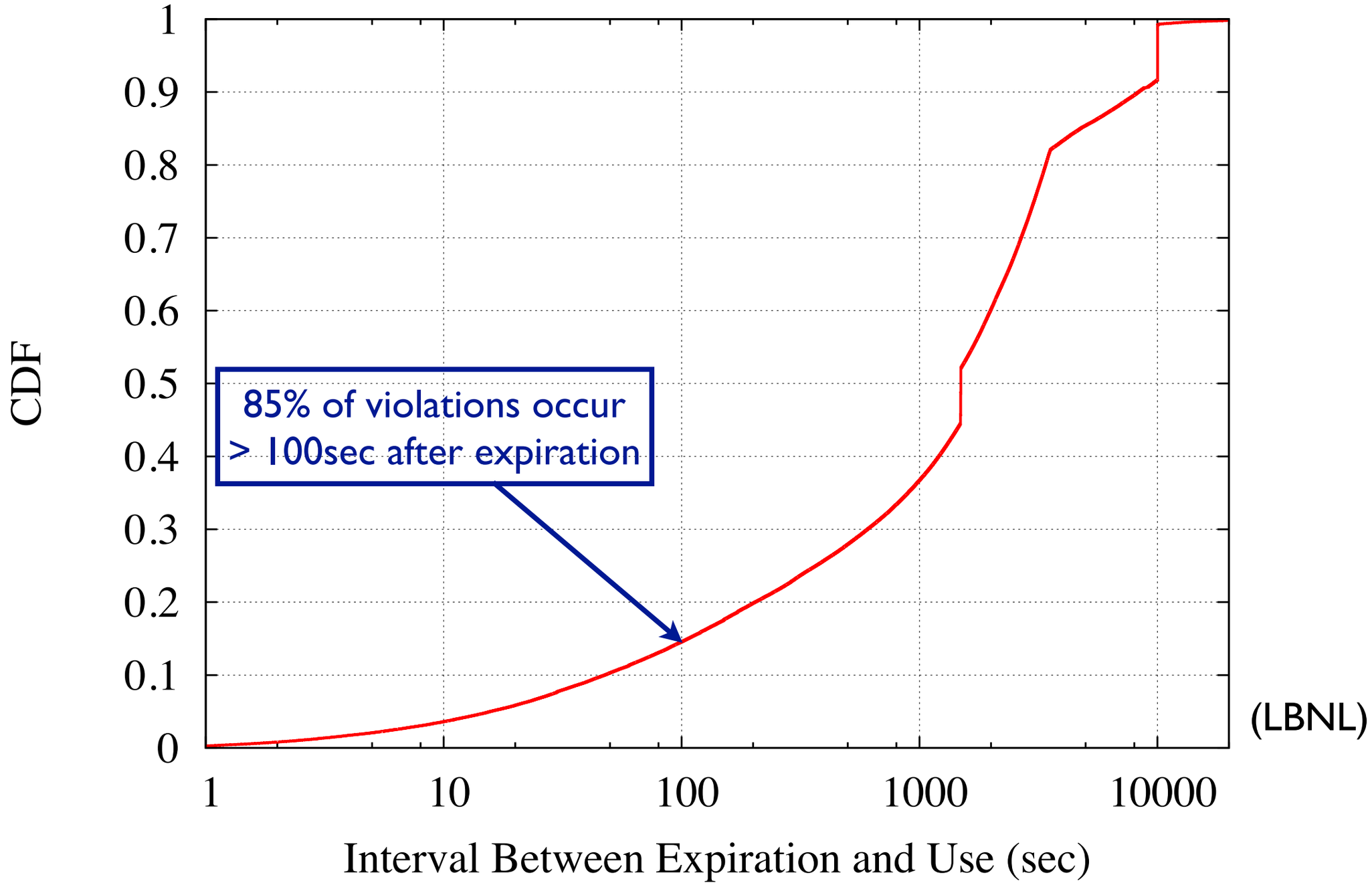
Network	Cnns.	TTL Exp.
ICSI	443K	30%
CCZ	817K	8%
LBNL	6.1M	14%

TTL Violations

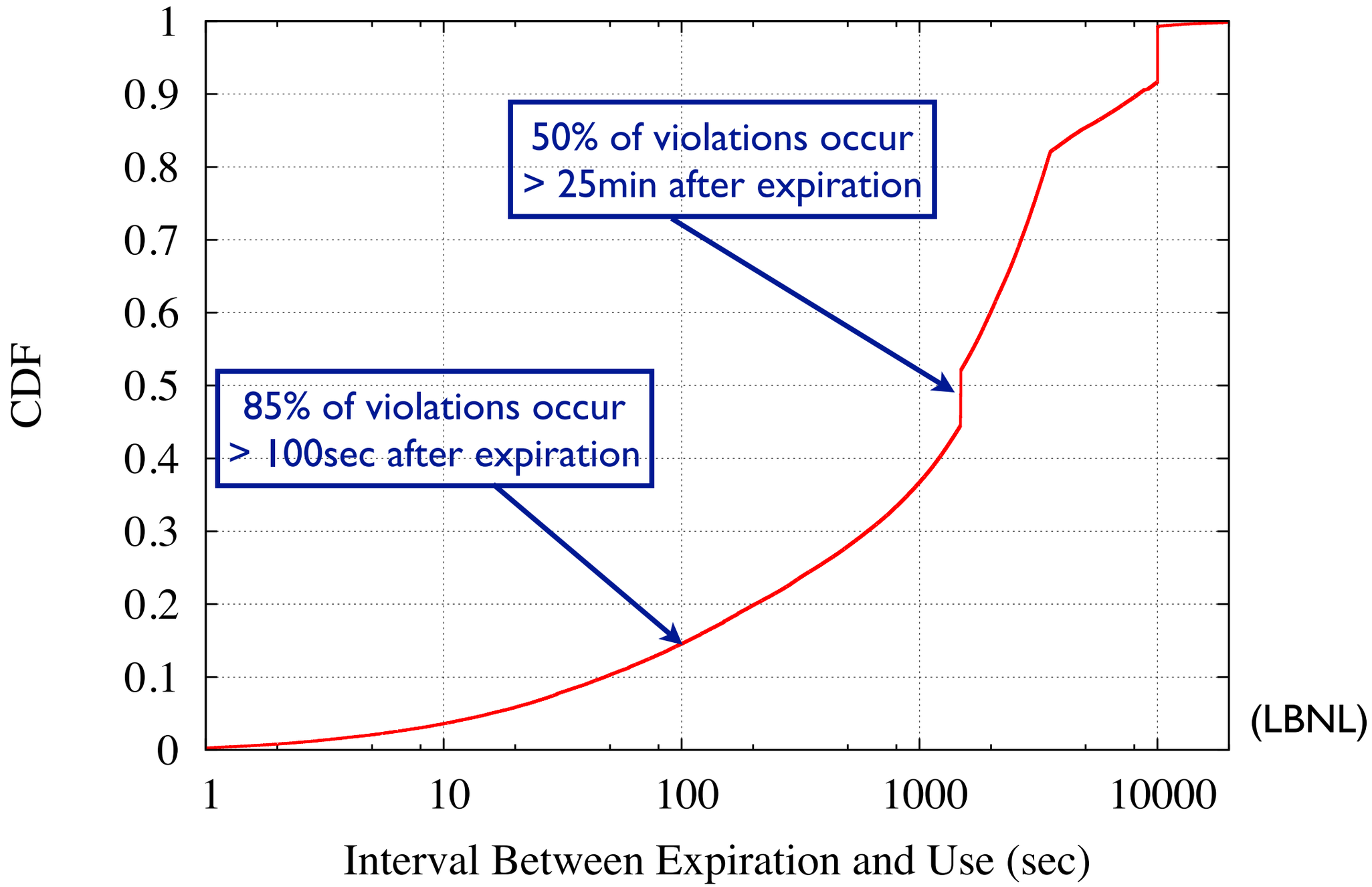


(LBNL)

TTL Violations



TTL Violations



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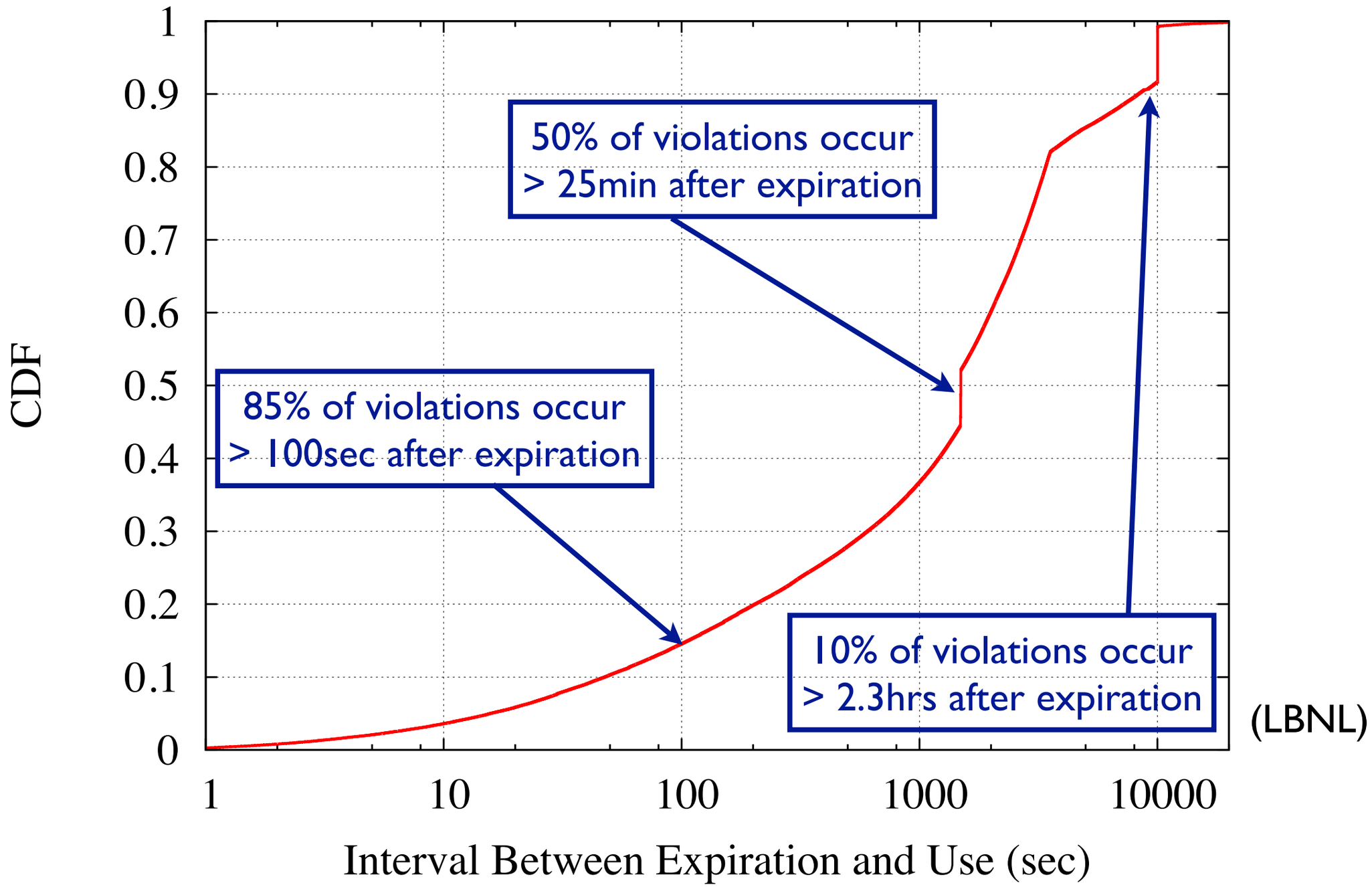
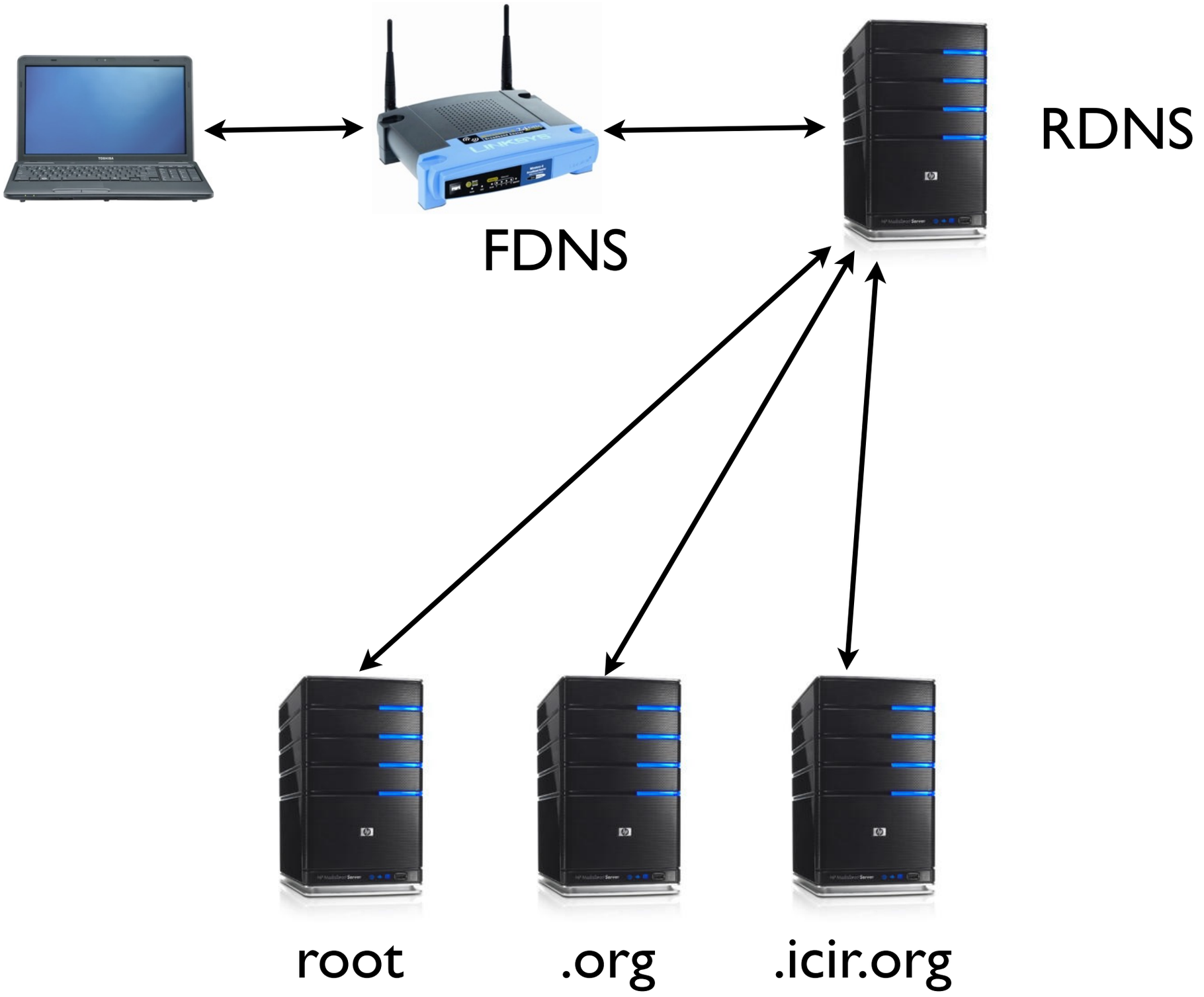


(LBNL)

Replication



Replication

RDNS

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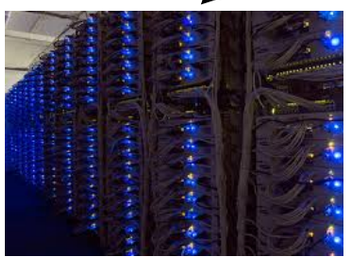
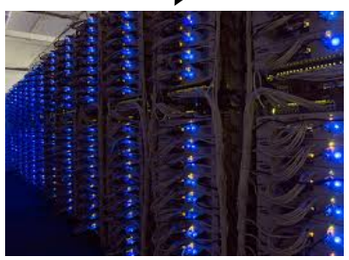
Replication

FDNS

RDNS



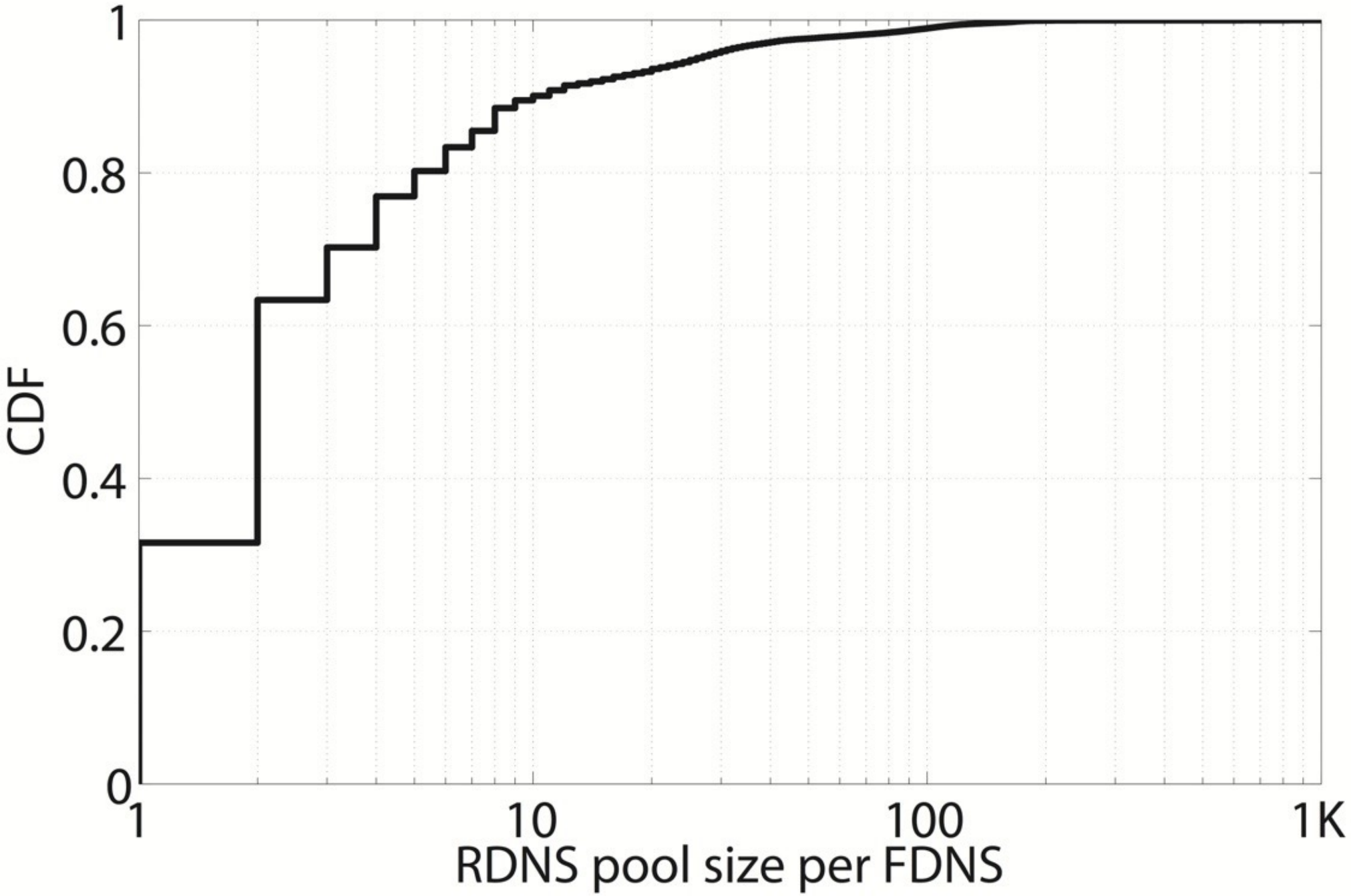
root



.org

.icir.org

RDNS Pool Size



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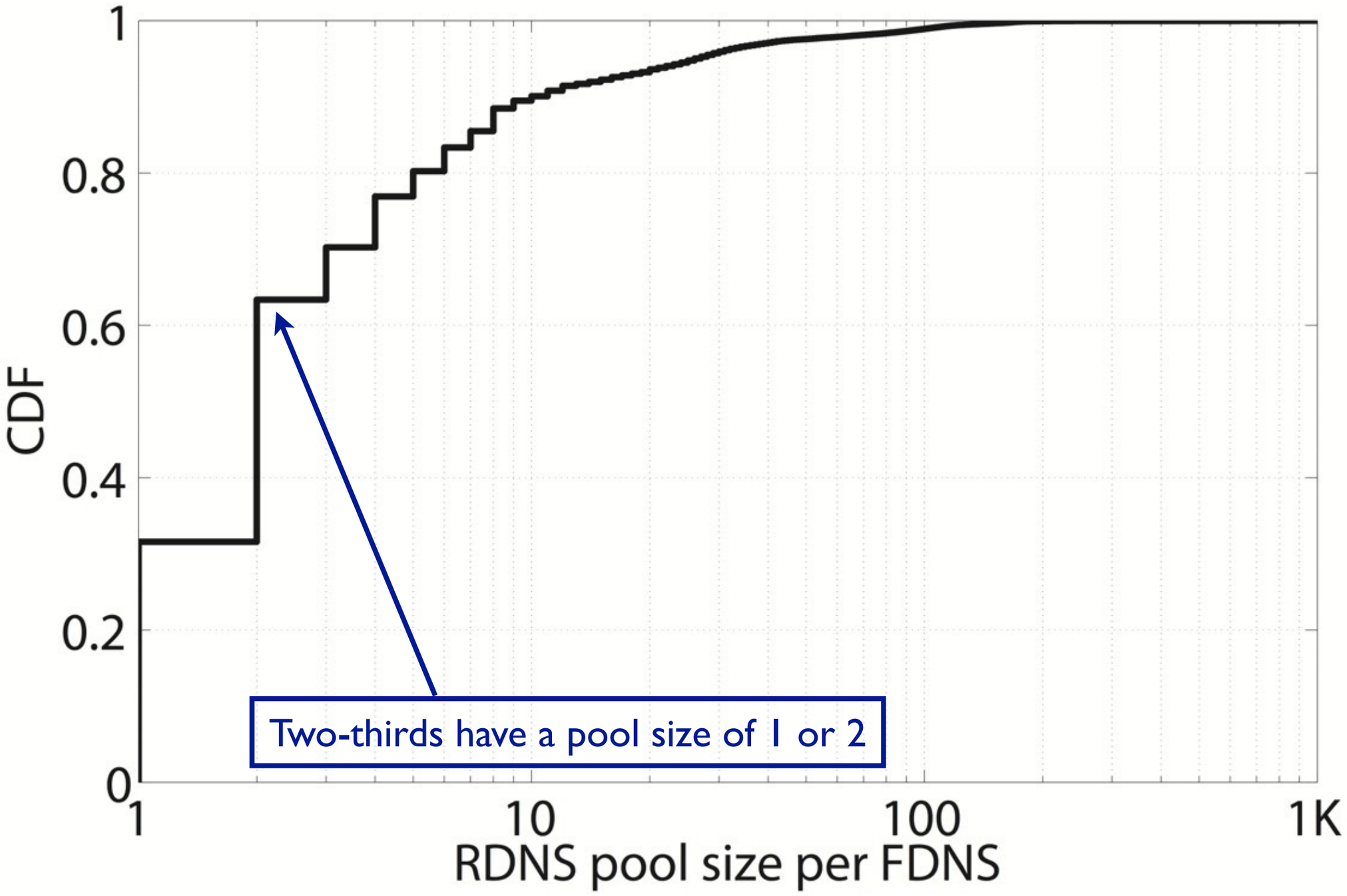

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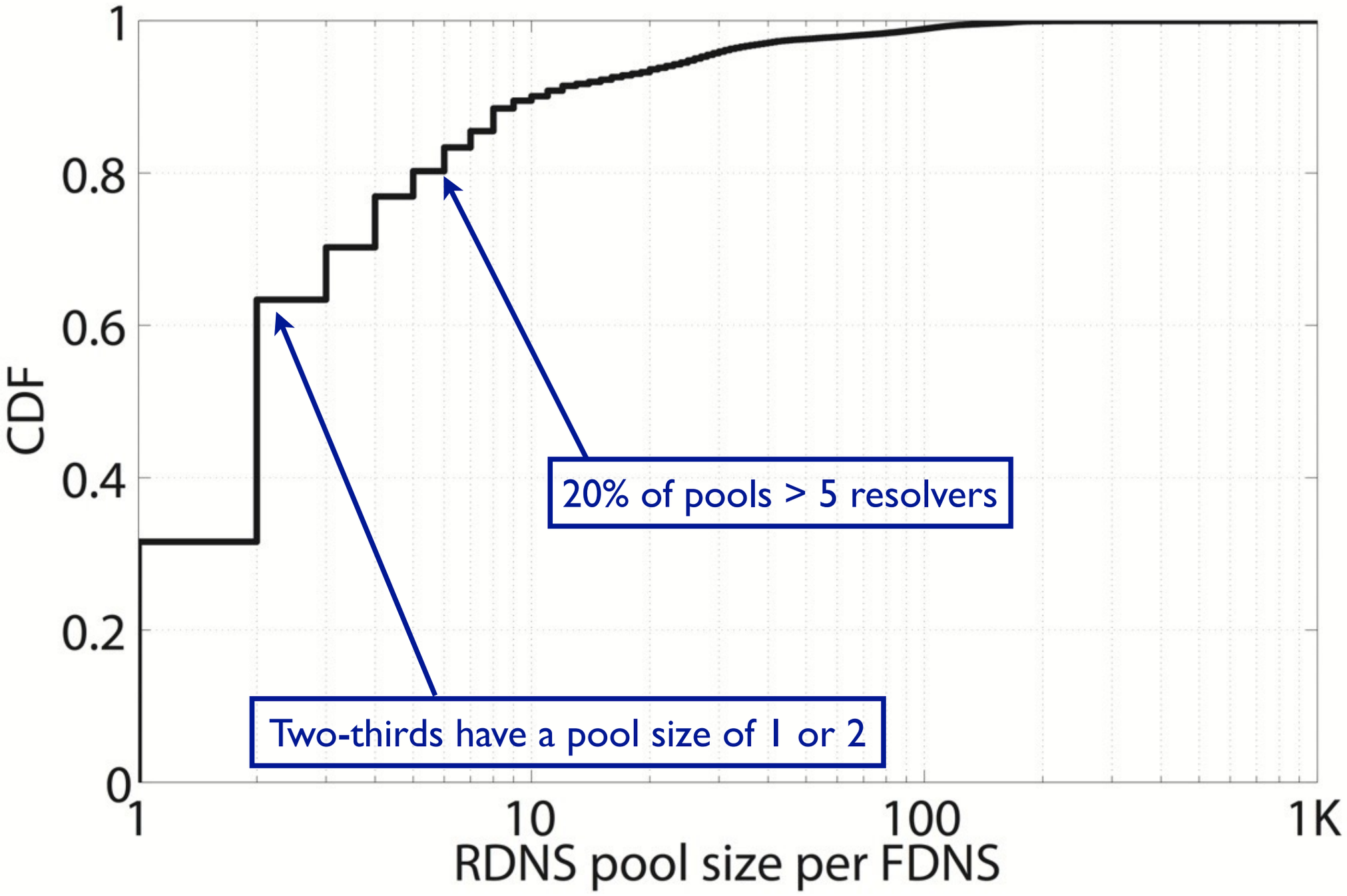

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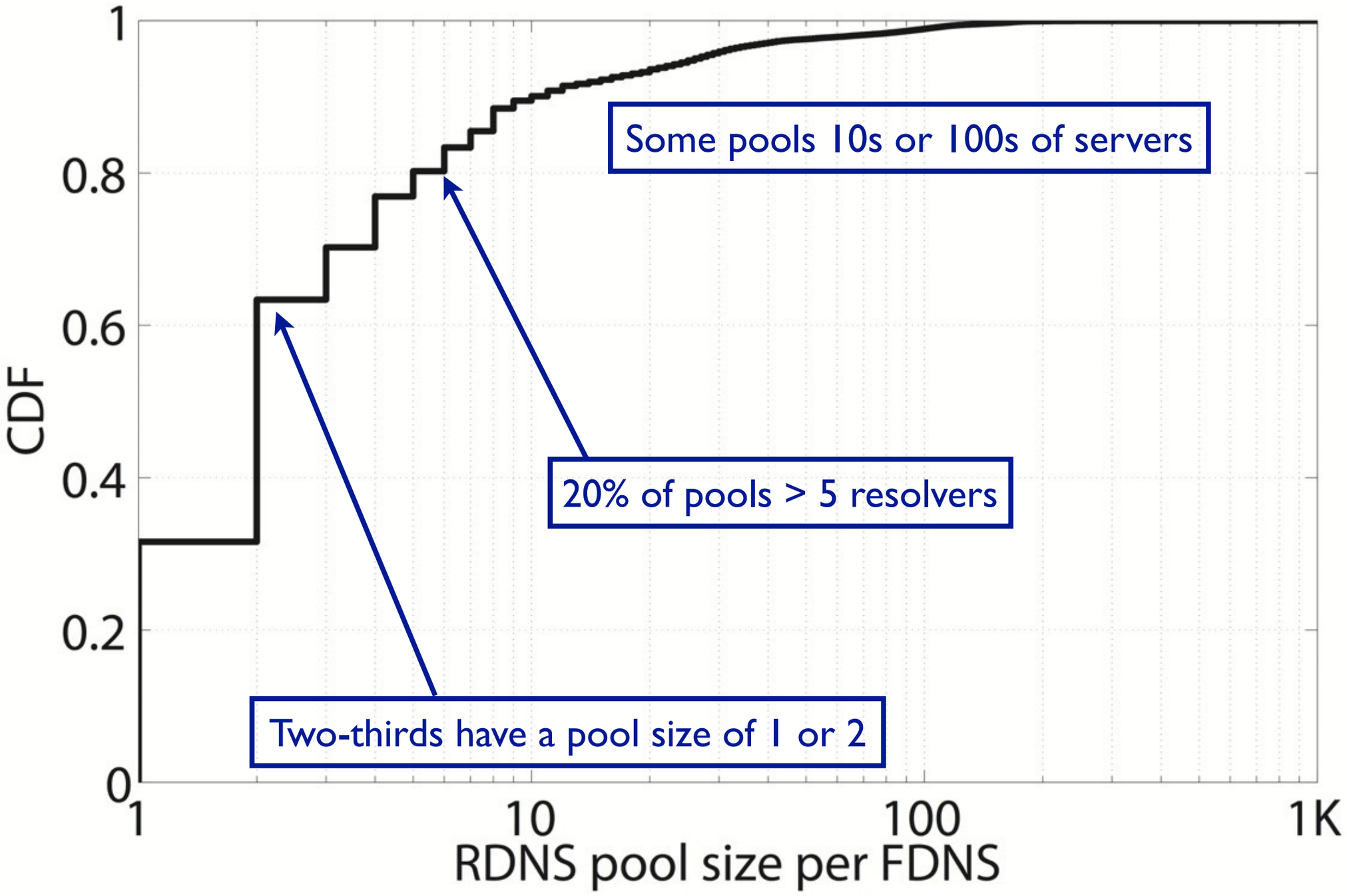
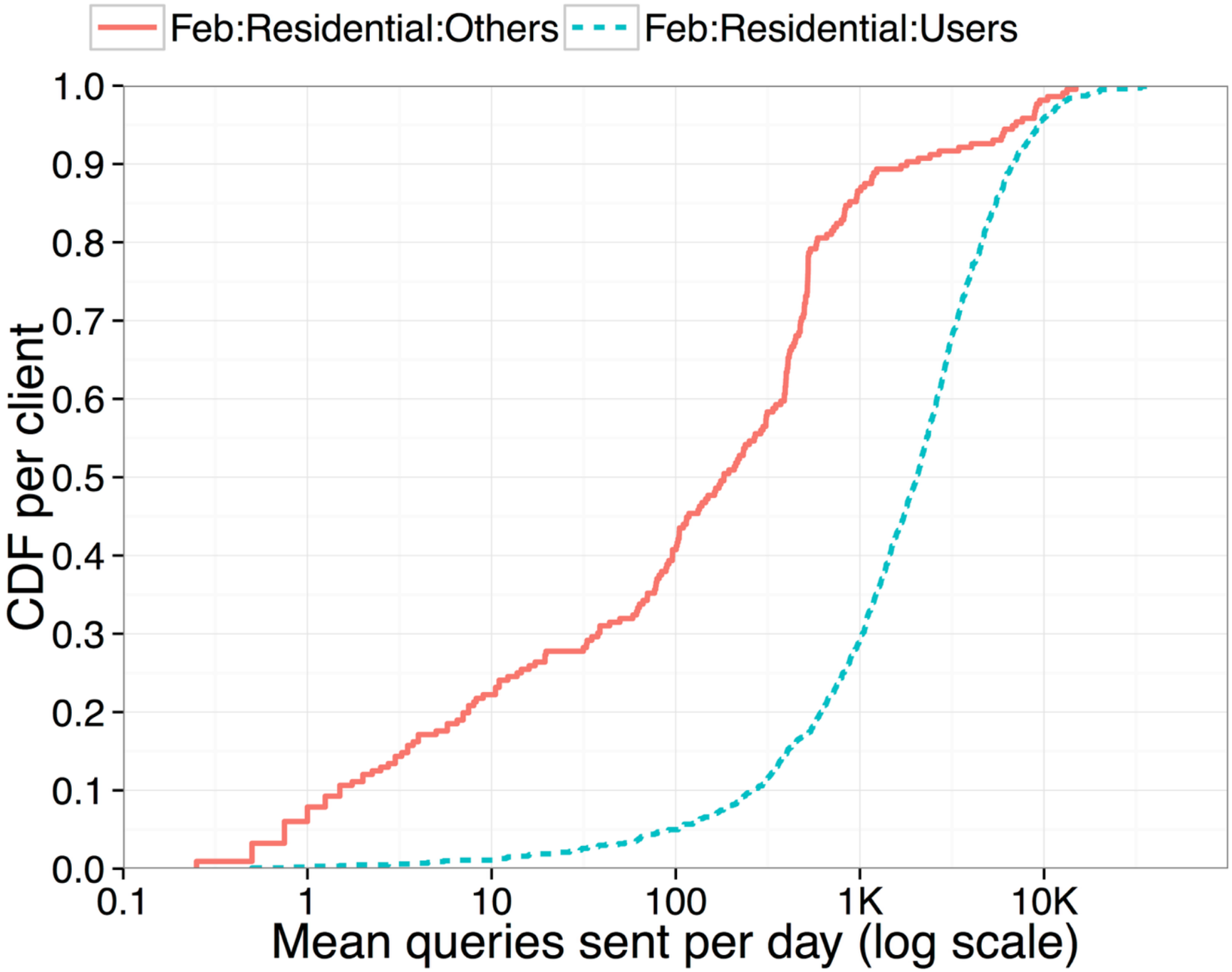


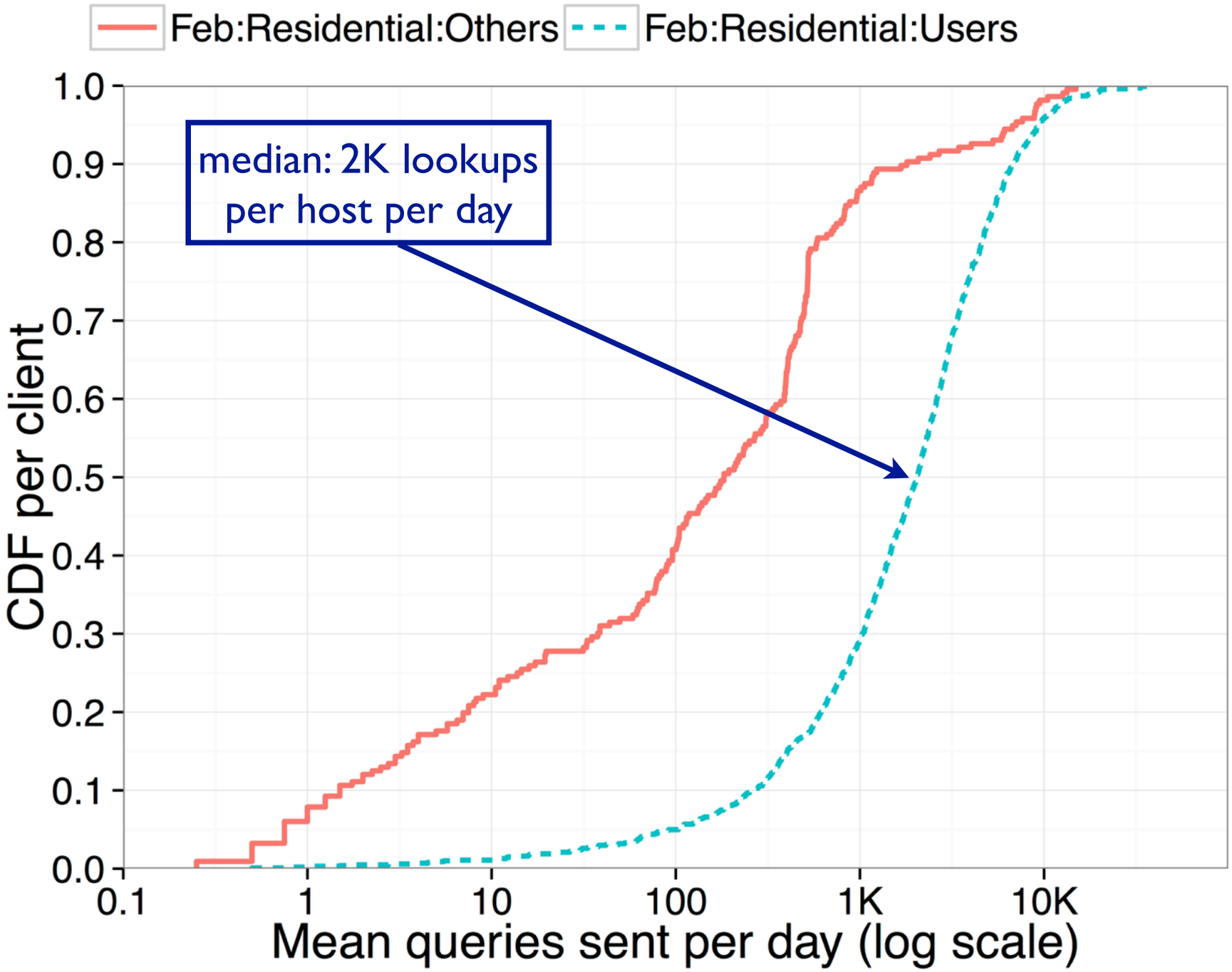
User Behavior

- Moving away from the infrastructure …
- How about user behavior?

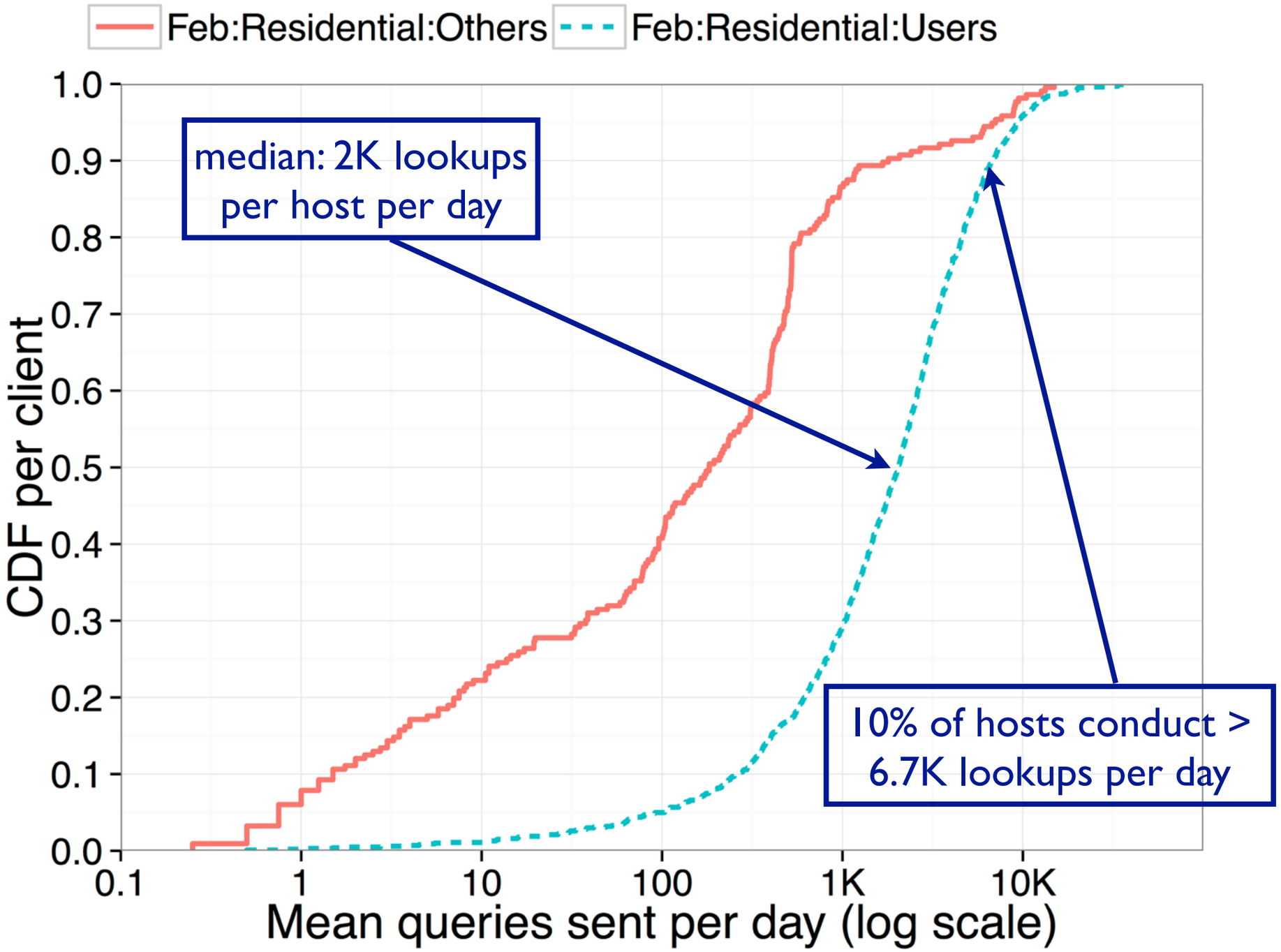
Query Rate


Feb:Residential:Others
Feb:Residential:Users
CDF per client
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
1
10
100
1K
10K
Mean queries sent per day (log scale)

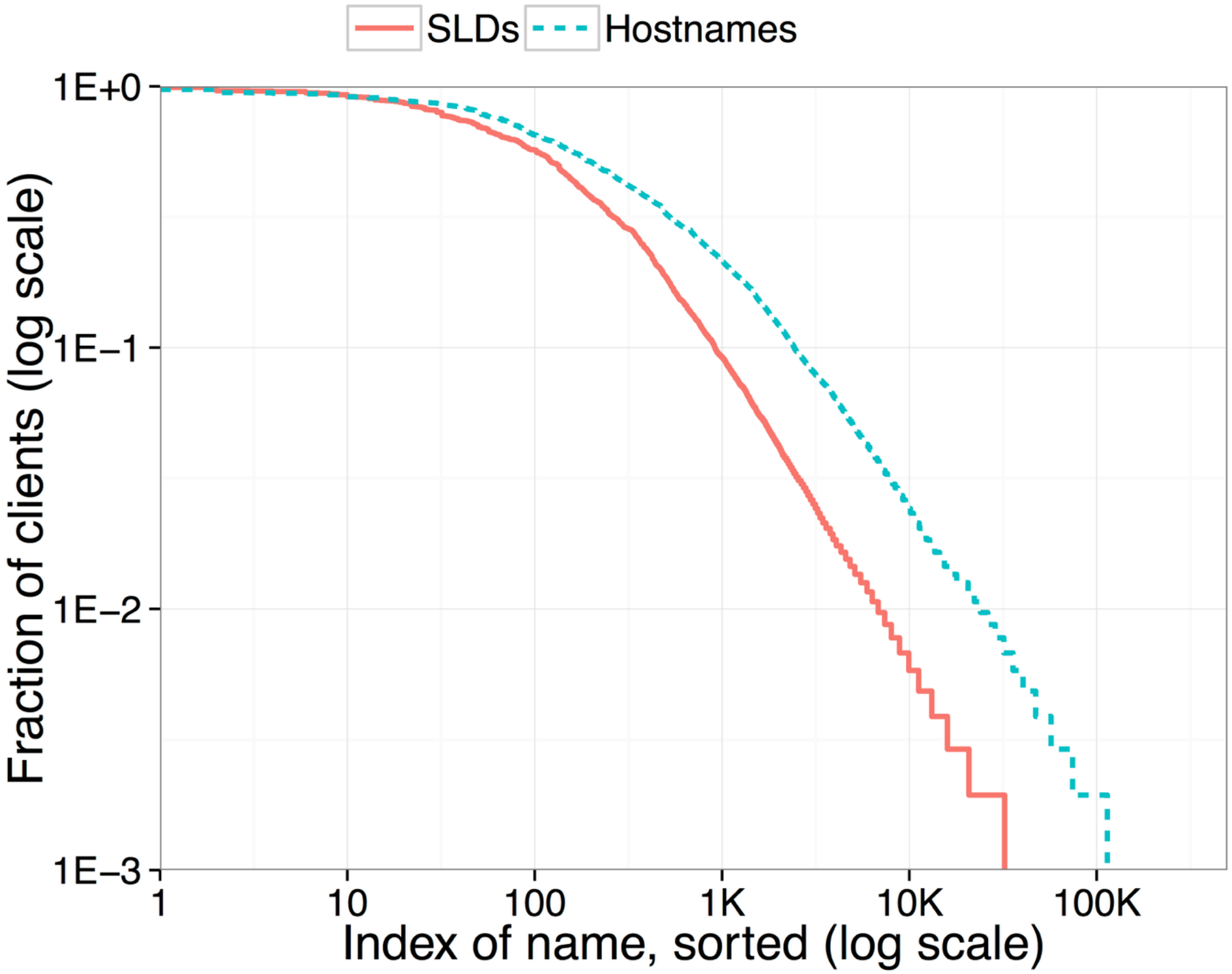
Query Rate


Feb:Residential:Others
Feb:Residential:Users
median: 2K lookups per host per day
CDF per client
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
1
10
100
1K
10K
Mean queries sent per day (log scale)

Query Rate


Feb:Residential:Others
Feb:Residential:Users
median: 2K lookups per host per day
10% of hosts conduct > 6.7K lookups per day
CDF per client
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
1
10
100
1K
10K
Mean queries sent per day (log scale)

Name Popularity



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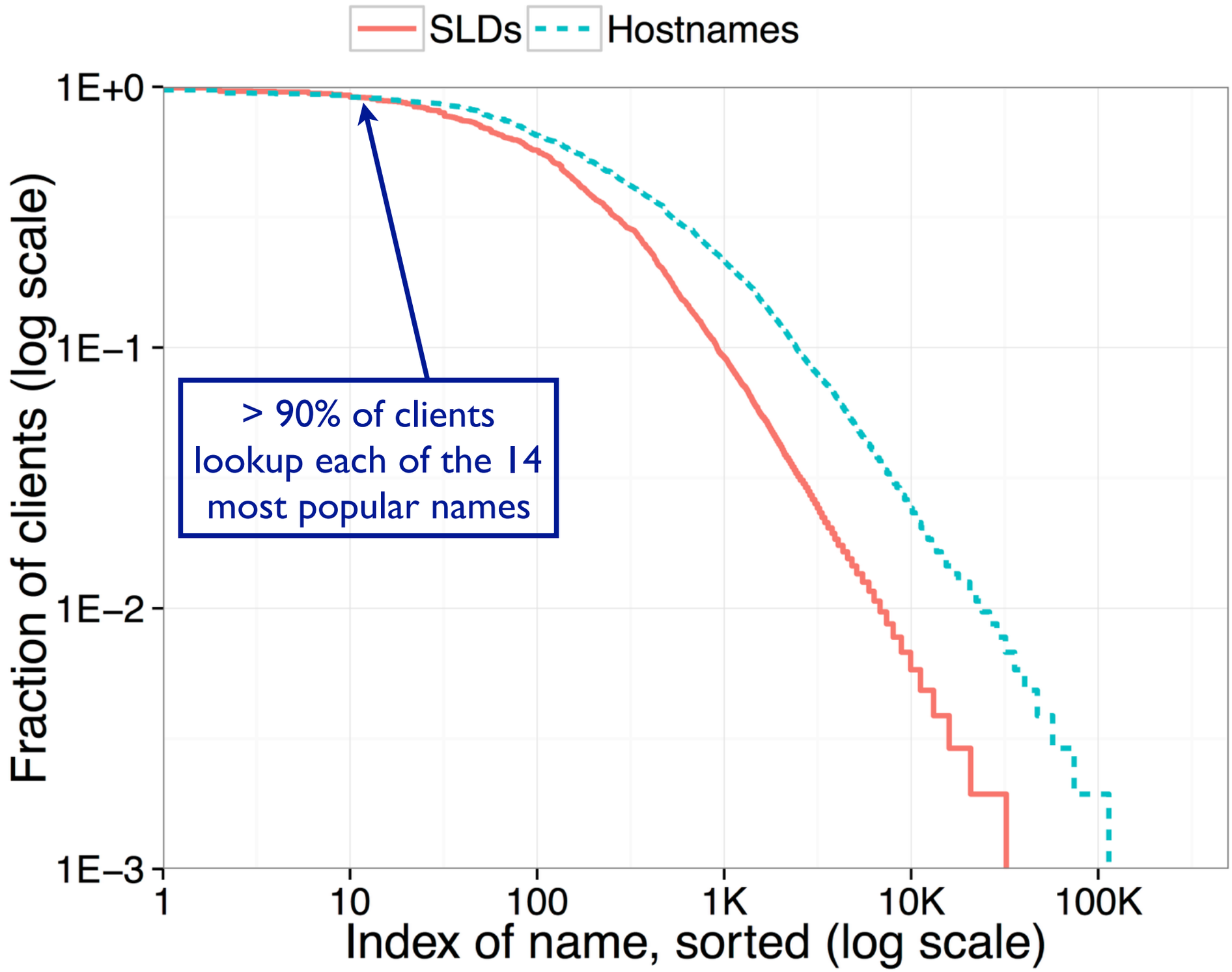

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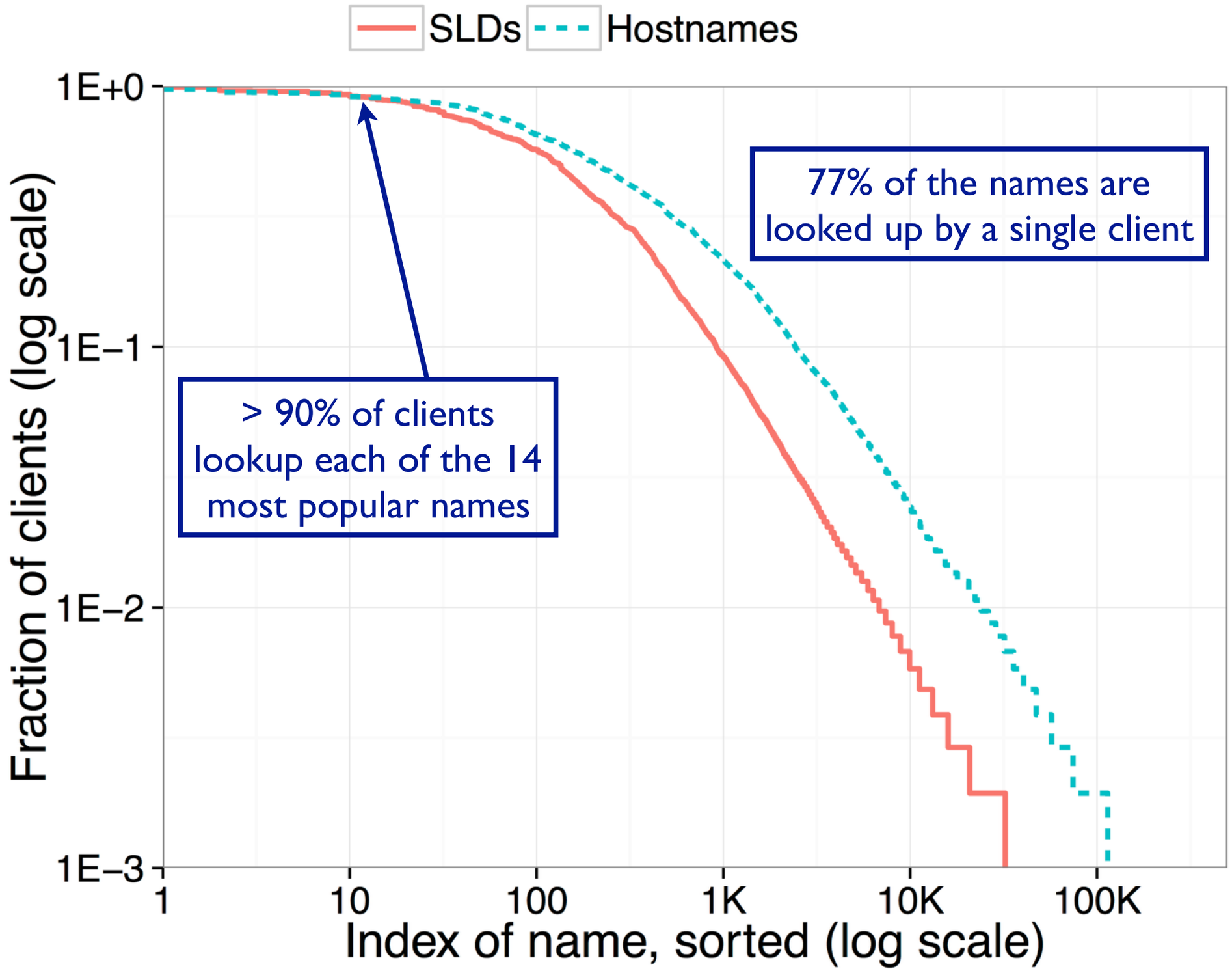

Of Blessings and Curses ....

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- *Open resolvers* are a common component of the DNS ecosystem
  - will answer DNS queries for *any host*

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- *Open resolvers* are a common component of the DNS ecosystem
  - will answer DNS queries for *any host*
- Curse: security issues
  - can circumvent RDNS policy, etc.
- Blessing: provide us with myriad *measurement vantage points*

Open Resolvers

Open Resolvers

- 15M open resolvers in 2010
  (Leonard & Loguinov, IMC 2010)

Open Resolvers

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DNS Security

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  - all transactions in clear text!
  - no trust, no privacy, no integrity

Security Implications

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  - ... modification
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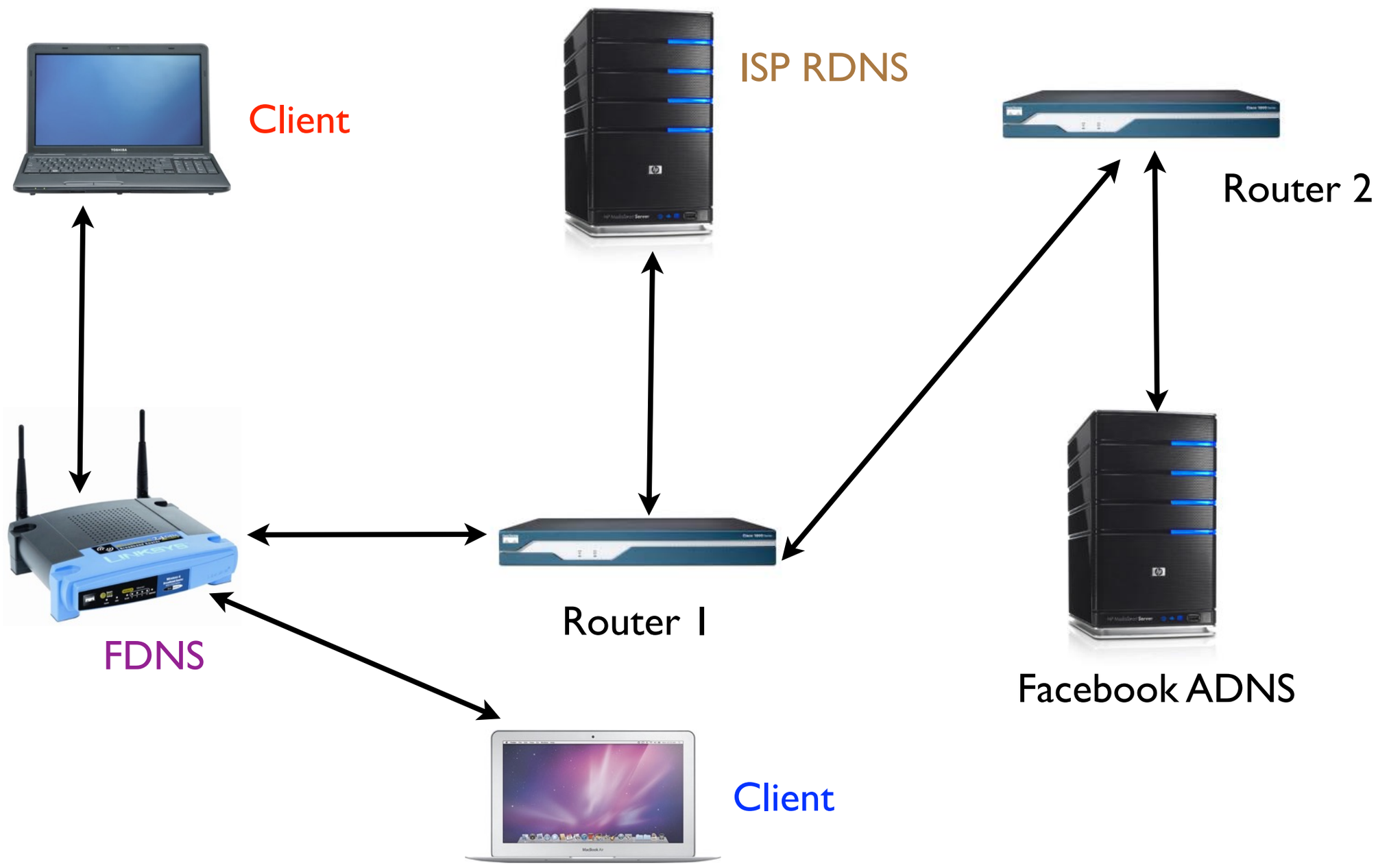
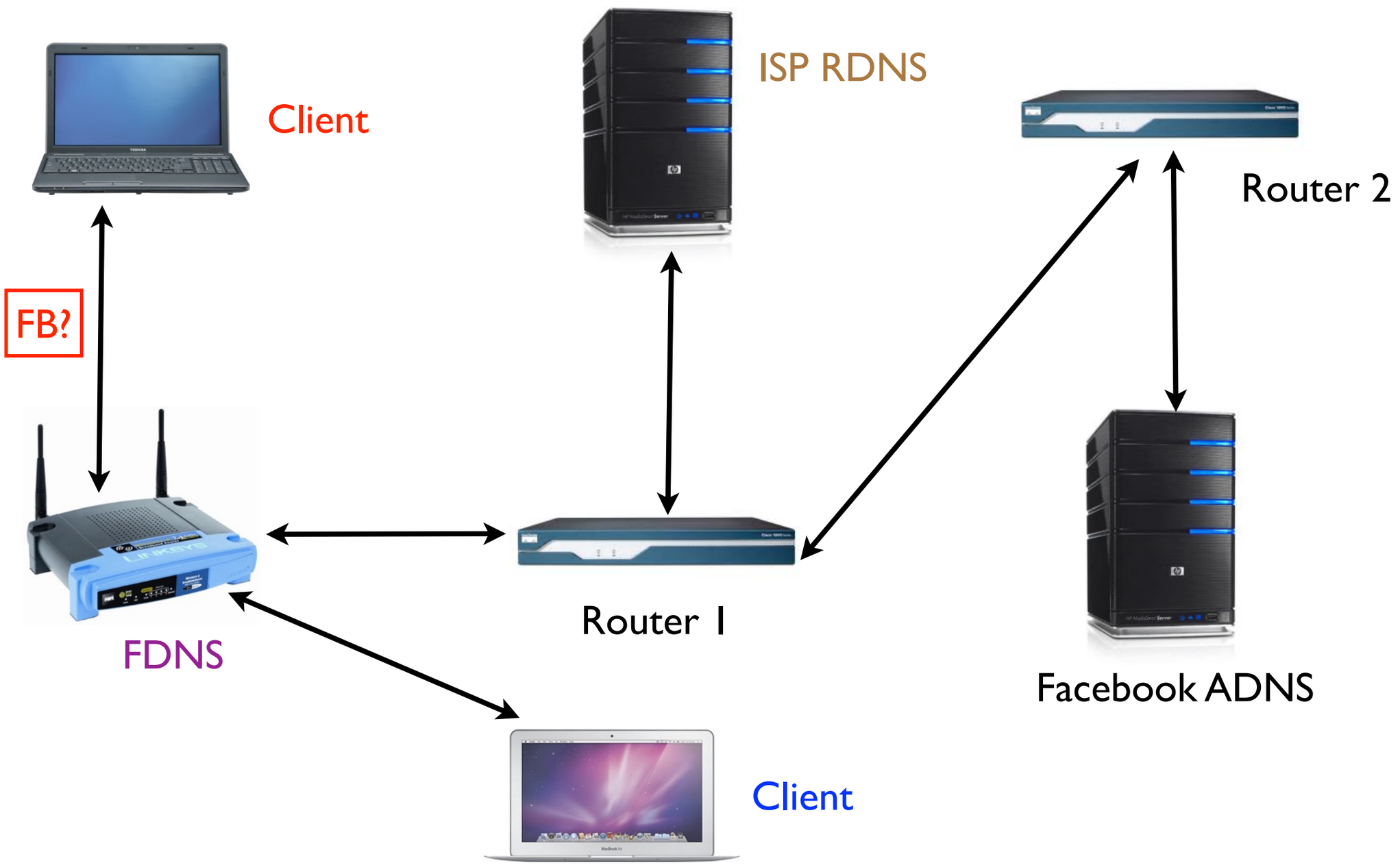
- Every component of the DNS ecosystem is a *potential adversary*

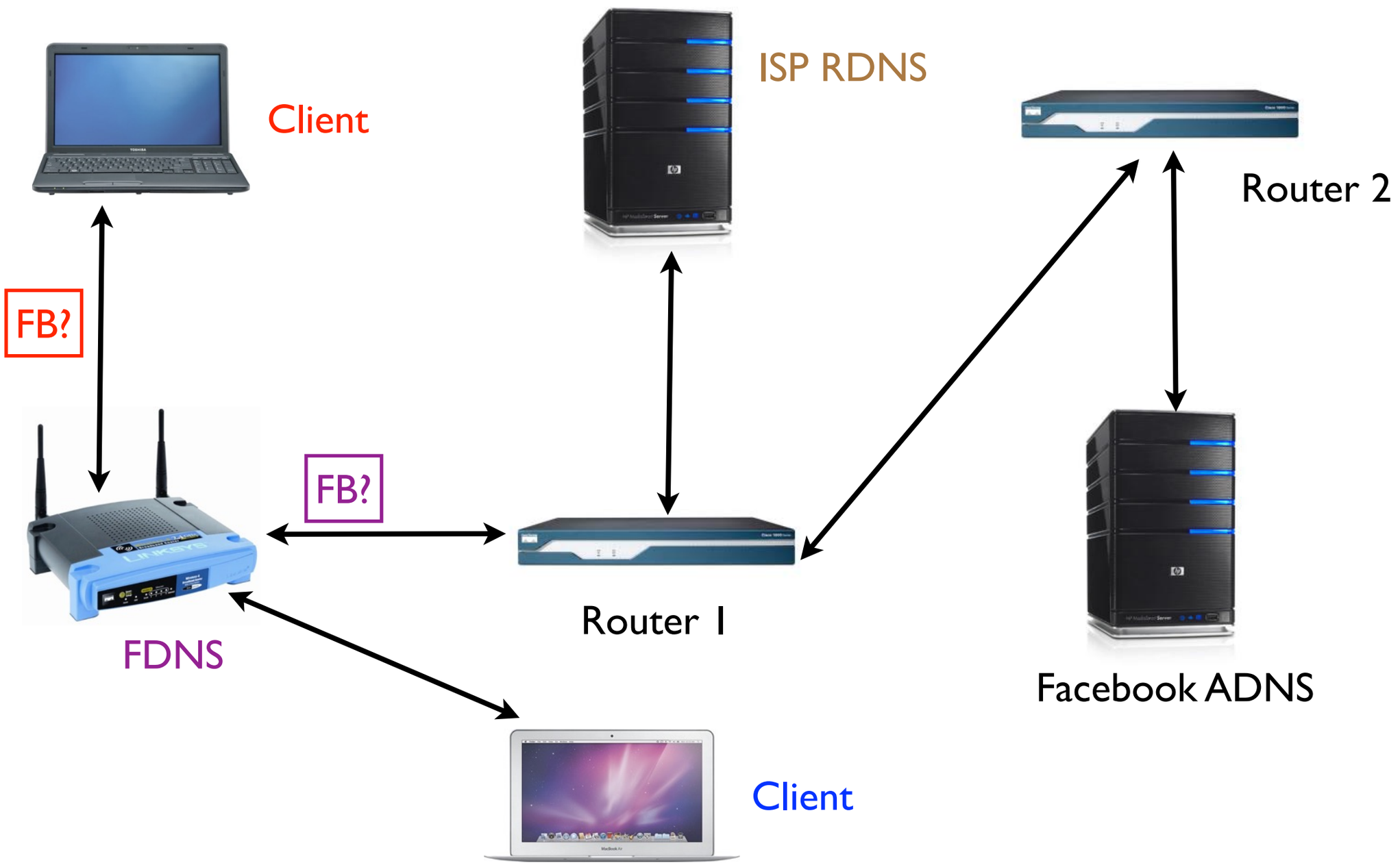
DNS Transaction Example



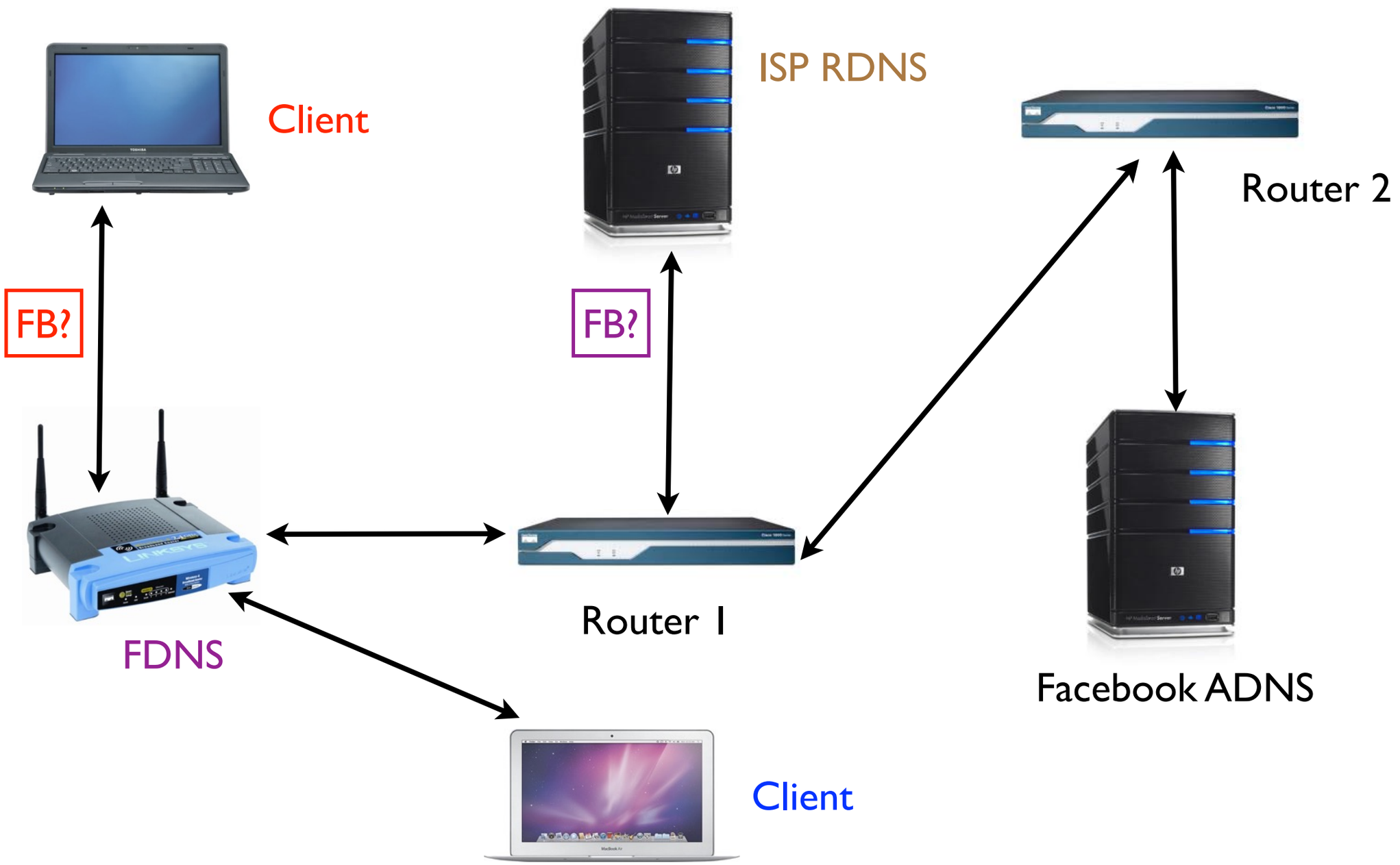
DNS Transaction Example



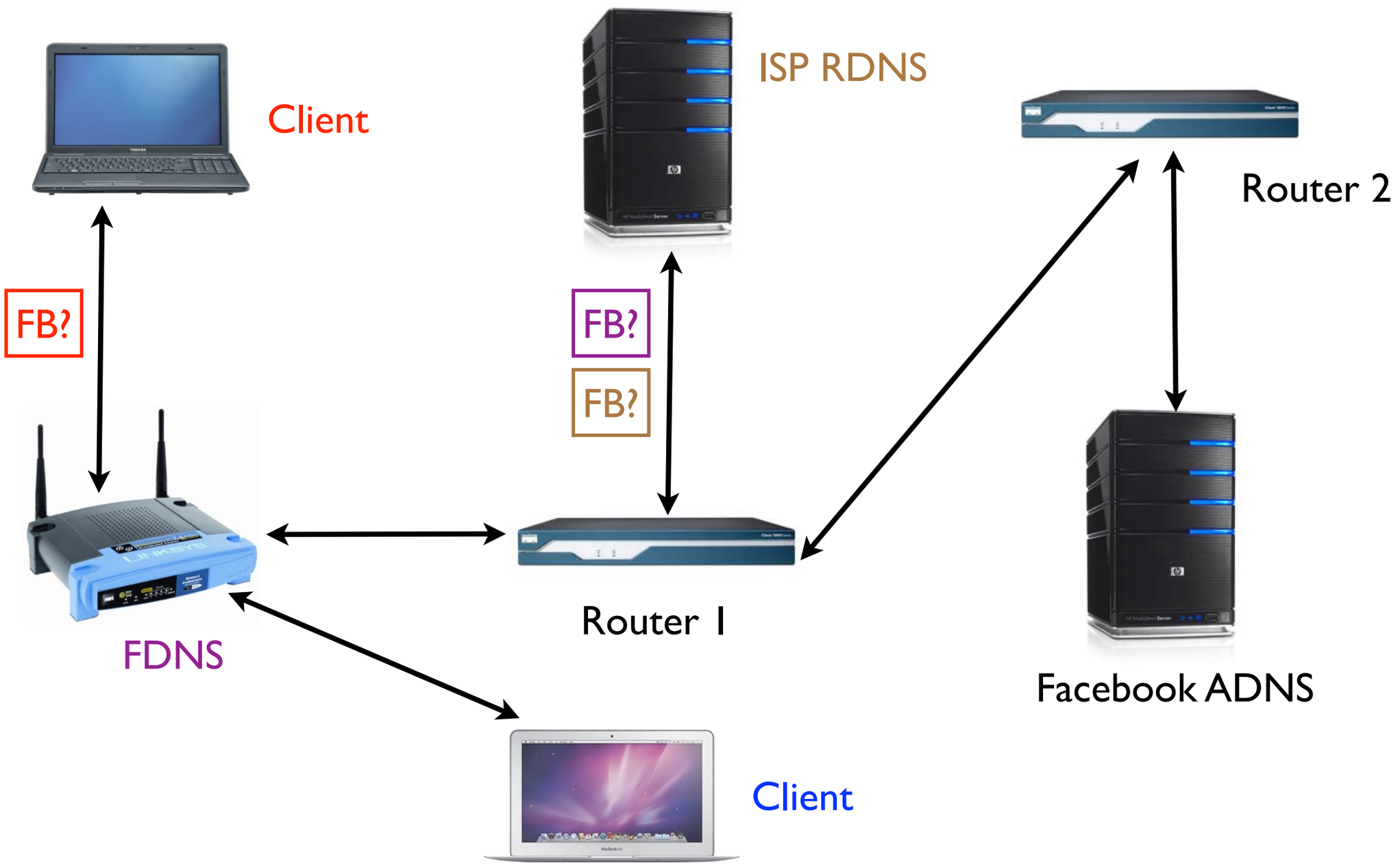
DNS Transaction Example



DNS Transaction Example



DNS Transaction Example



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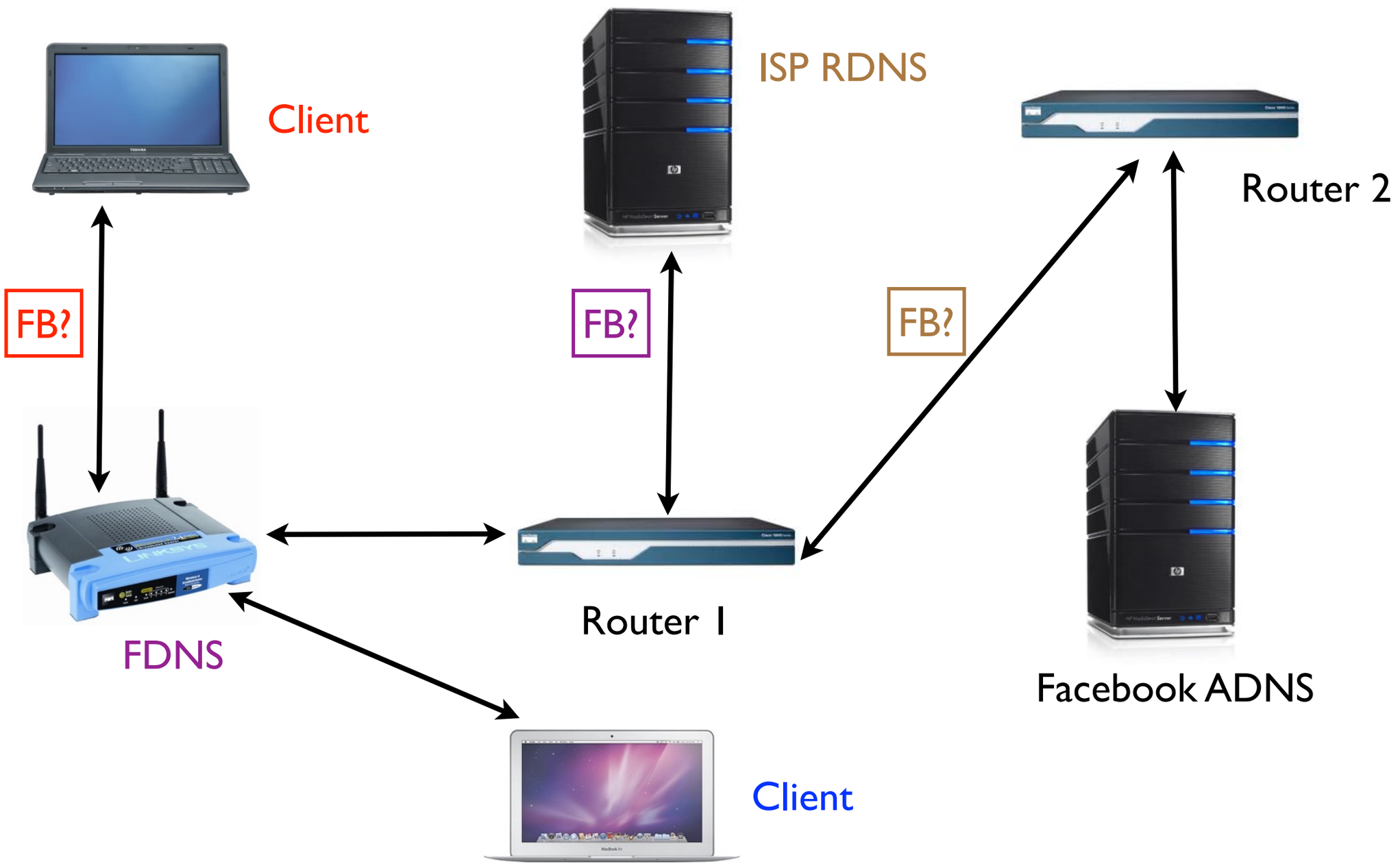

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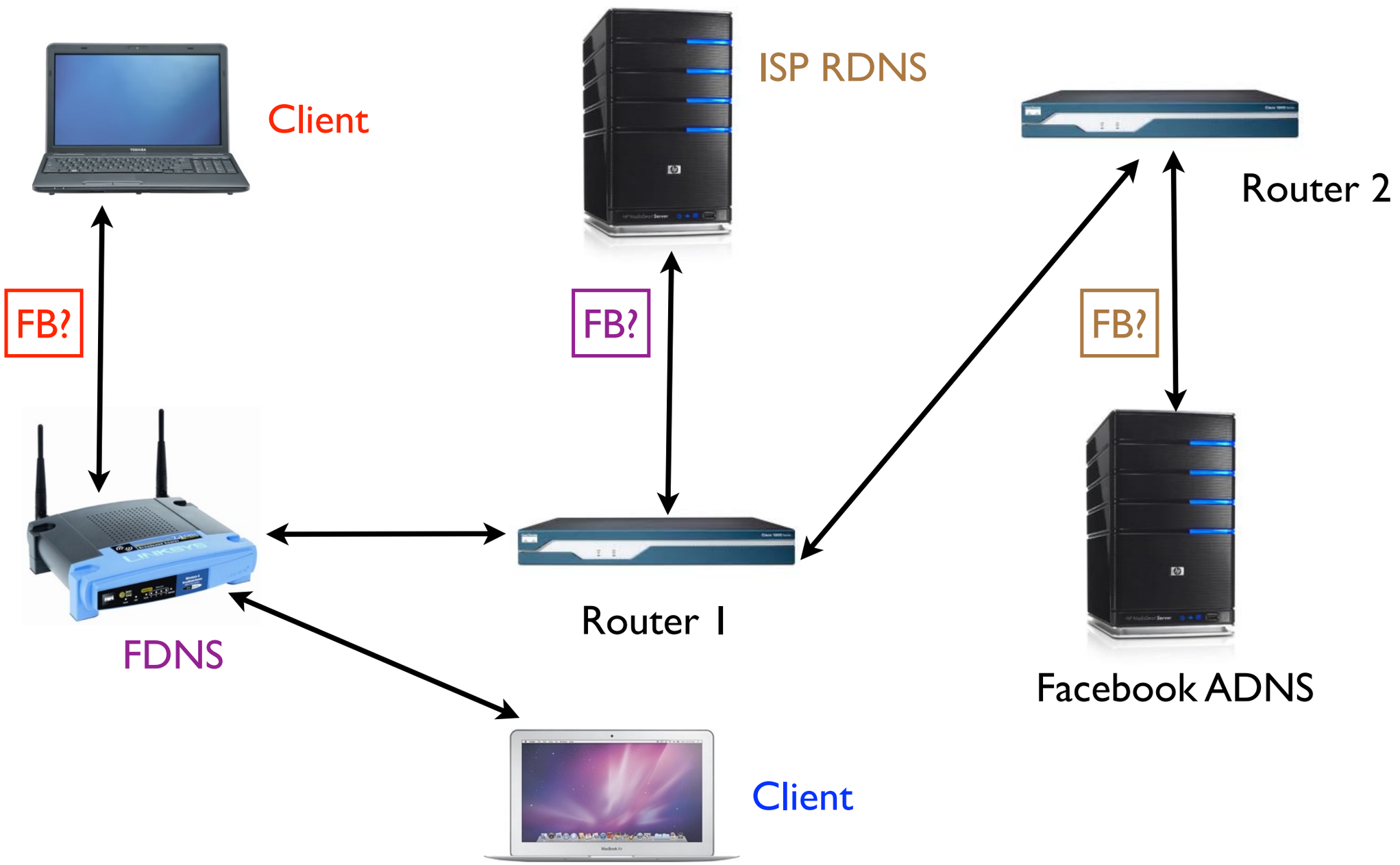
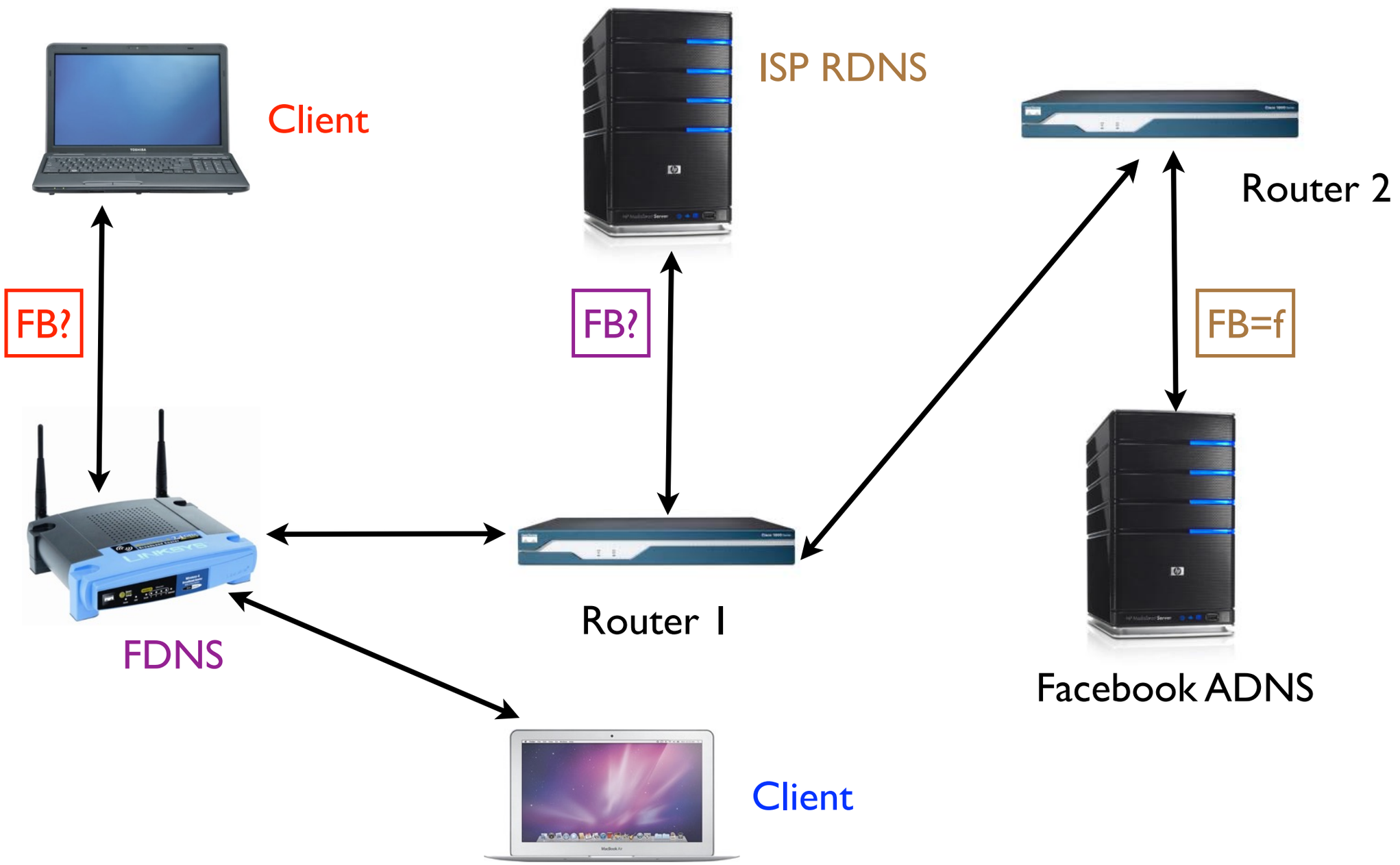


DNS Transaction Example



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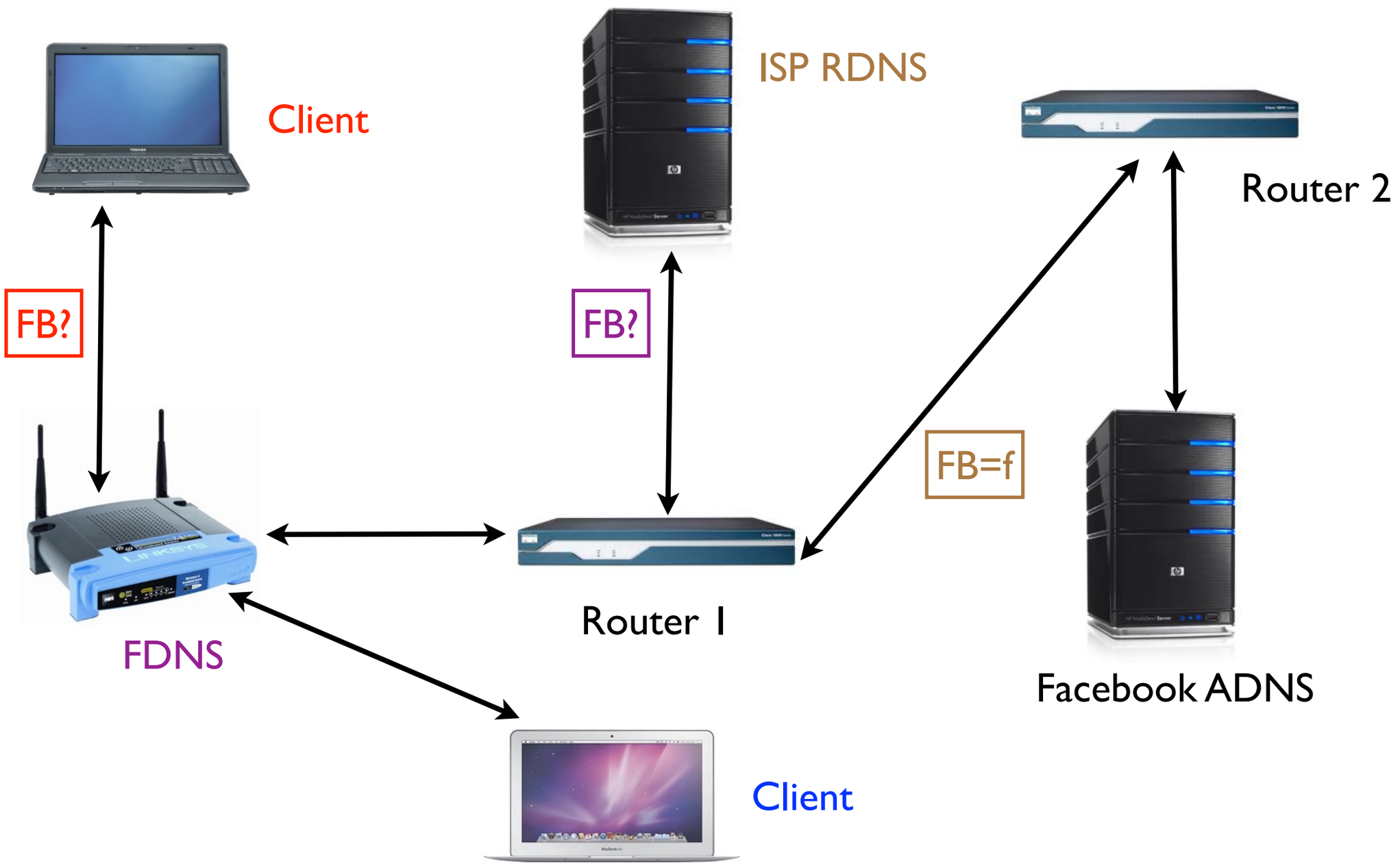

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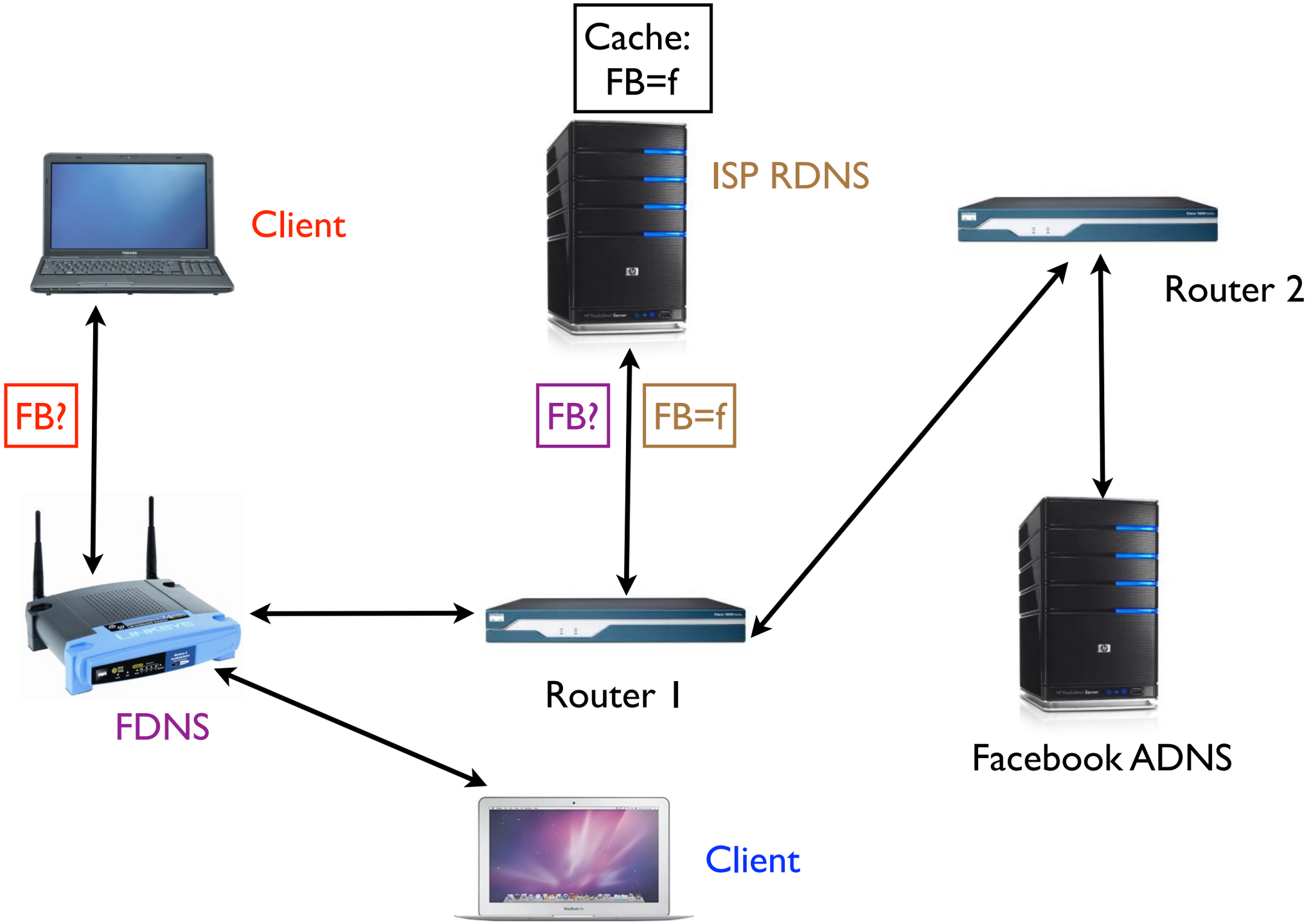

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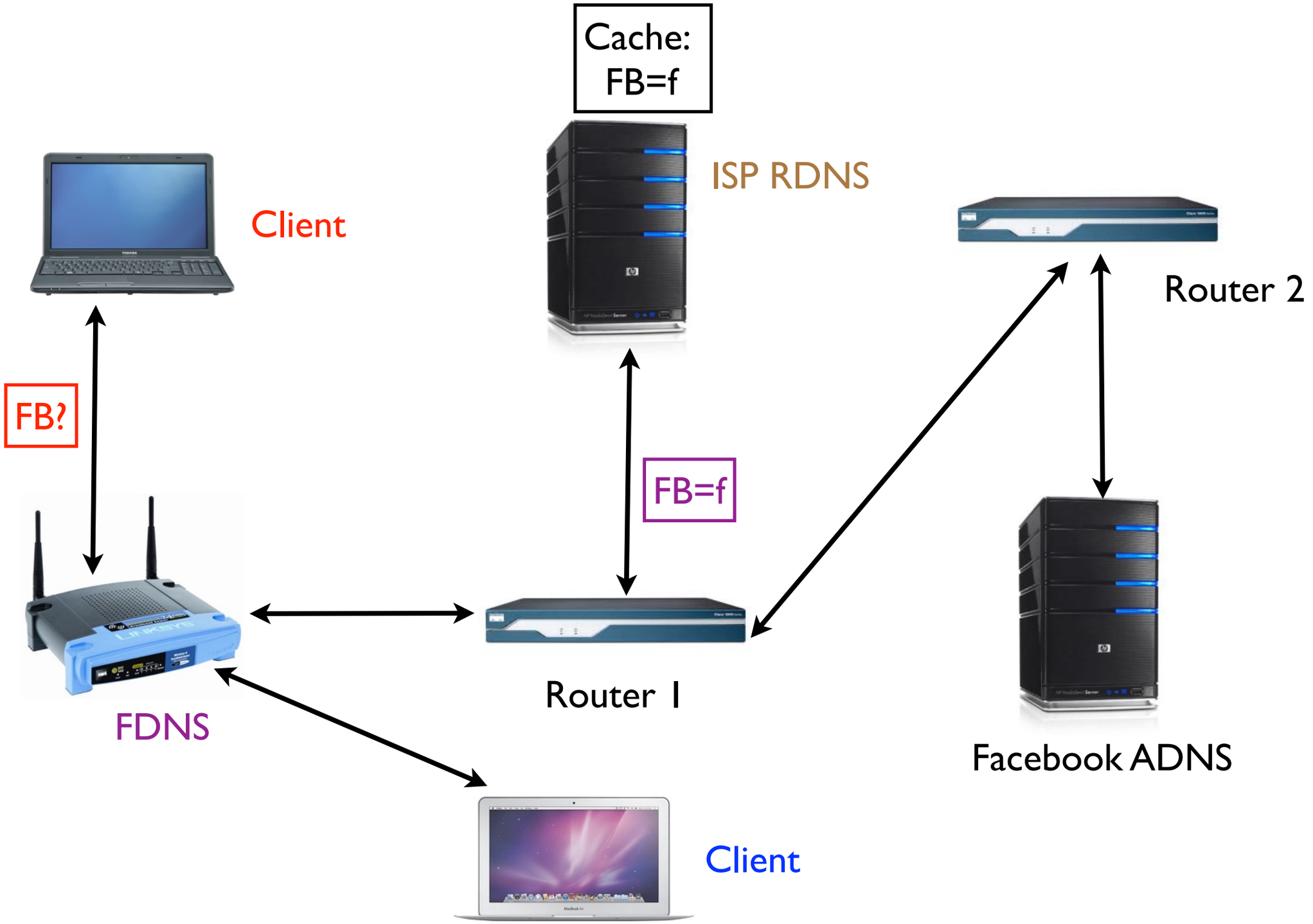

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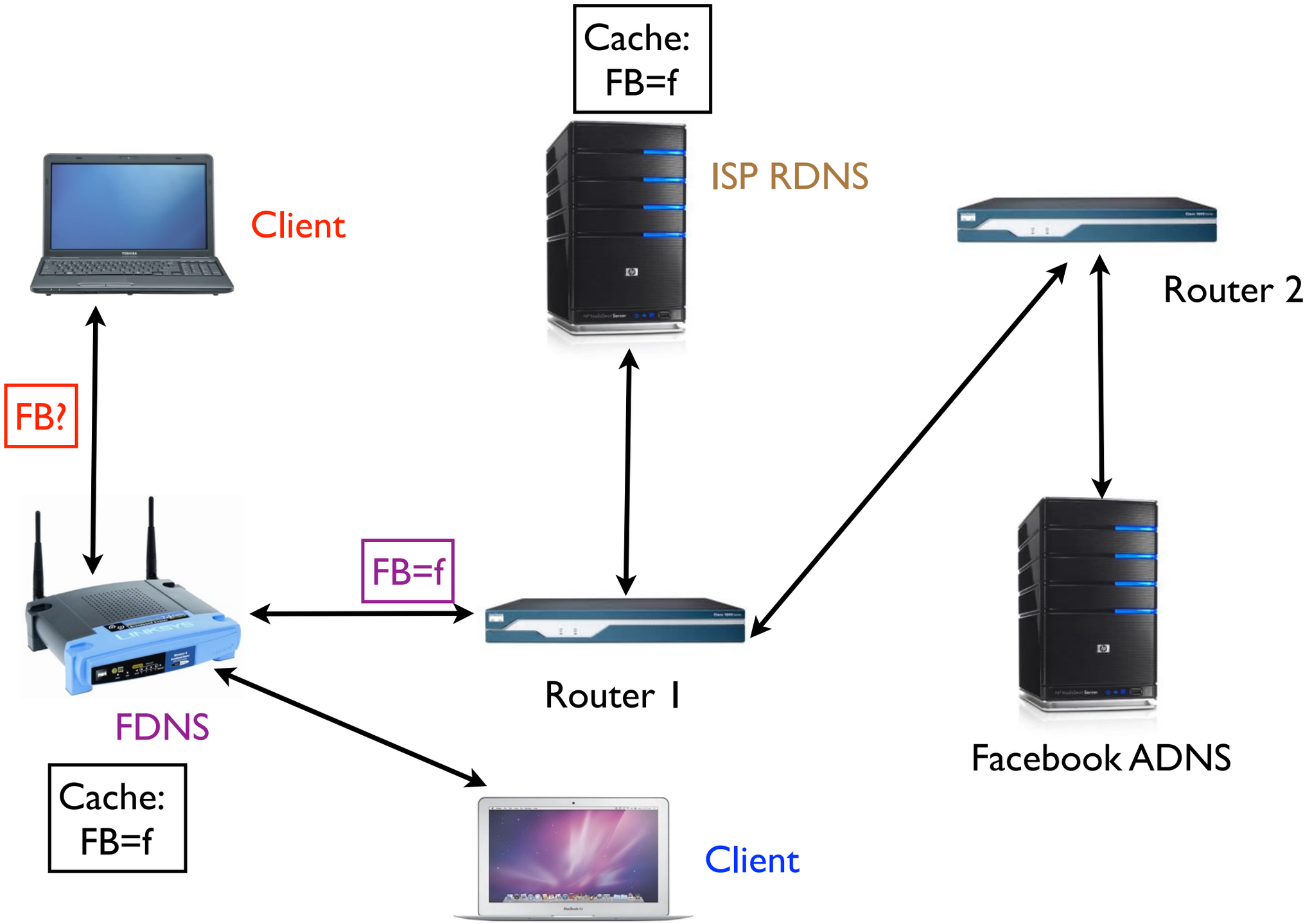

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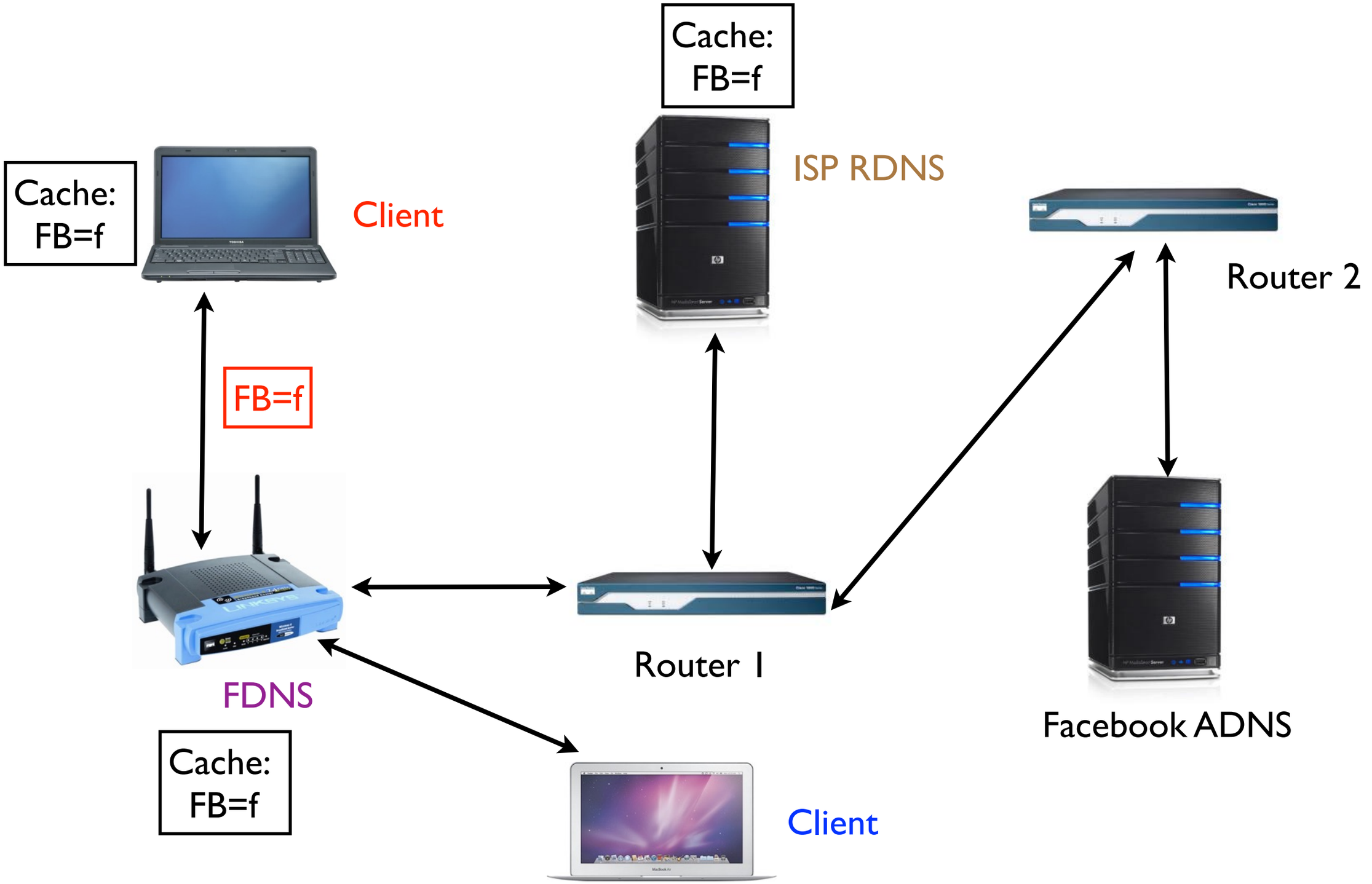

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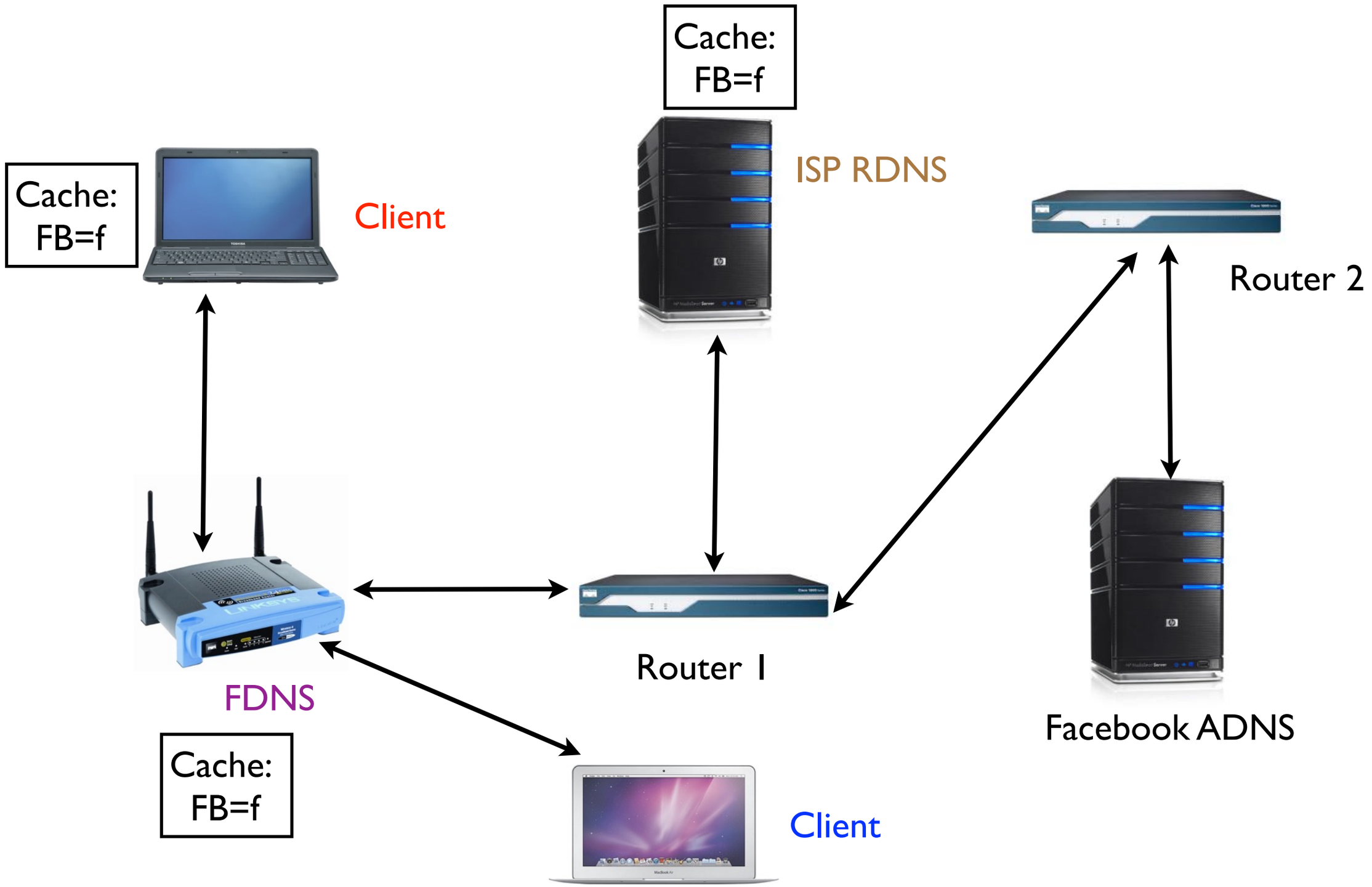

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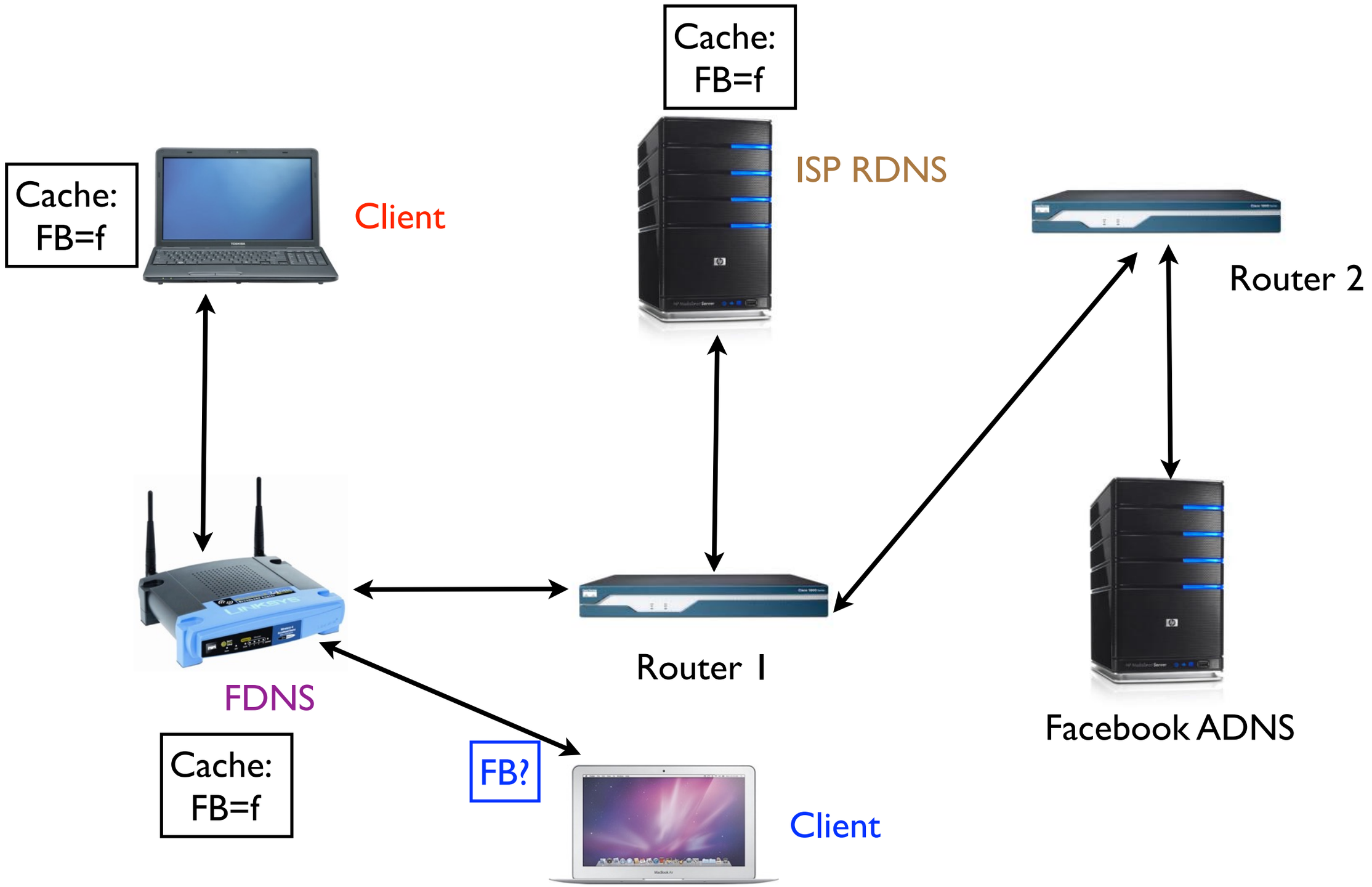

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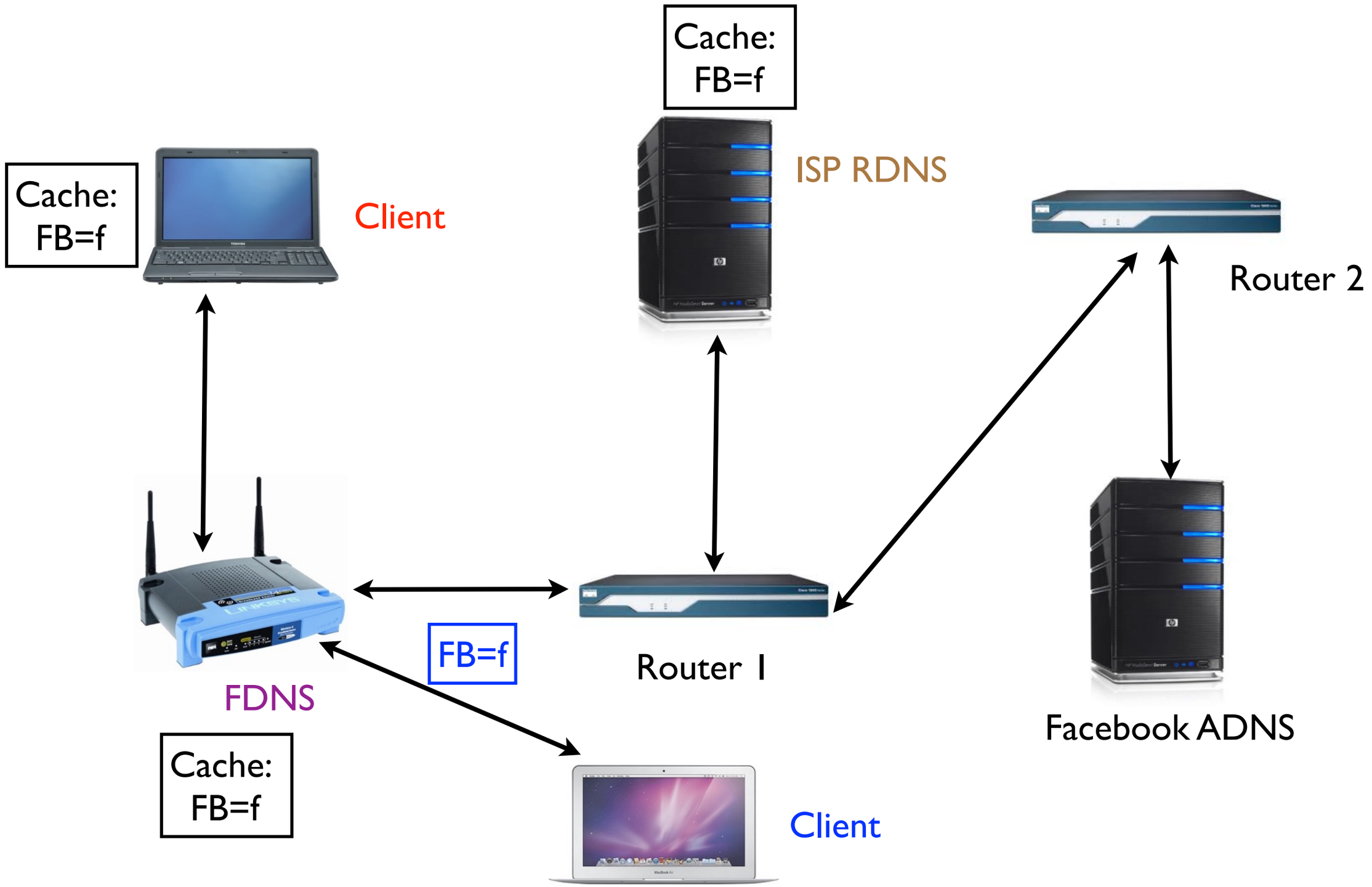
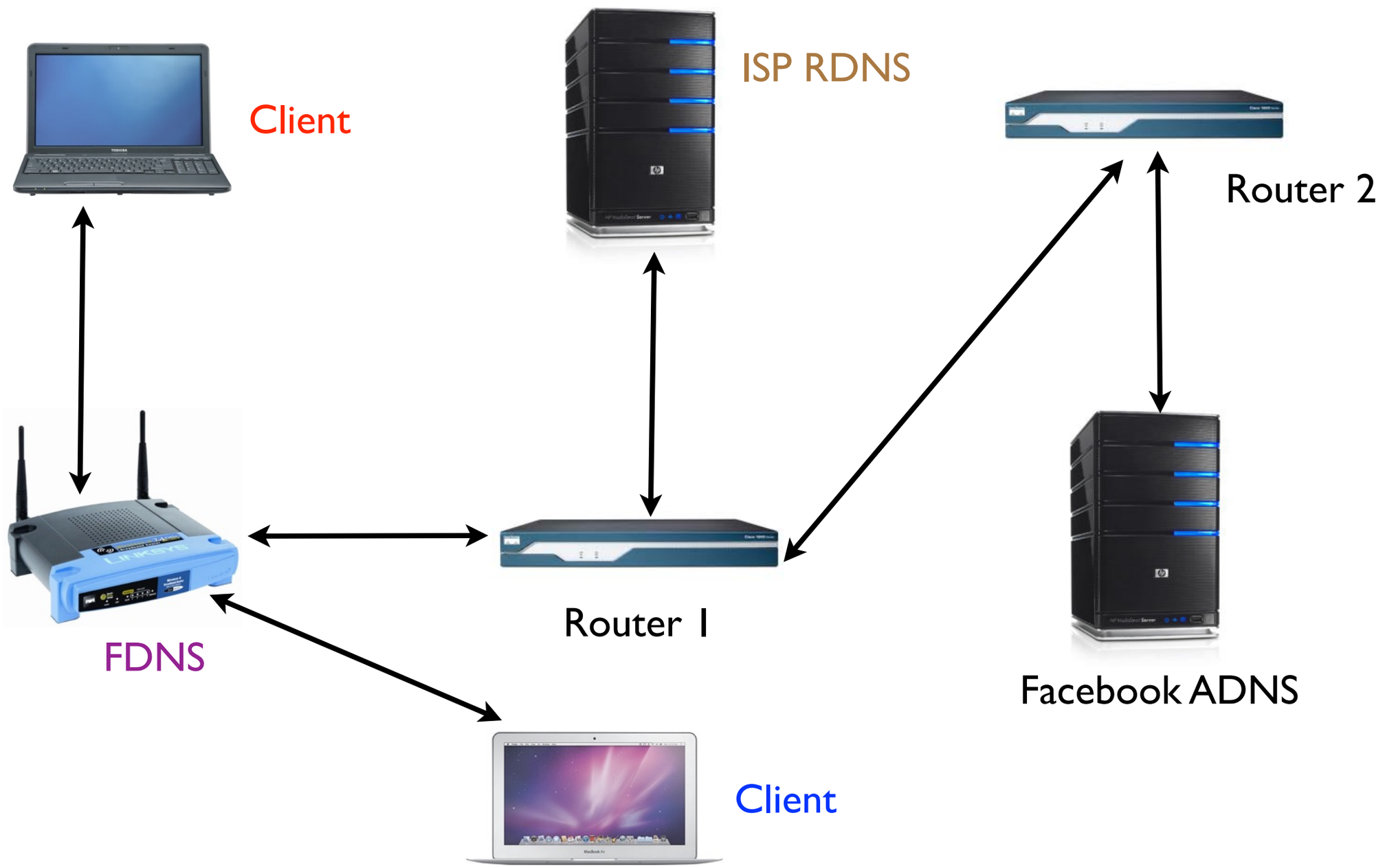


What Can Go Wrong? (1)



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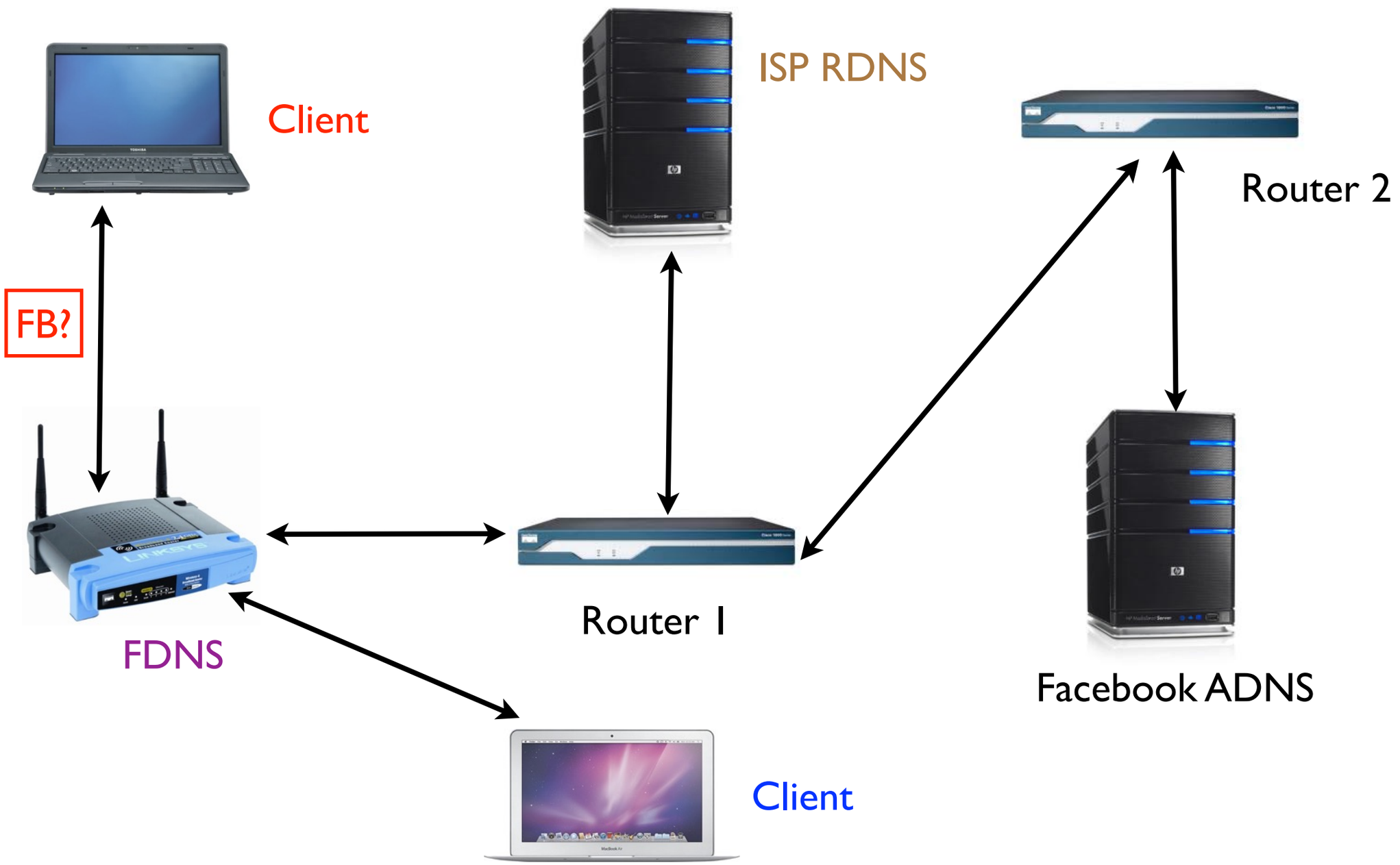

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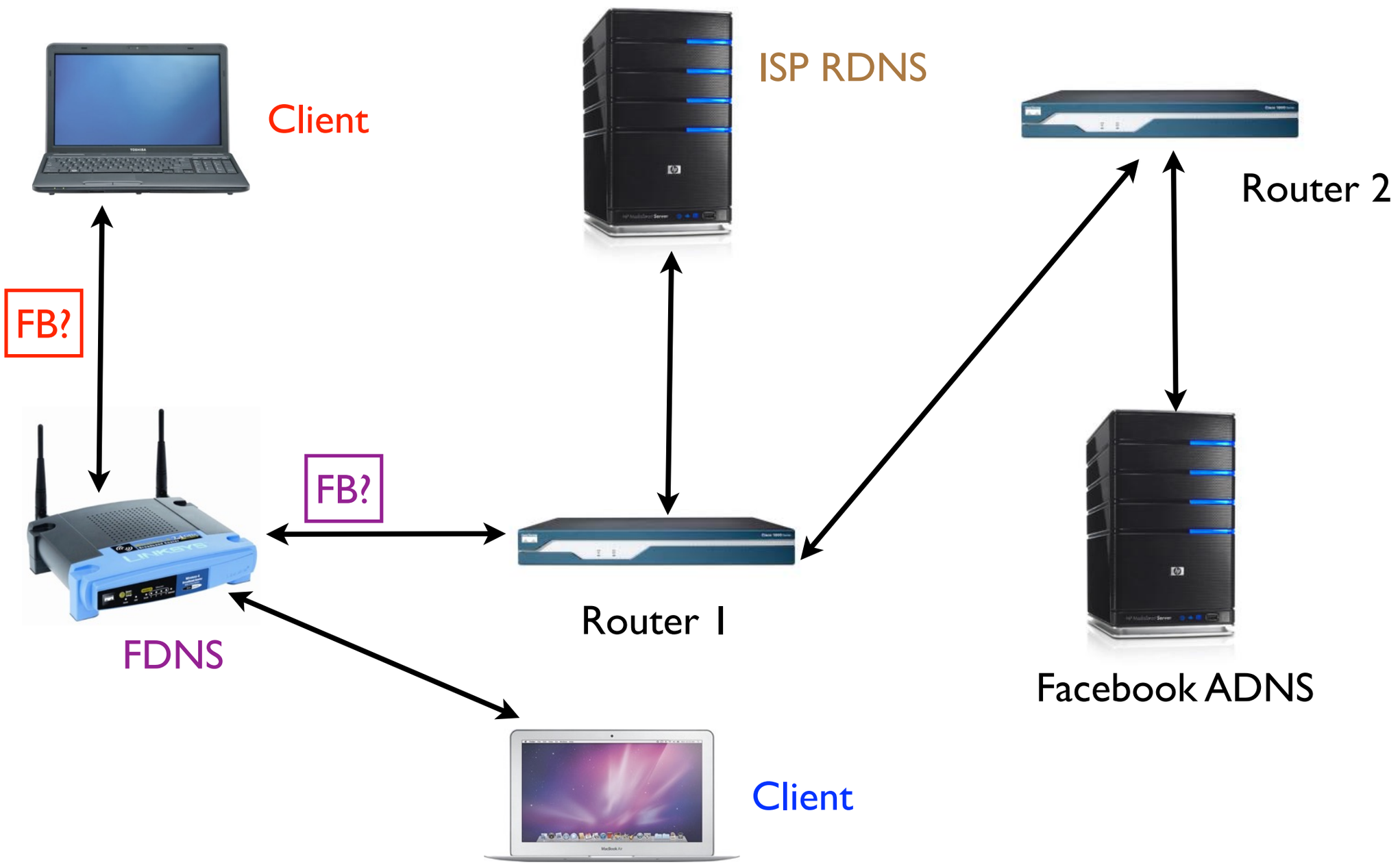

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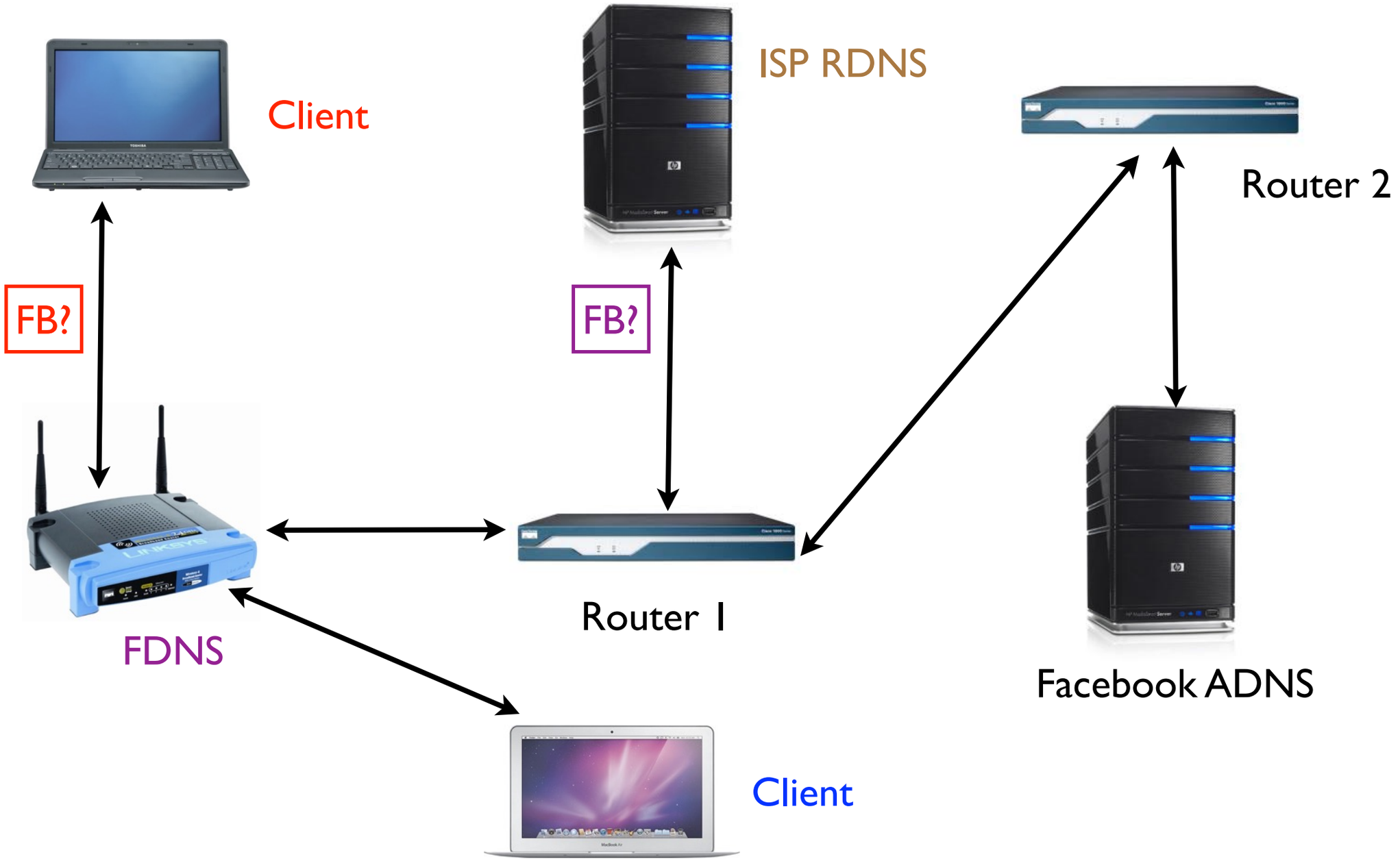

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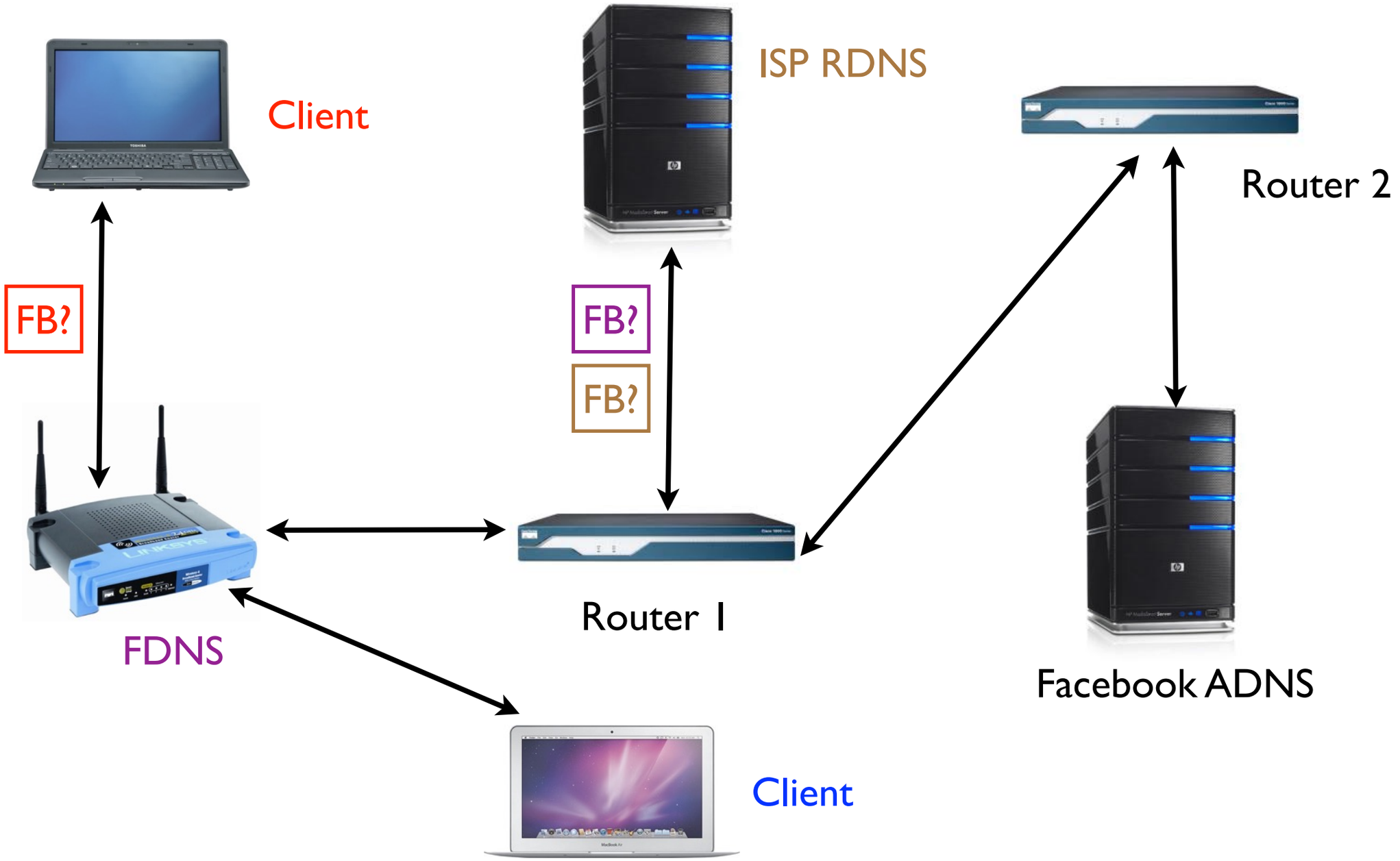

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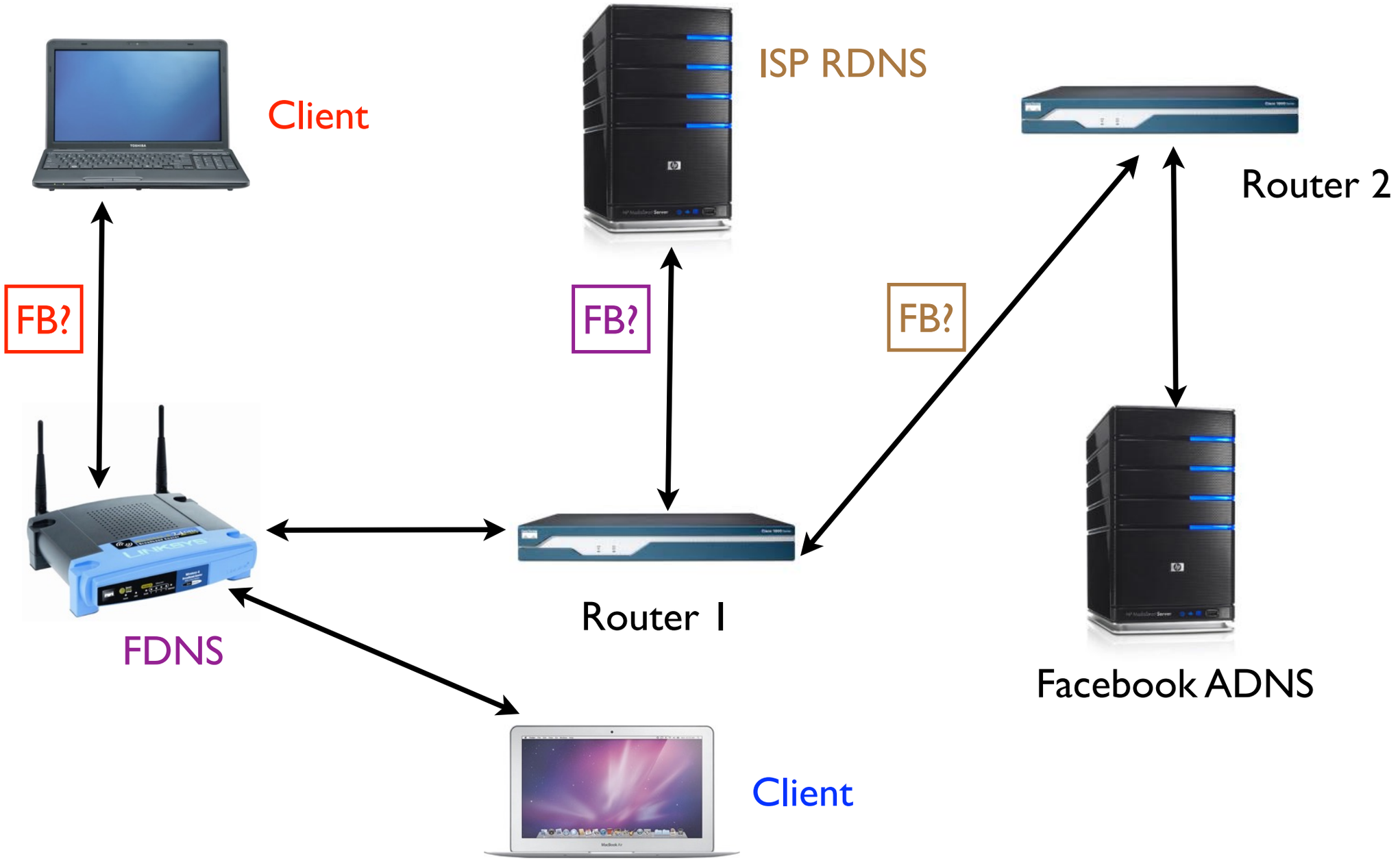

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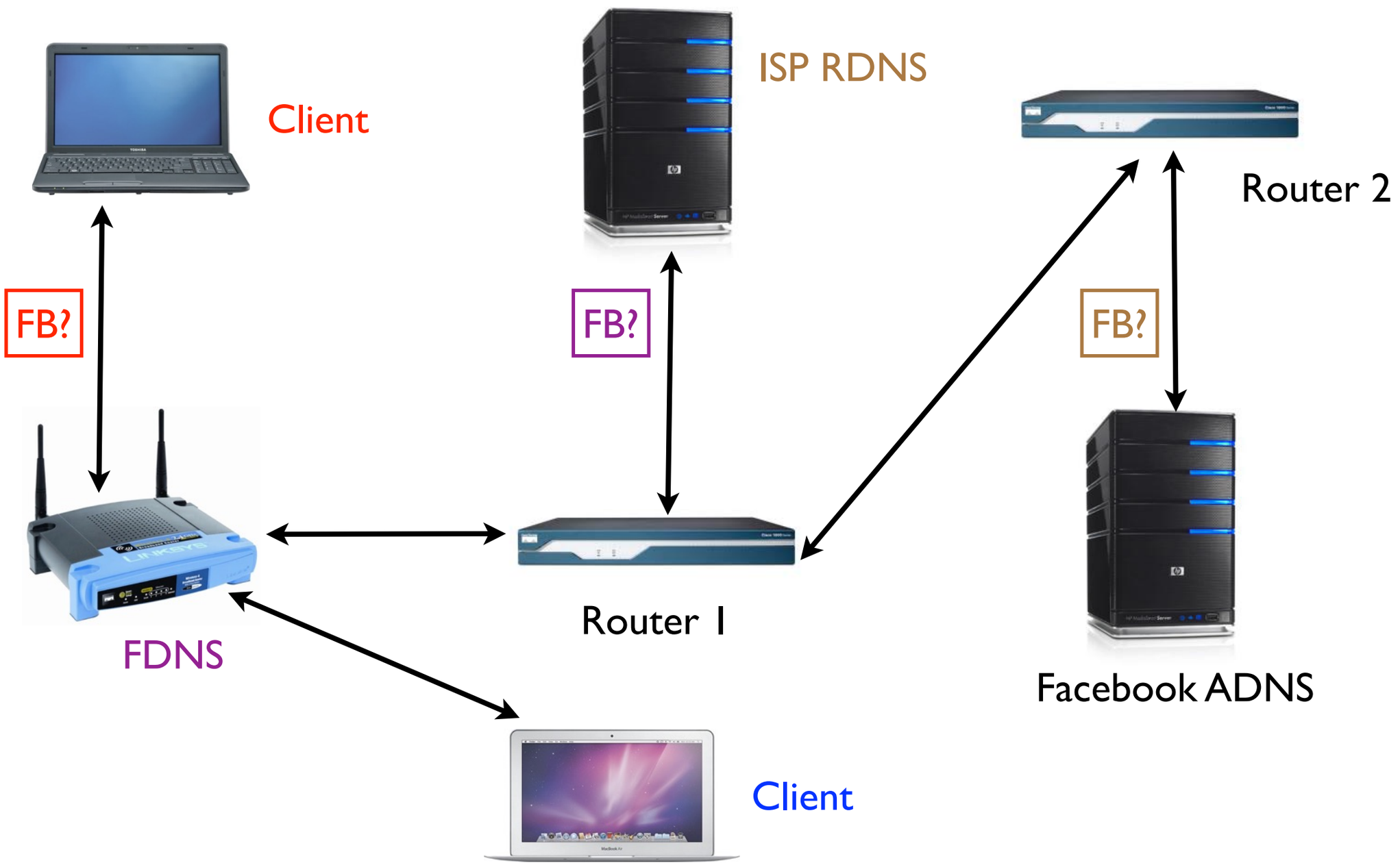

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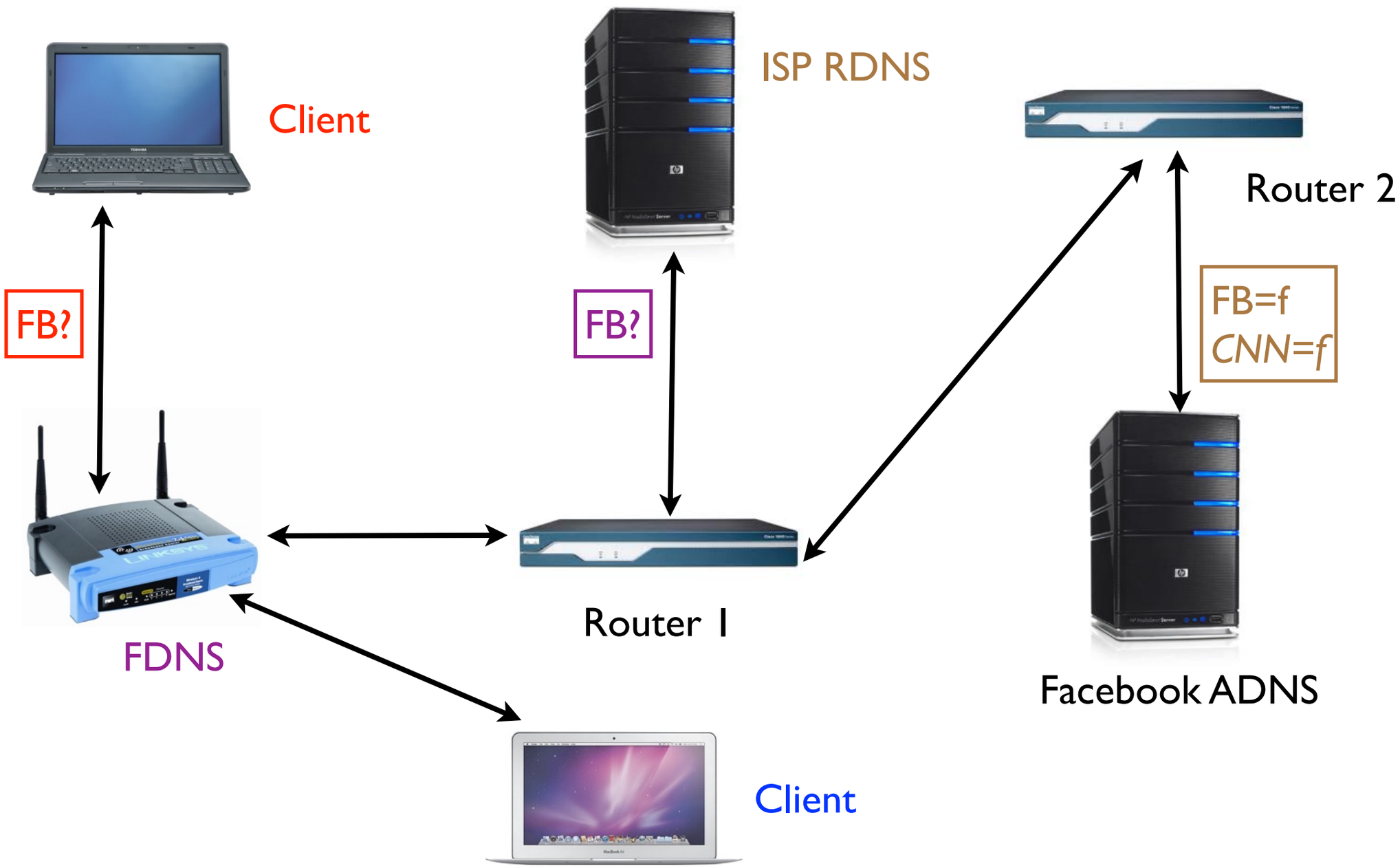

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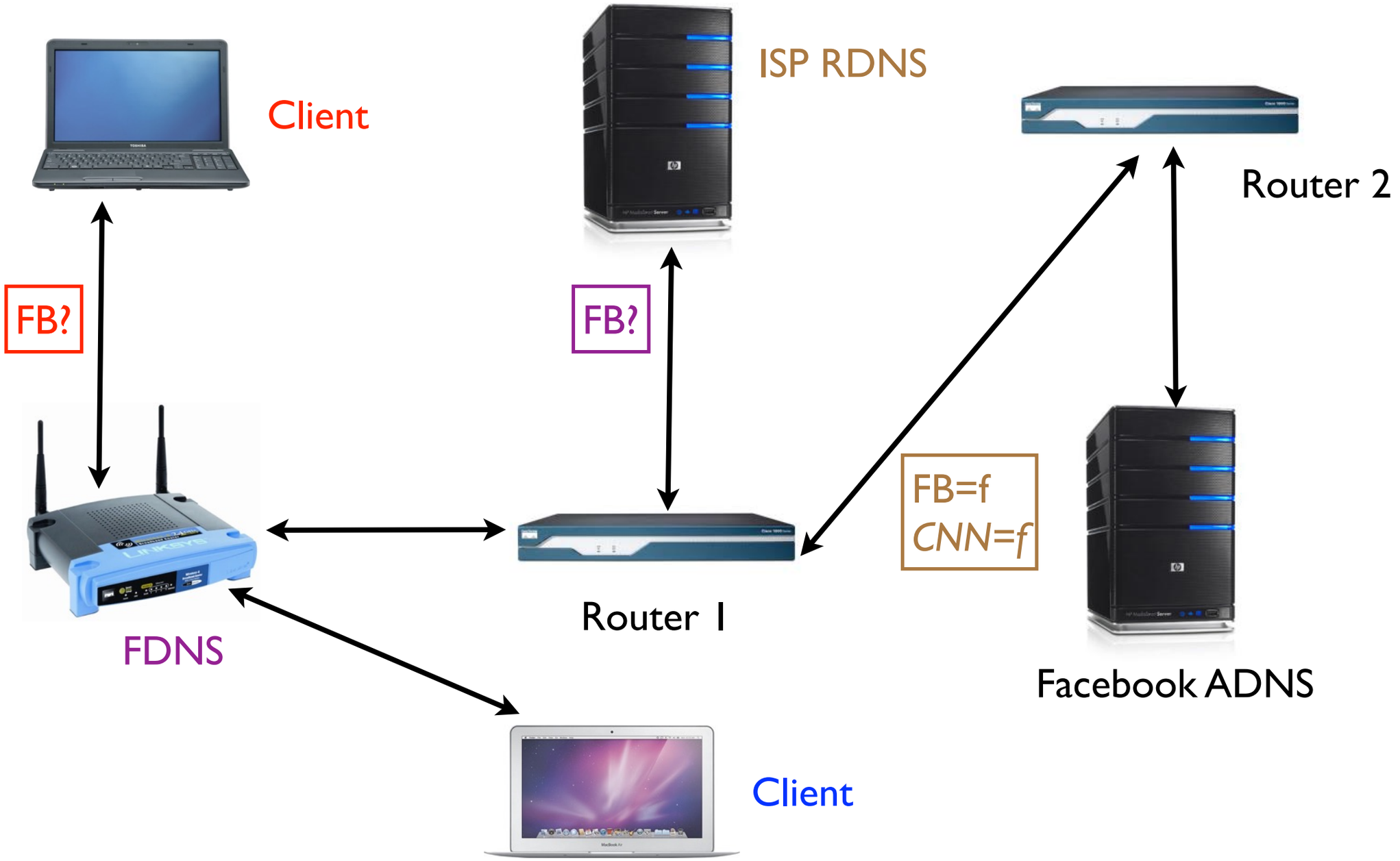

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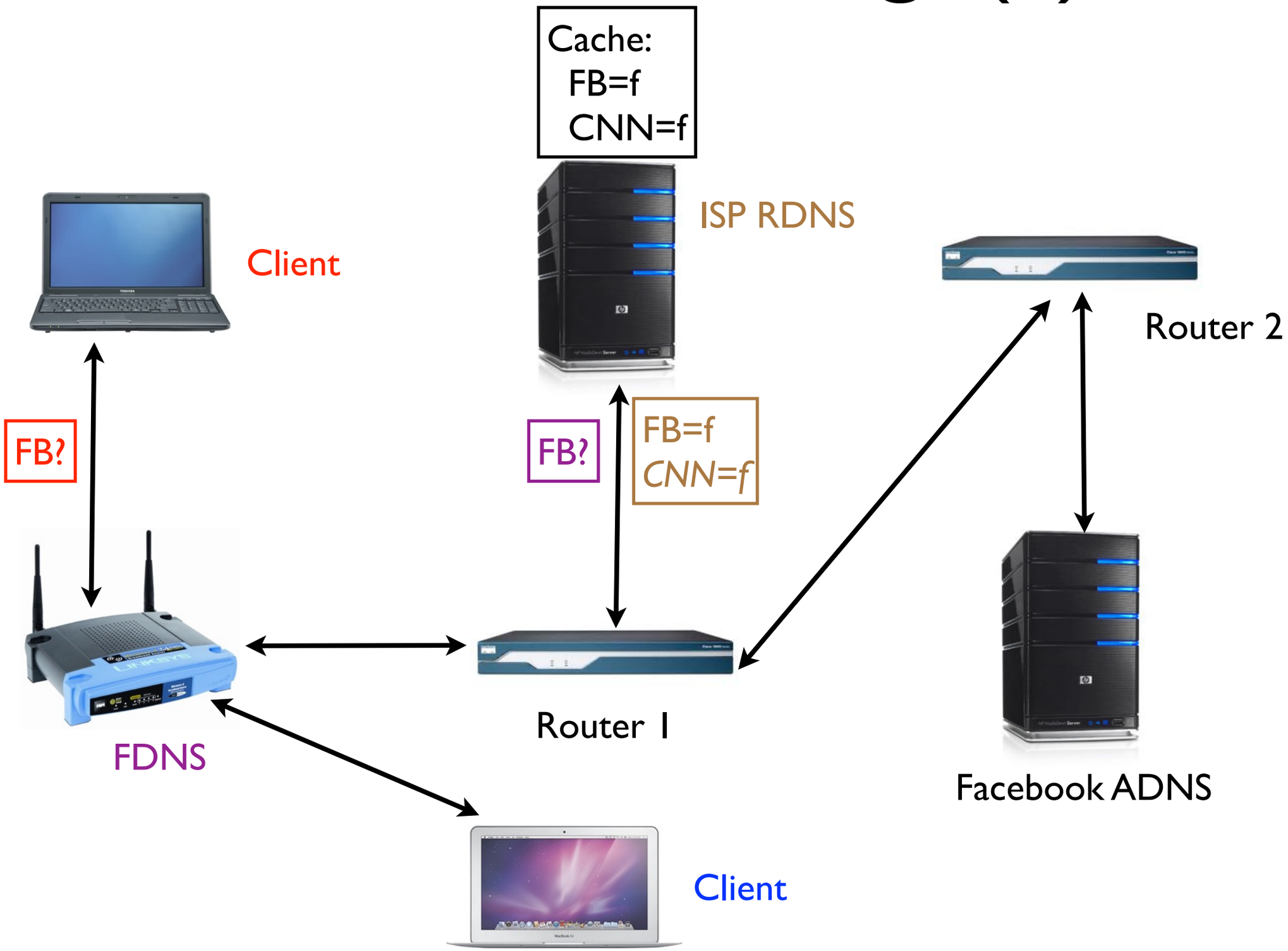

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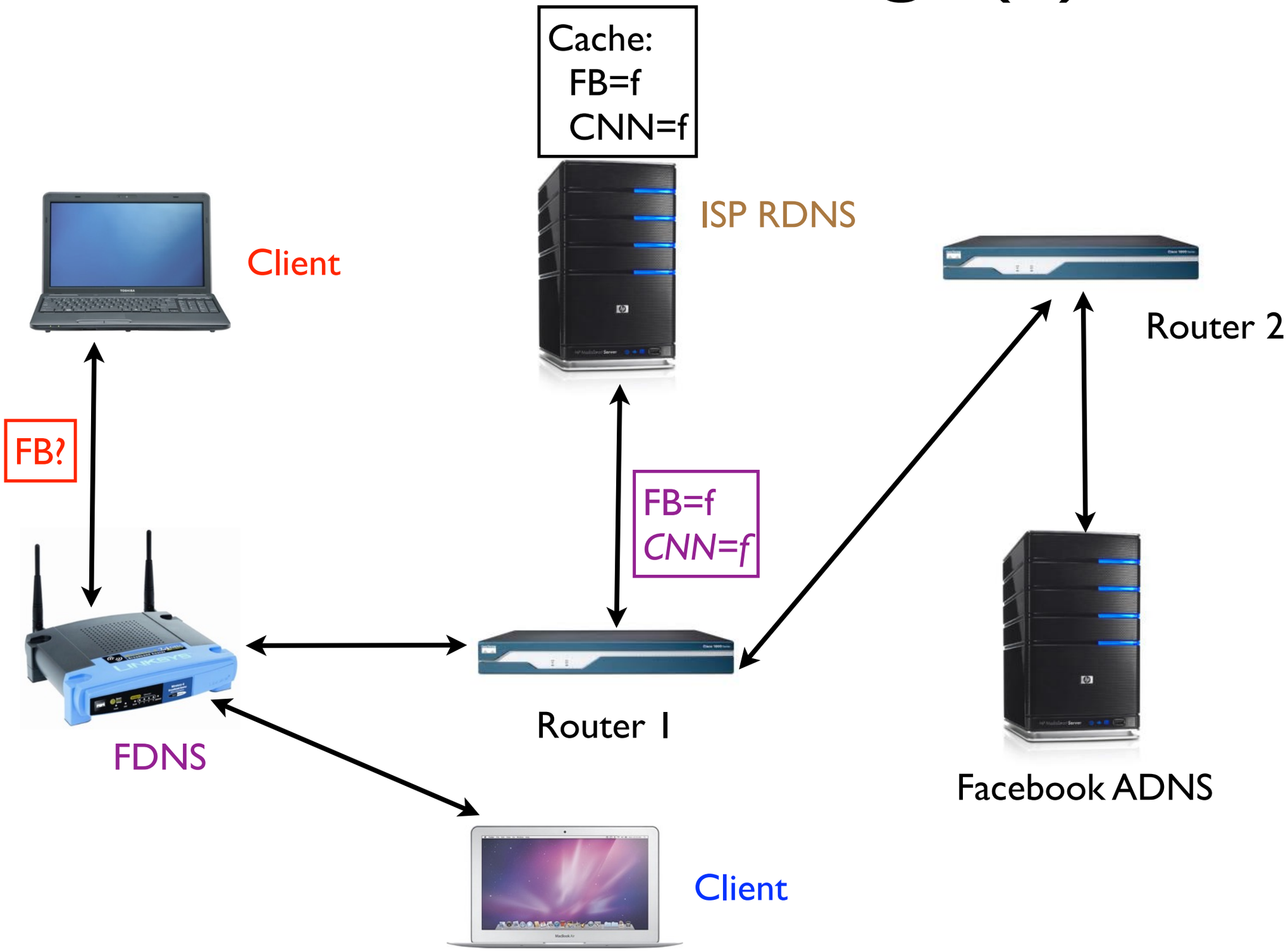

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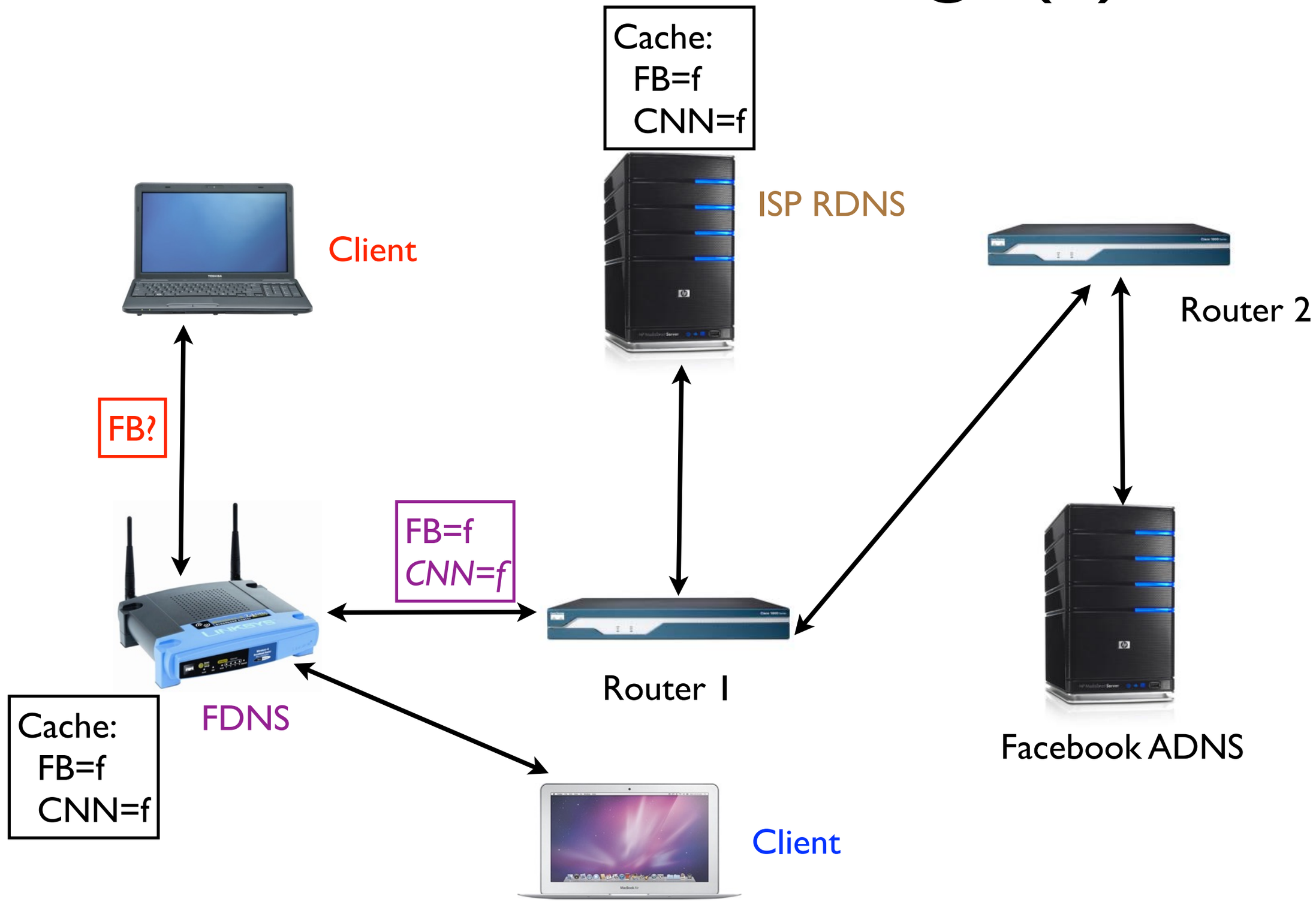

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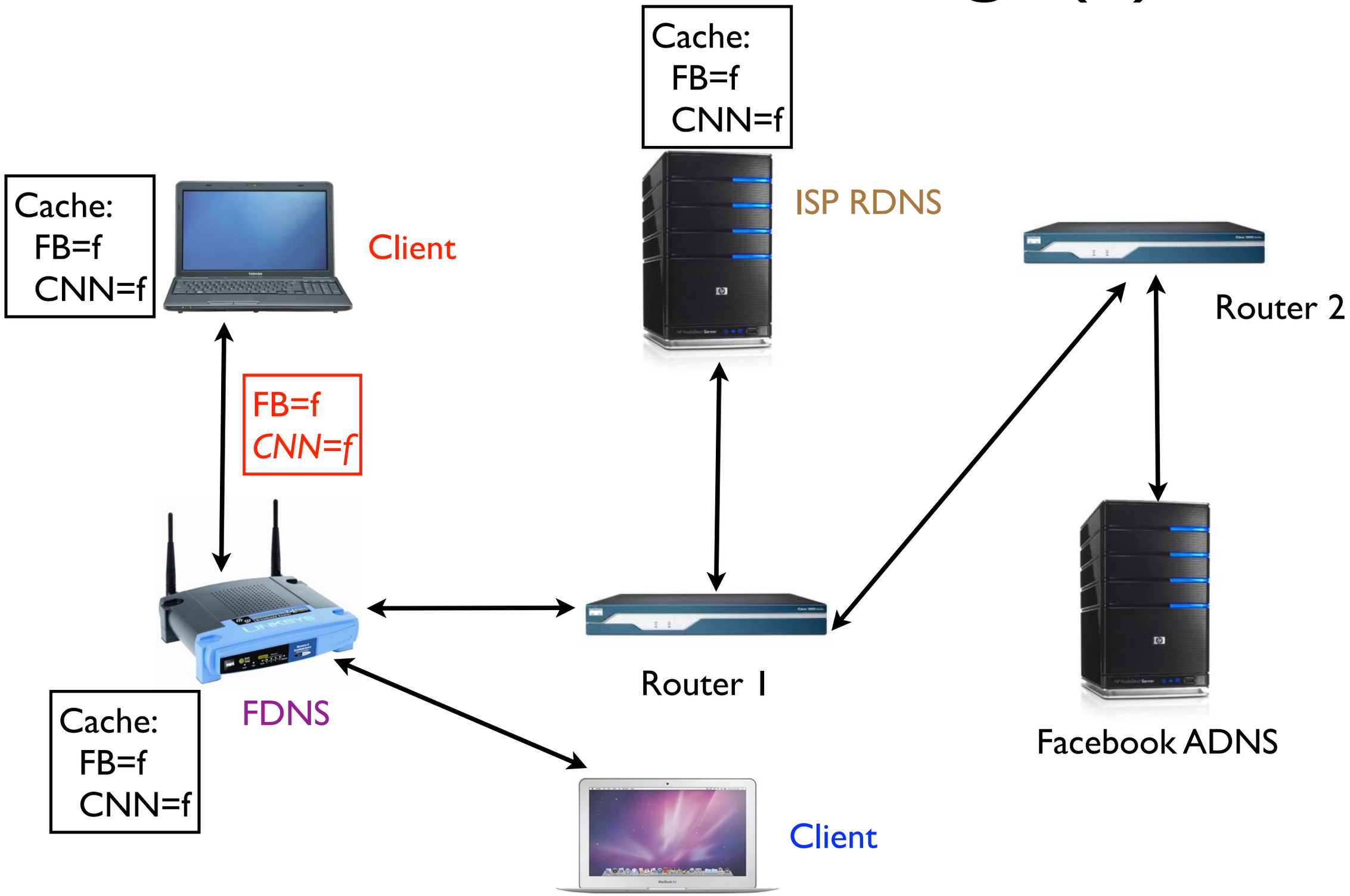

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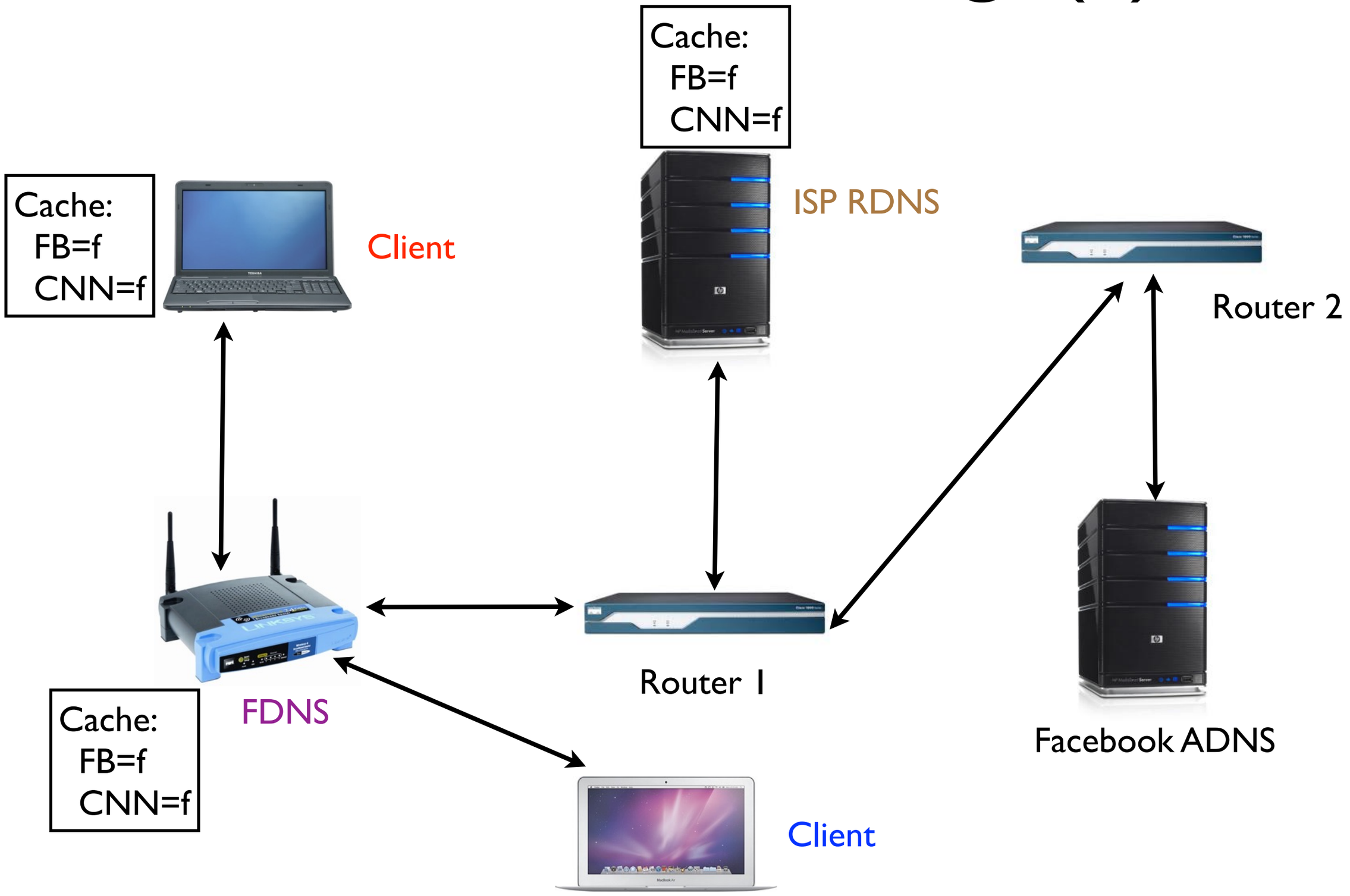

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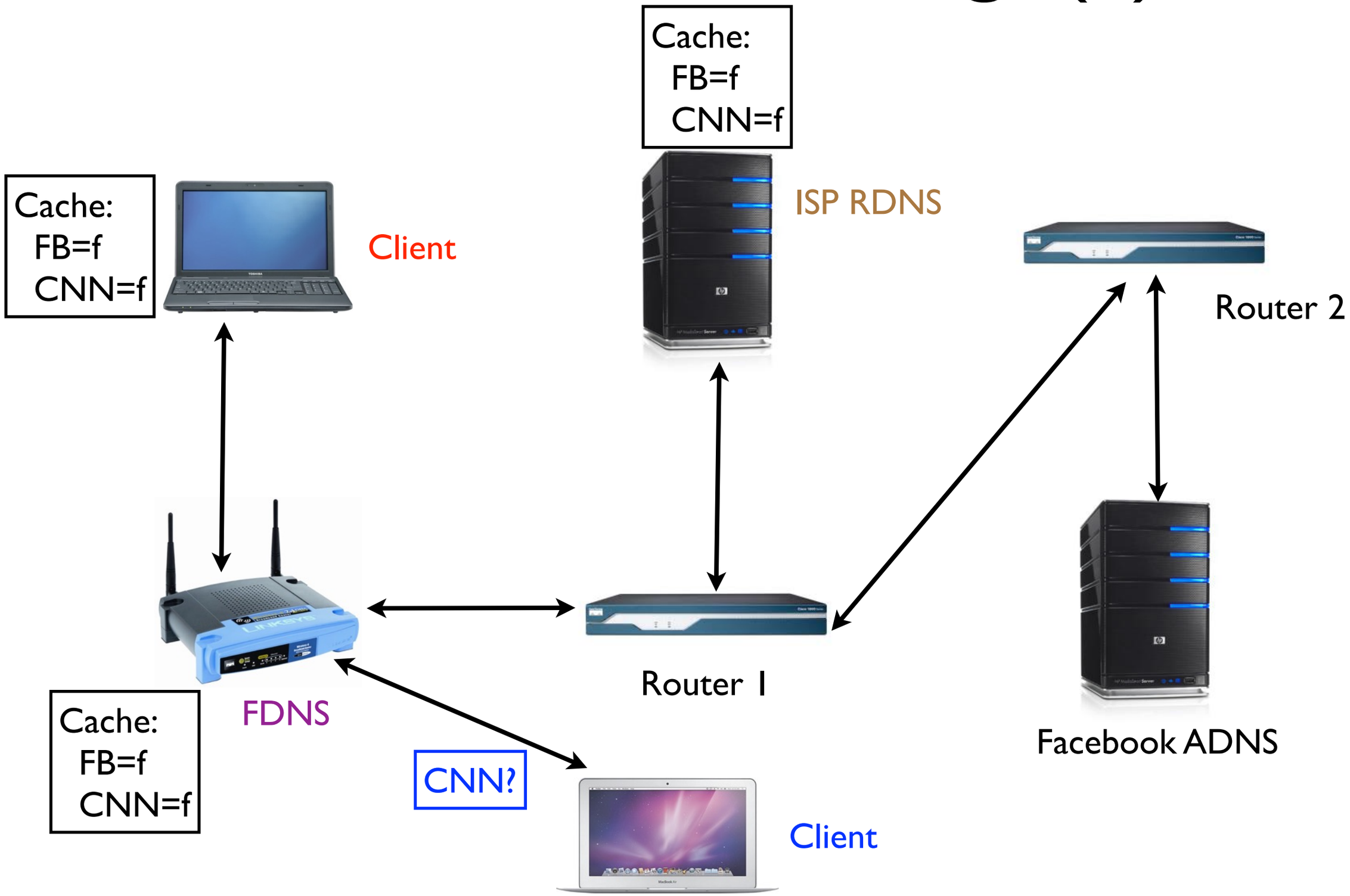

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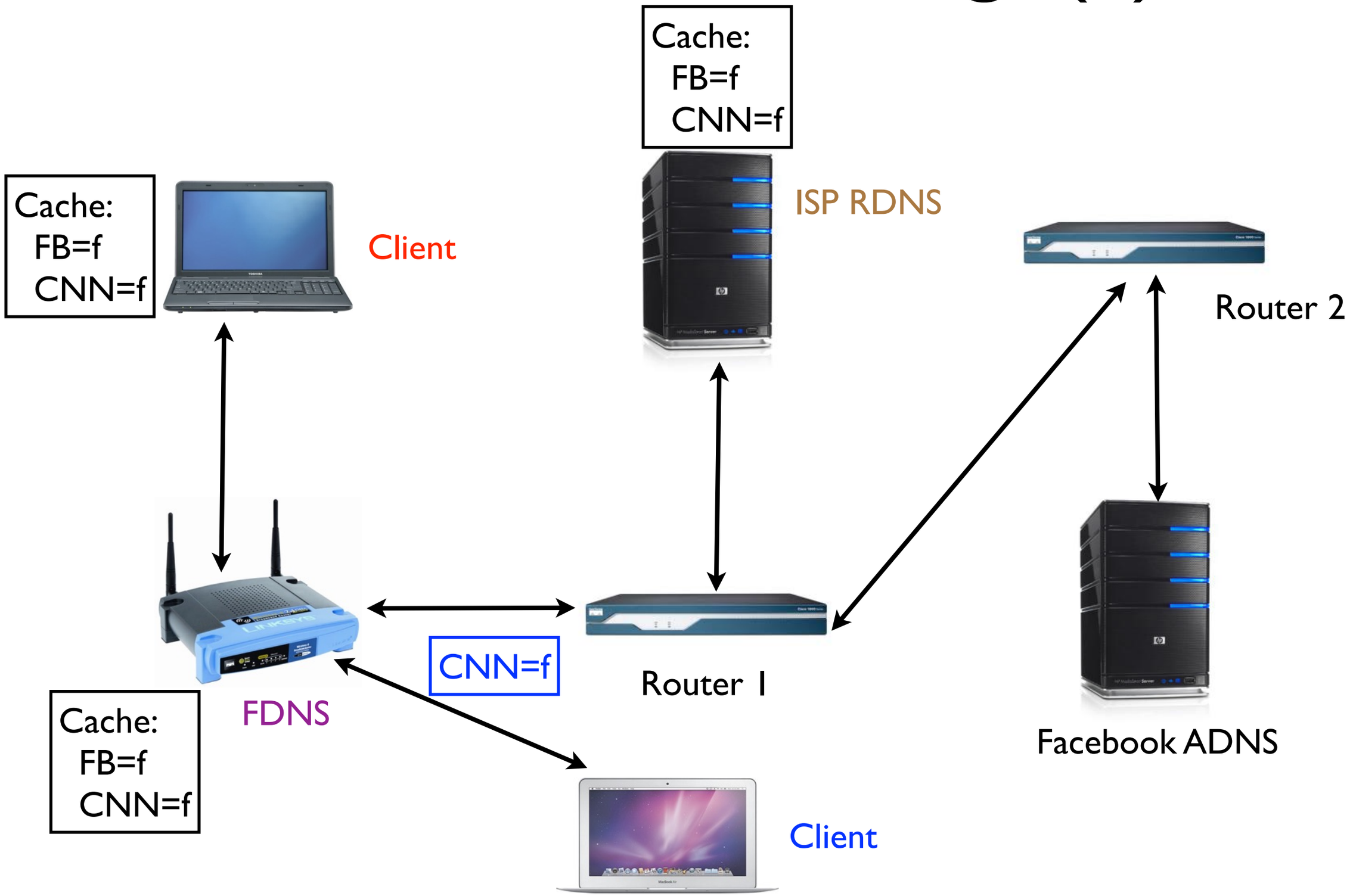

ADNS Lying

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  - prevents names from outside an ADNS' control from being accepted in responses

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- Out of 1.09M open resolvers scanned we find 749 cases where bogus names are cached by part of the DNS infrastructure