TCP Congestion Control Advanced Techniques (Contd.)

CPSC 433/533, Spring 2021

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Router-assisted Congestion Control

- **Three tasks for CC:**
  - Isolation/fairness
  - Adjustment
  - Detecting congestion

Max-Min Fairness

- Given a set of bandwidth demands r_i and total bandwidth C, max-min bandwidth allocations are:

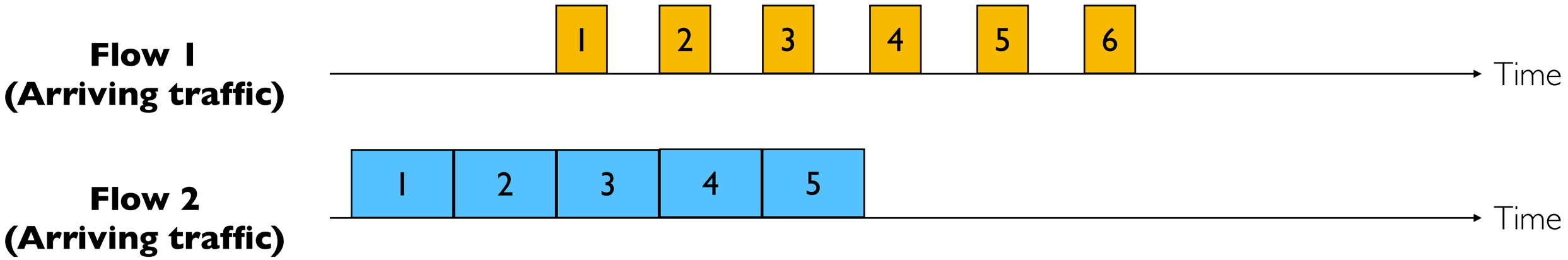
$$a_i = min(f, r_i)$$

  where f is the unique value such that $\sum_i a_i = C$

- Property:
  - If you don't get full demand, no one gets more than you

- This is what round robin service gives if all packets are the same size

Practical Fair Queueing (FQ)



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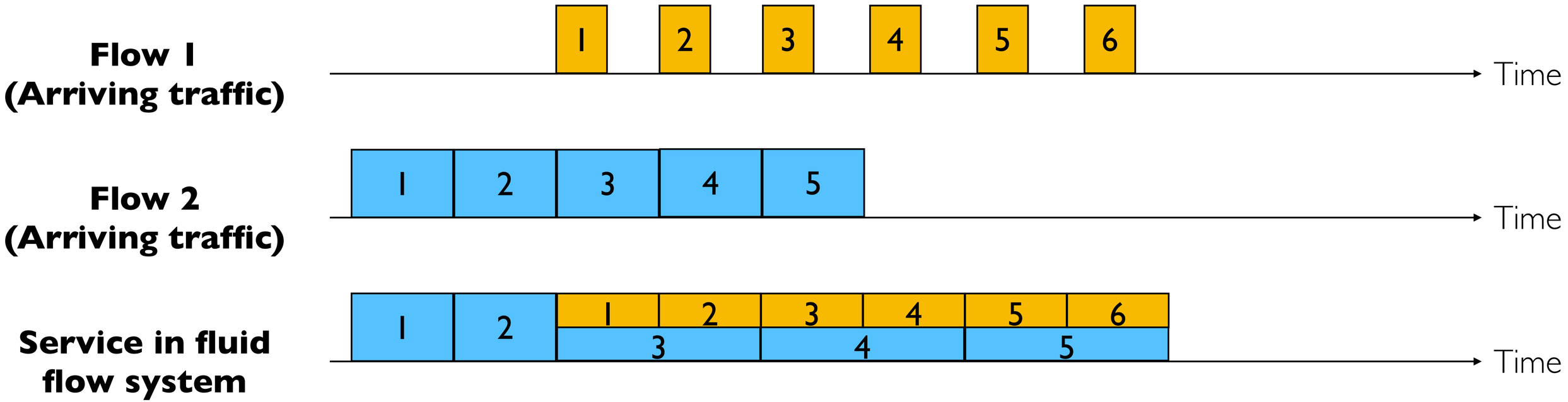

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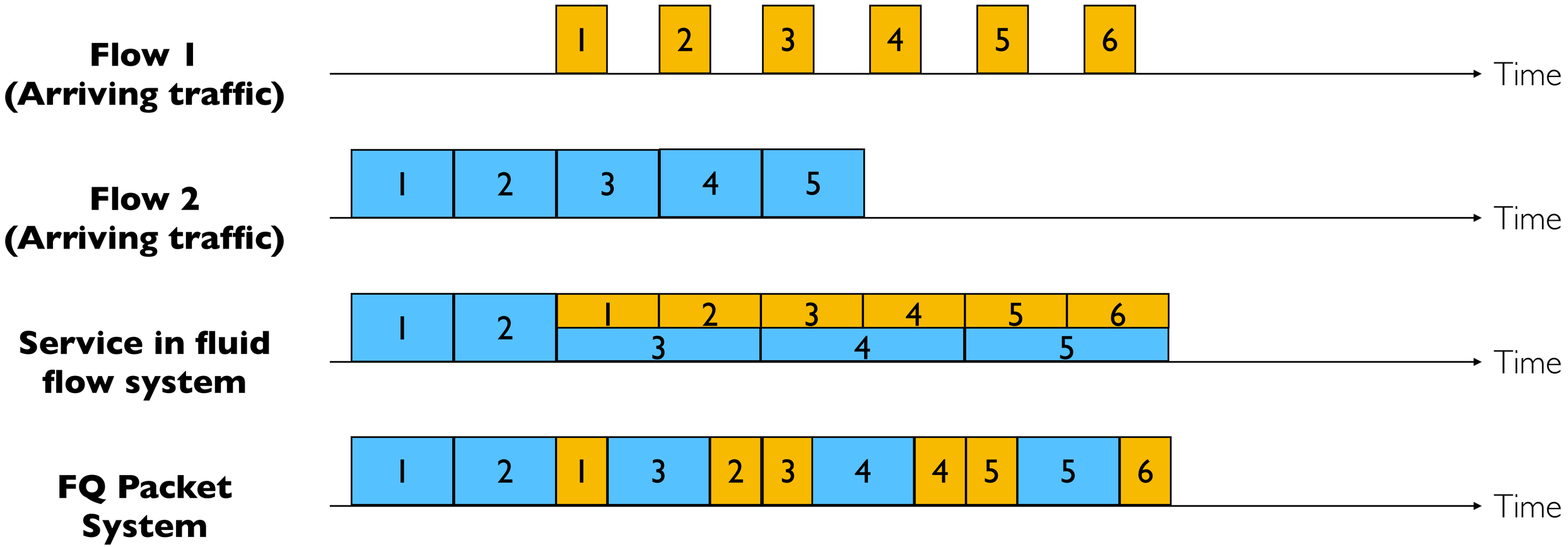

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  - Isolation: cheating flows don't benefit
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  - Isolation: cheating flows don't benefit
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- **Disadvantages**
  - More complex than FIFO: per flow queue/state, additional per-packet book-keeping

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- End-systems set sending rate (or window size) to f
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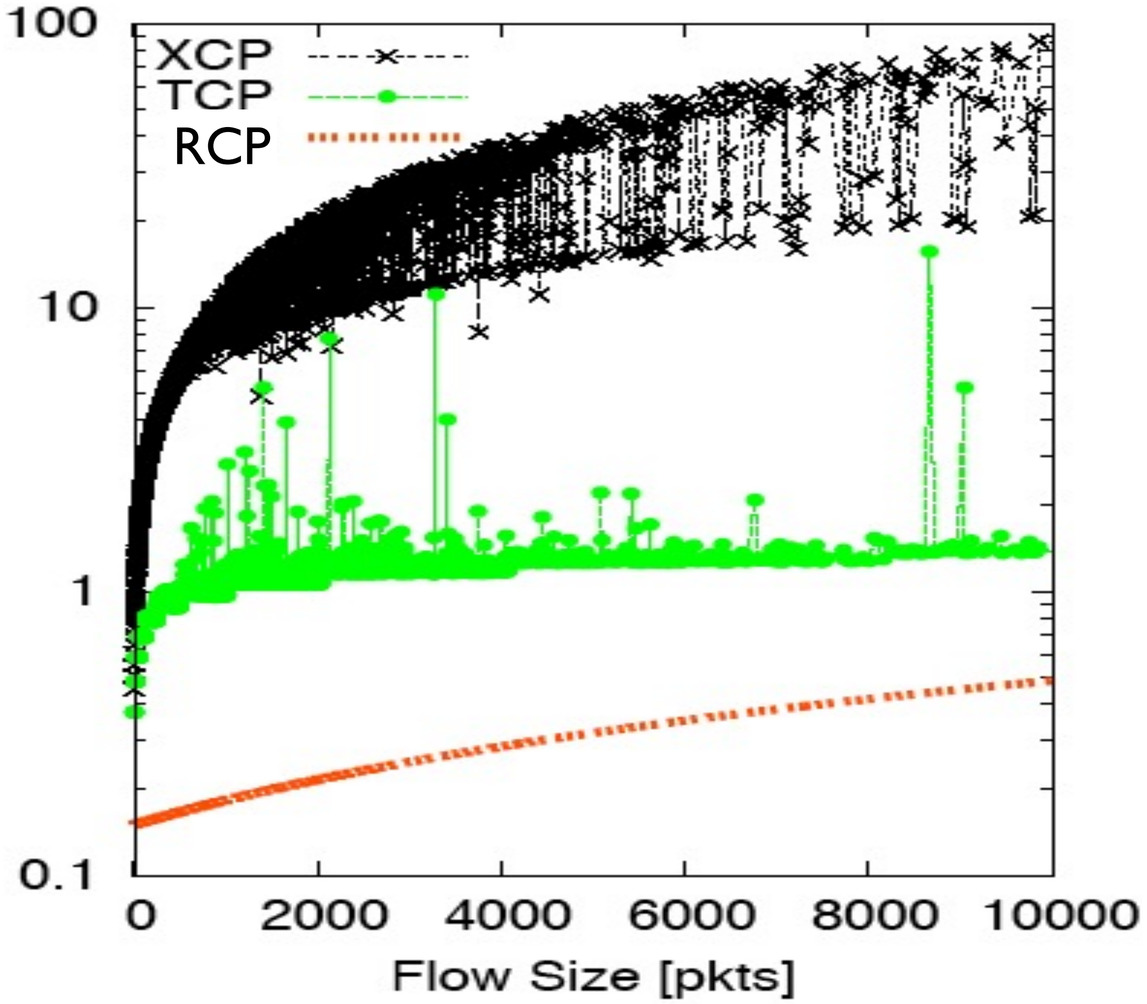
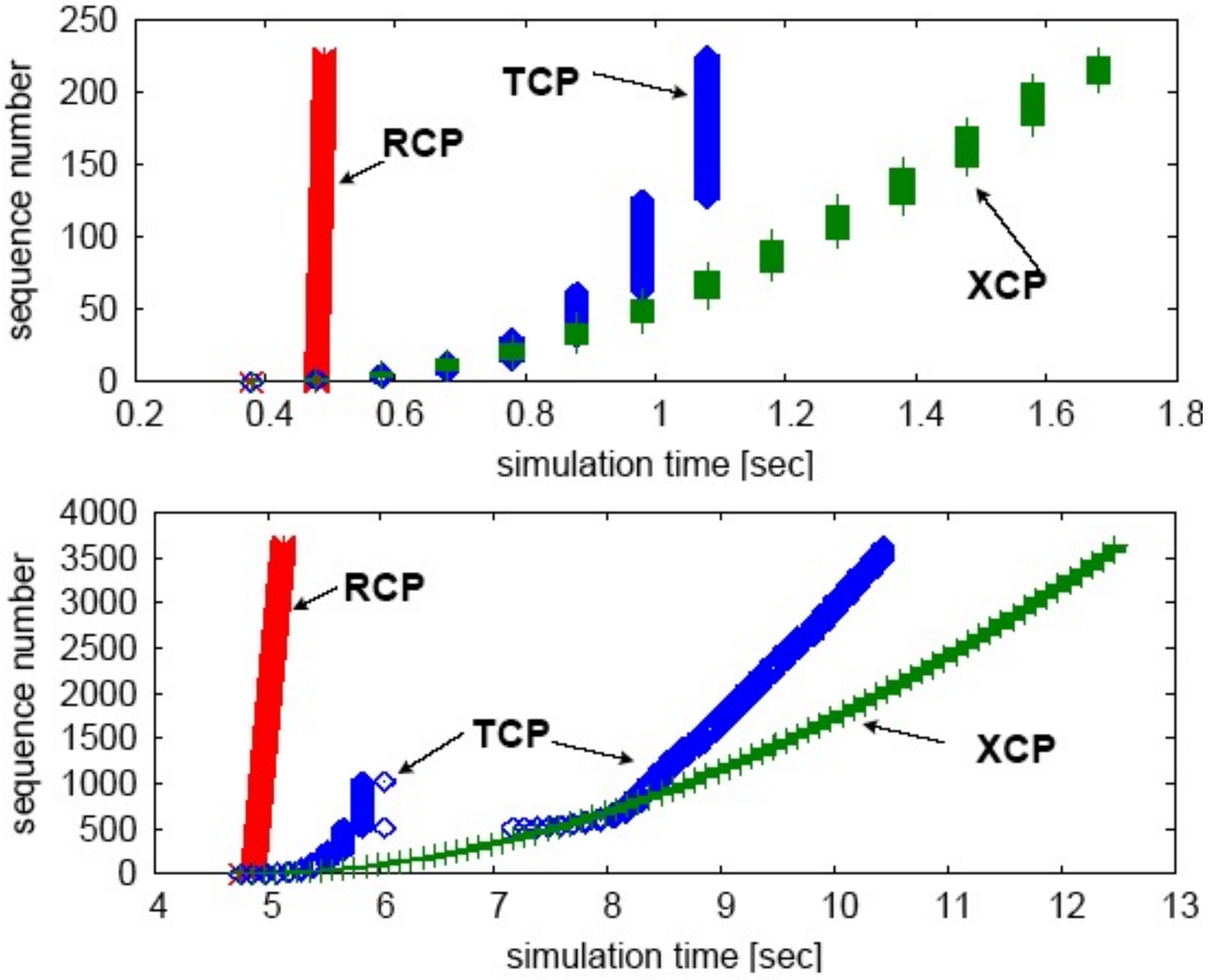
- *Basic idea behind the "Rate Control Protocol" (RCP) from Dukkipati et. al.'07*

Flow Completion Time: TCP vs. RCP (Ignore XCP)

Flow Duration (seconds) vs. Flow Size



Why the Improvement?



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- **Advantages:**
  - Don't confuse corruption with congestion; recovery with rate adjustment
  - Can serve as an early indicator of congestion to avoid delays
  - Easy (easier) to incrementally deploy
    - Today: defined in RFC 3168 using **ToS/DSCP** bits in the IP header

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- Now there's no debate over what a flow is, or what fair is…
- Idea started by Frank Kelly at Cambridge
  - "Optimal" solution, backed by much math
  - Great idea: simple, elegant, effective
  - Unclear that it will impact practice

Recap: TCP

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- TCP
  - Somewhat hacky
  - But practical/deployable
  - Good enough for Internet traffic
  - Needs of data centers might change status quo (future lecture)

Taking Stock: Transport Layer

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- **Communication between application processes**
  - Multiplex and demultiplex from/to application processes using ***ports***

Taking Stock: Transport Layer

- **Communication between application processes**

- **Provide common end-to-end services for application layer [optional]**
  - Reliable, in-order data delivery
  - Well-placed data delivery
    - Too fast may overwhelm the receiver/network
    - Too slow is not efficient

Taking Stock: Transport Layer

- **Communication between application processes**
- **Provide common end-to-end services for application layer [optional]**
- **TCP and UDP are the common transport protocols**
  - Also SCTP, MTCP, SST, RDP, DCCP, …

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  - Only provides multiplex/demultiplex capabilities

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- **TCP and UDP are the common transport protocols**
- **UDP is a minimalist, no-frills transport protocol**
- **TCP is the whole-hog protocol**
  - Offers applications a reliable, in-order, byte stream abstraction
  - With congestion control
  - But no performance guarantees (delay, bw, etc.)

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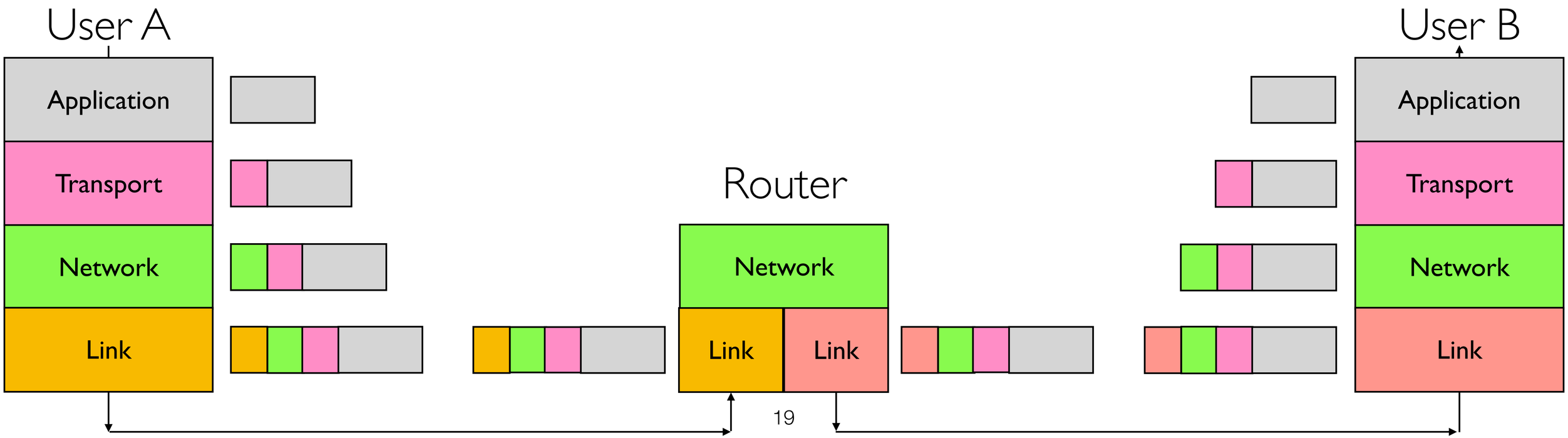

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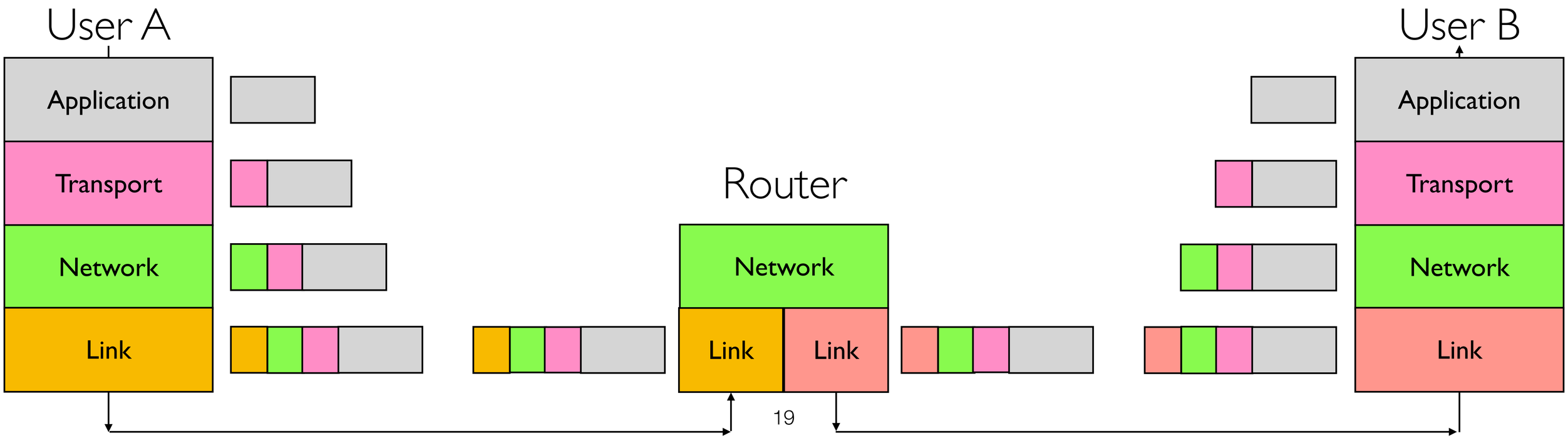

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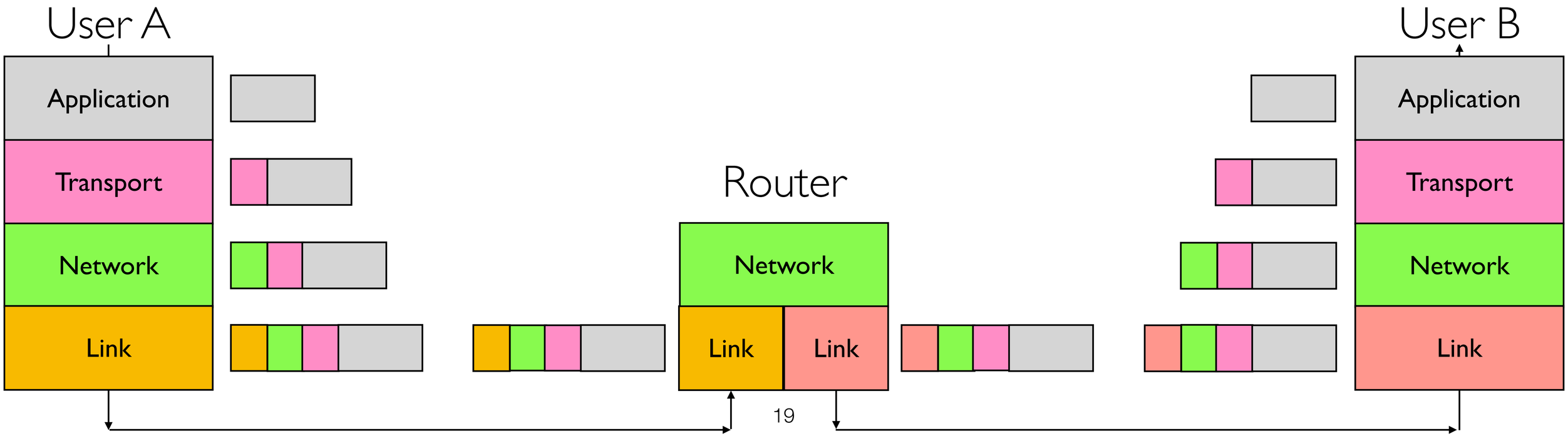

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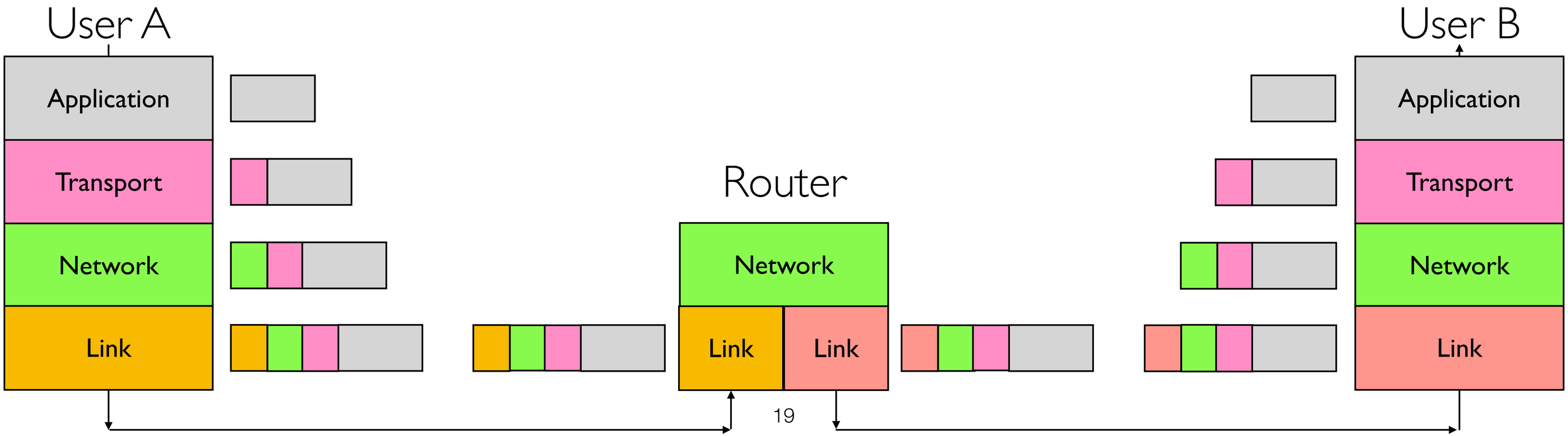

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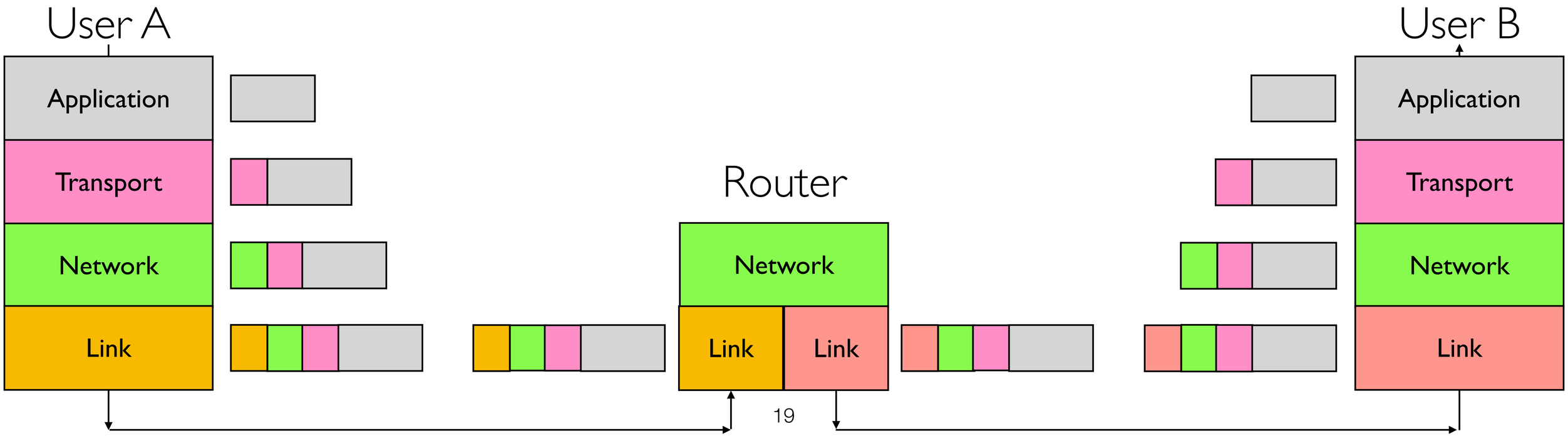

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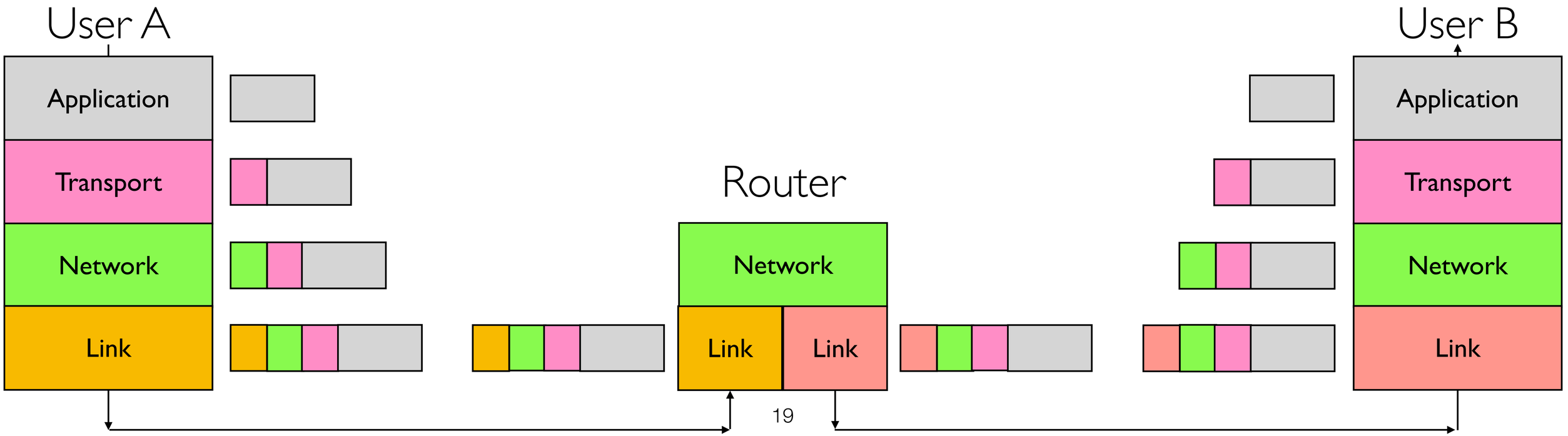

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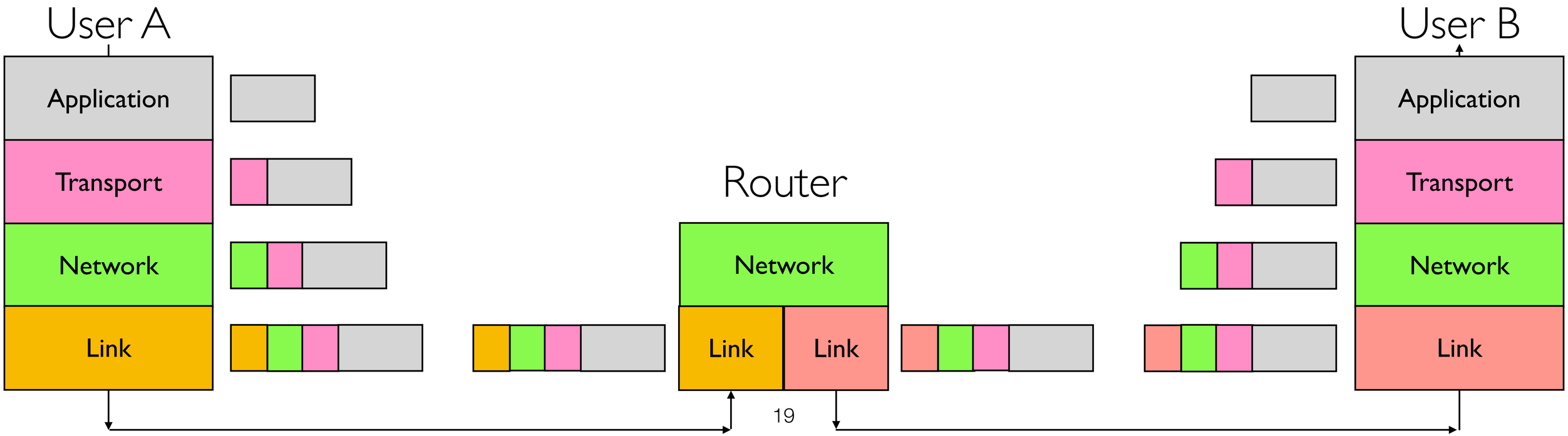

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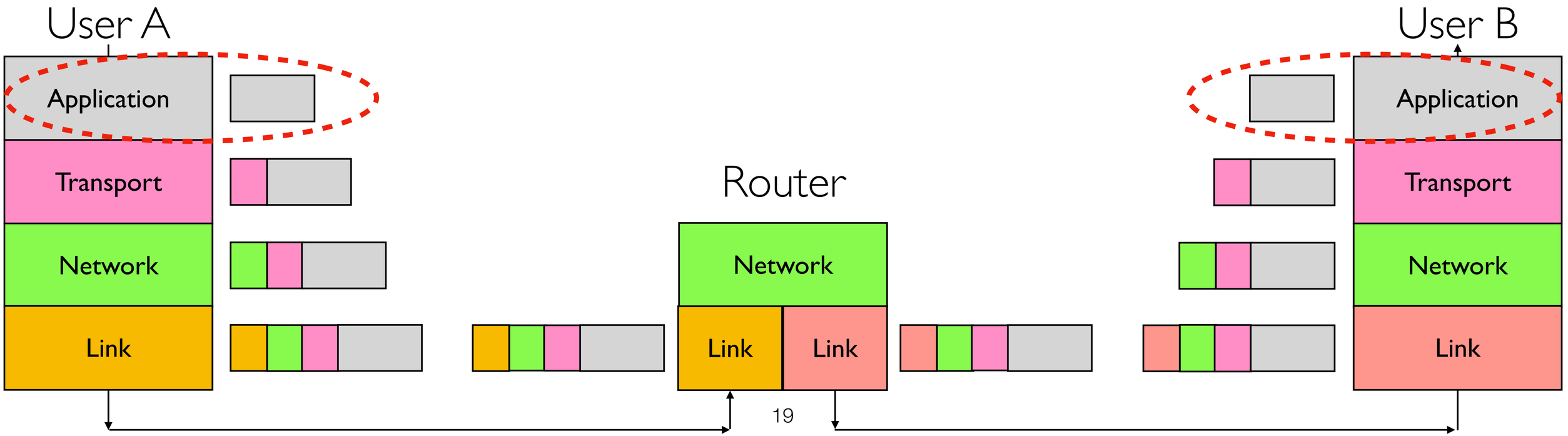

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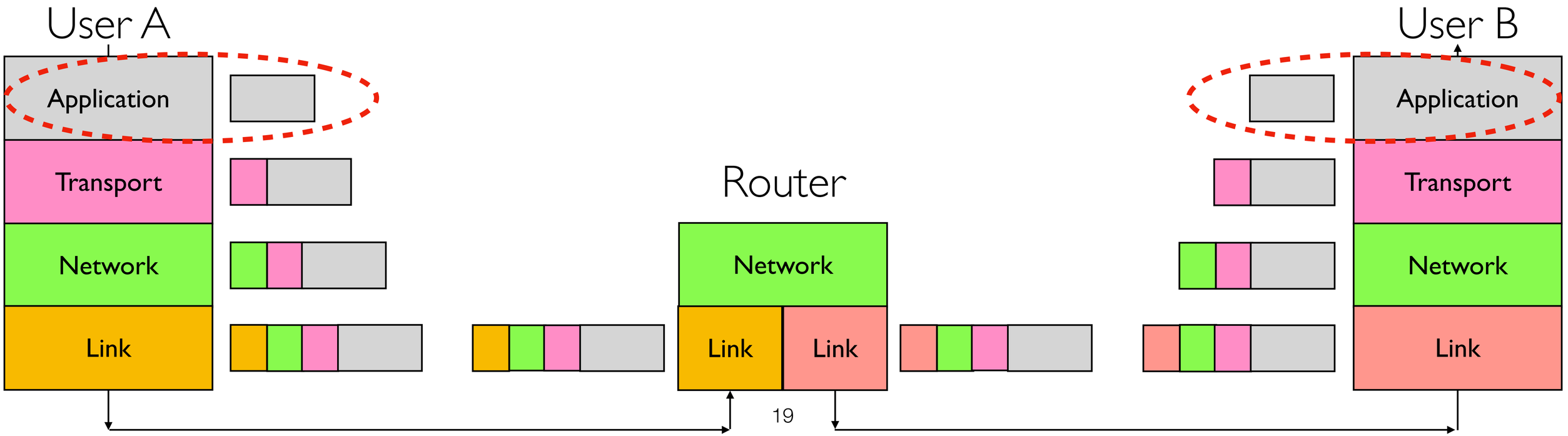

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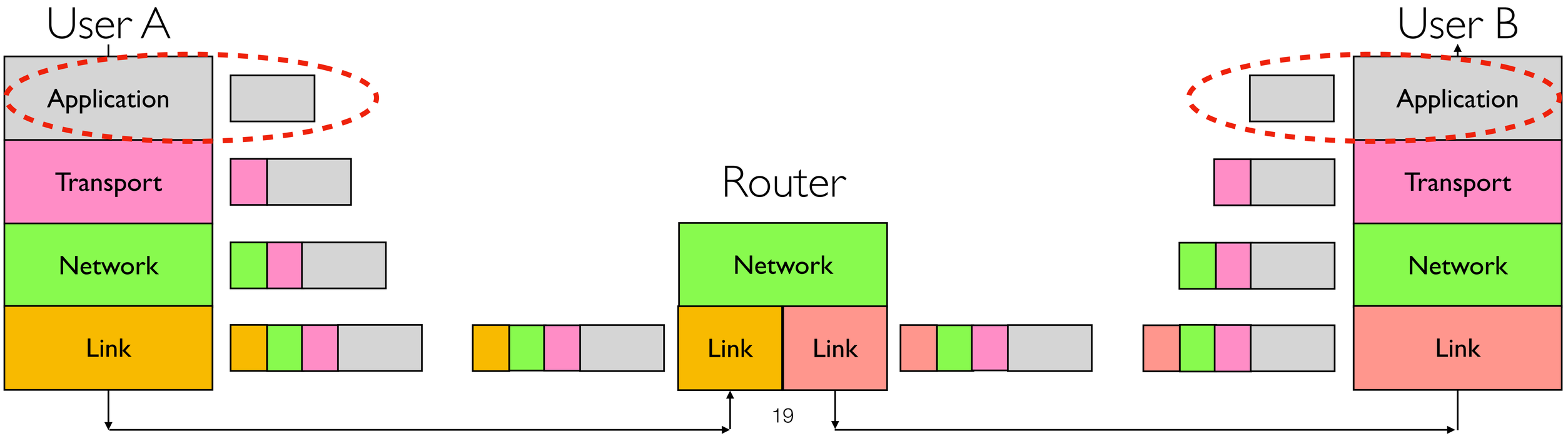
- **Advanced Topics,** *Datacenters, SDN*



On to the Application Layer!

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- **The Domain Name System (DNS) is how we map from one to the other**
  - A *directory service* for hosts on the Internet

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- **Provides a level of indirection!**
  - Decoupled names from addresses
  - Many uses beyond just naming a specific host

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- ***How should we partition things?***

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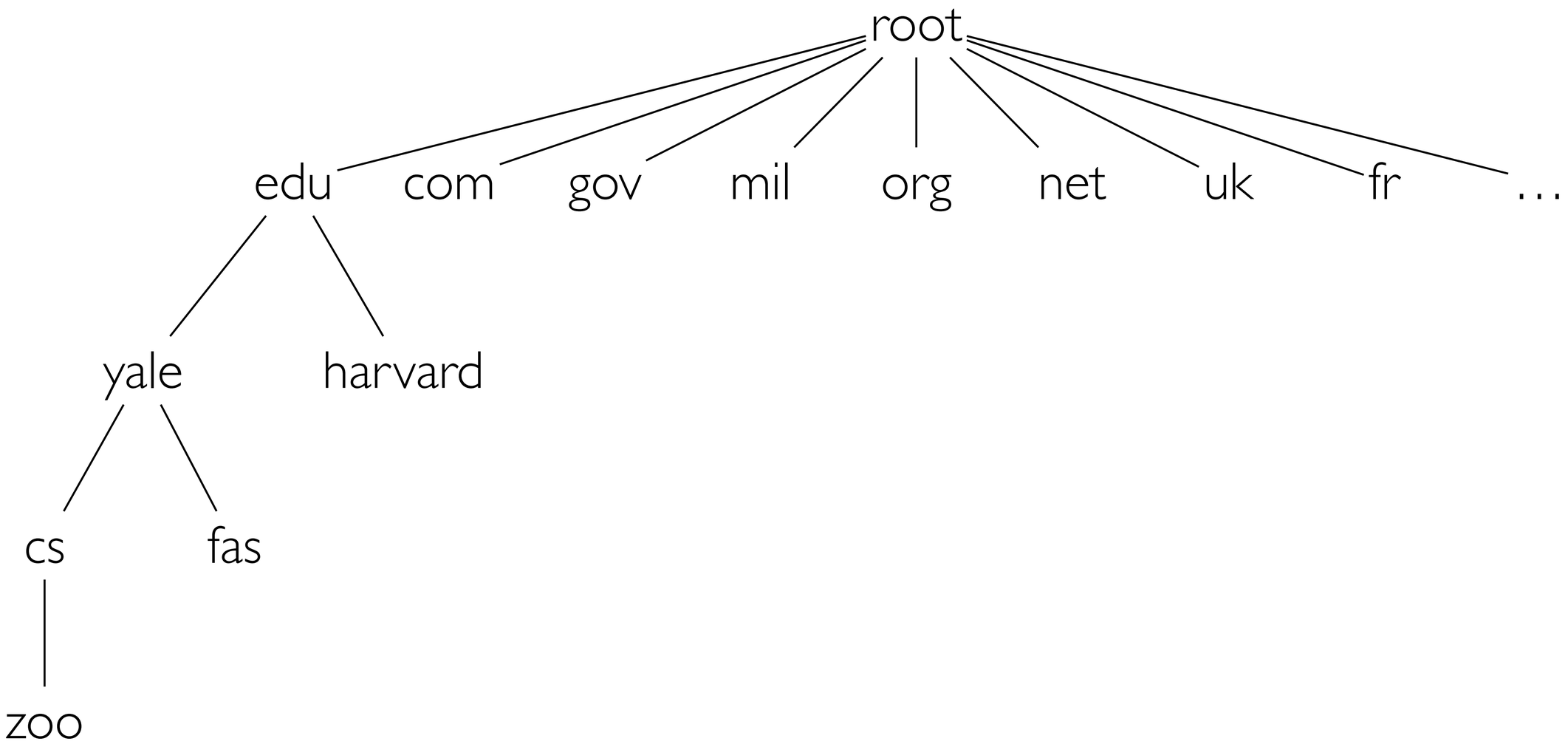

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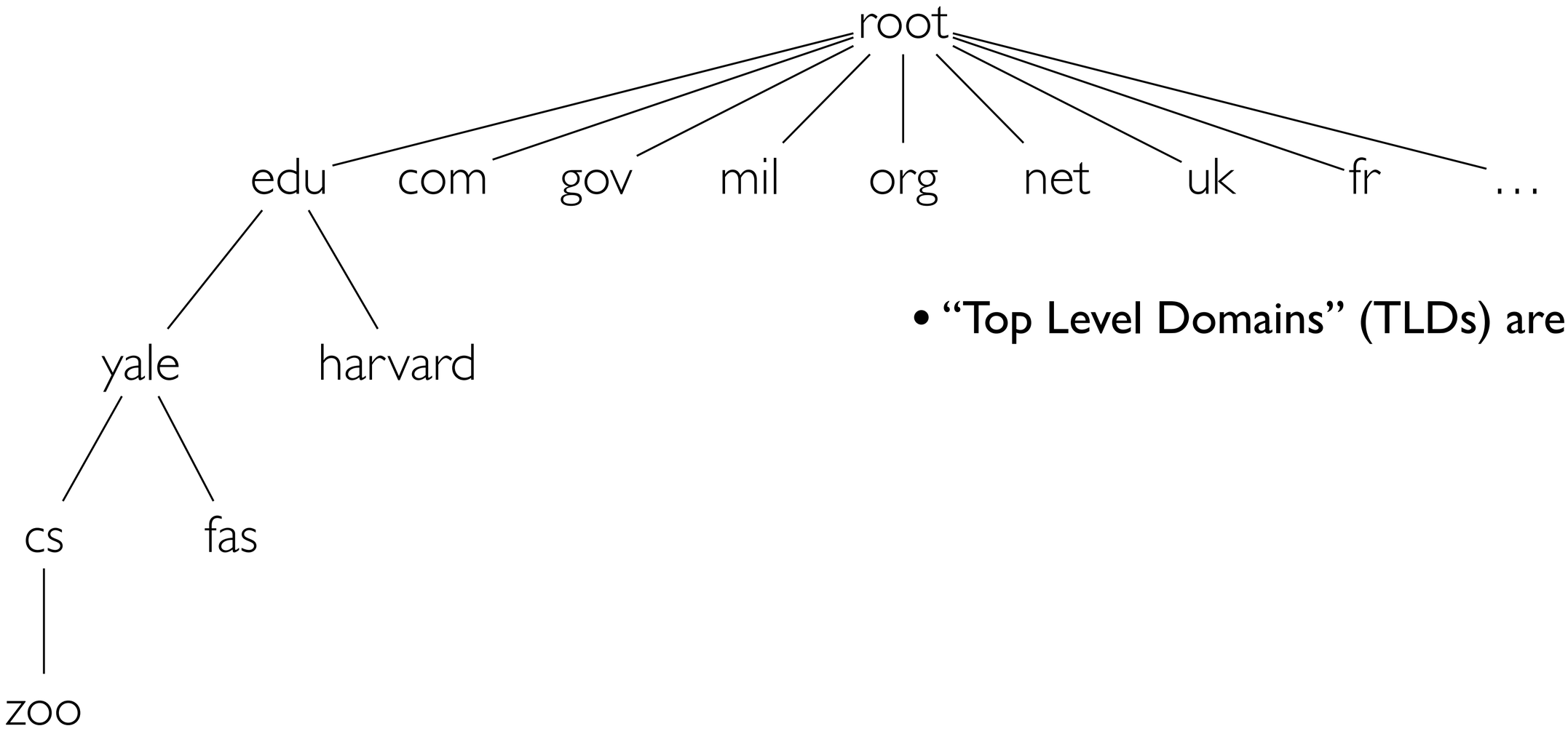

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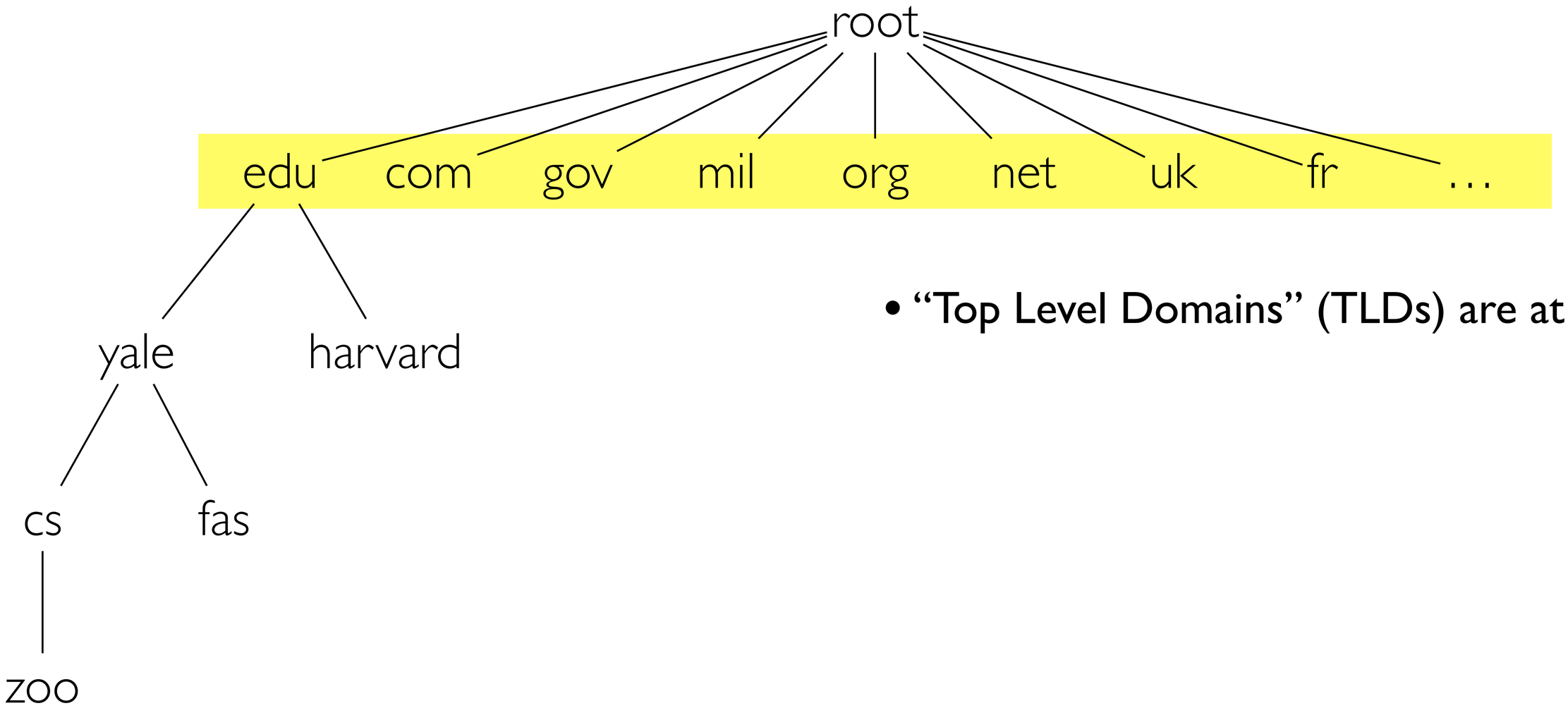

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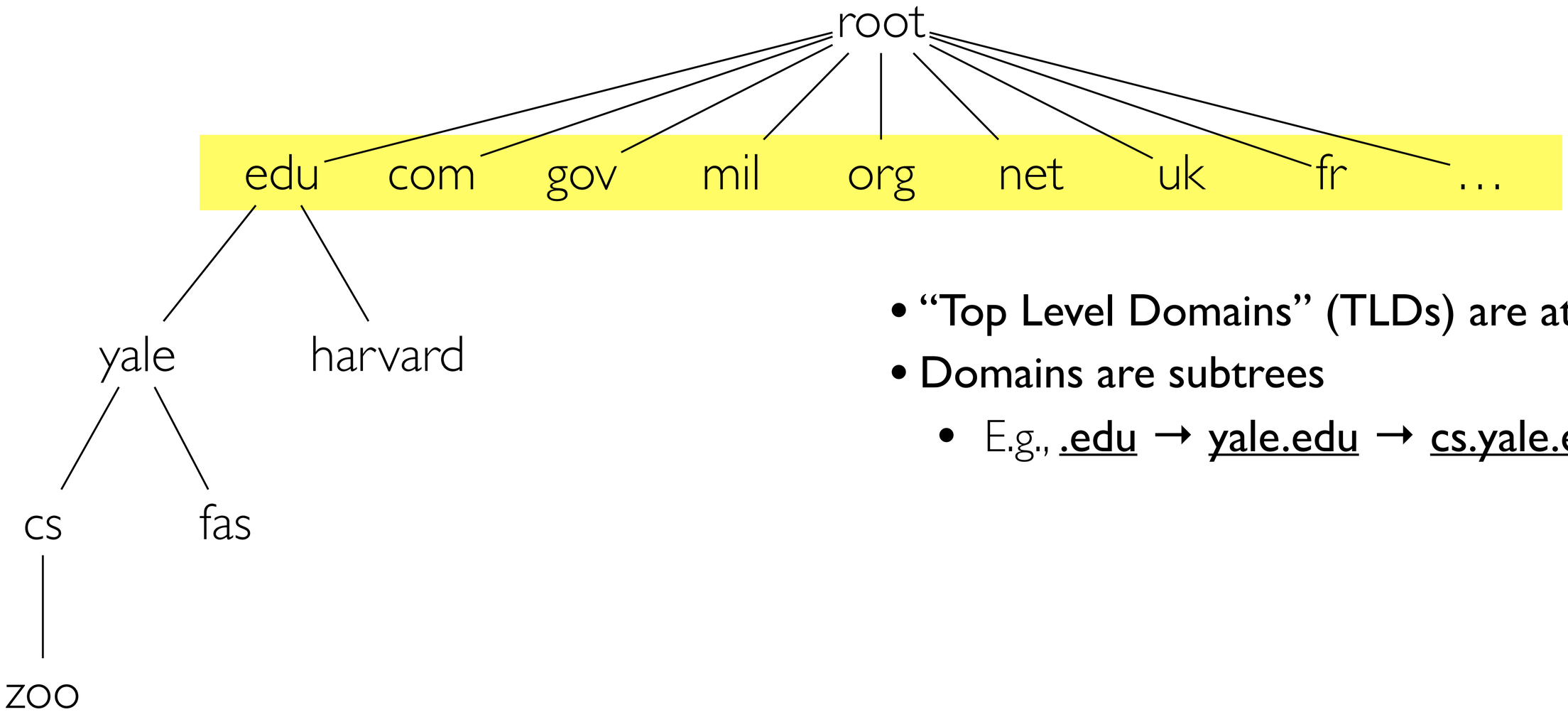

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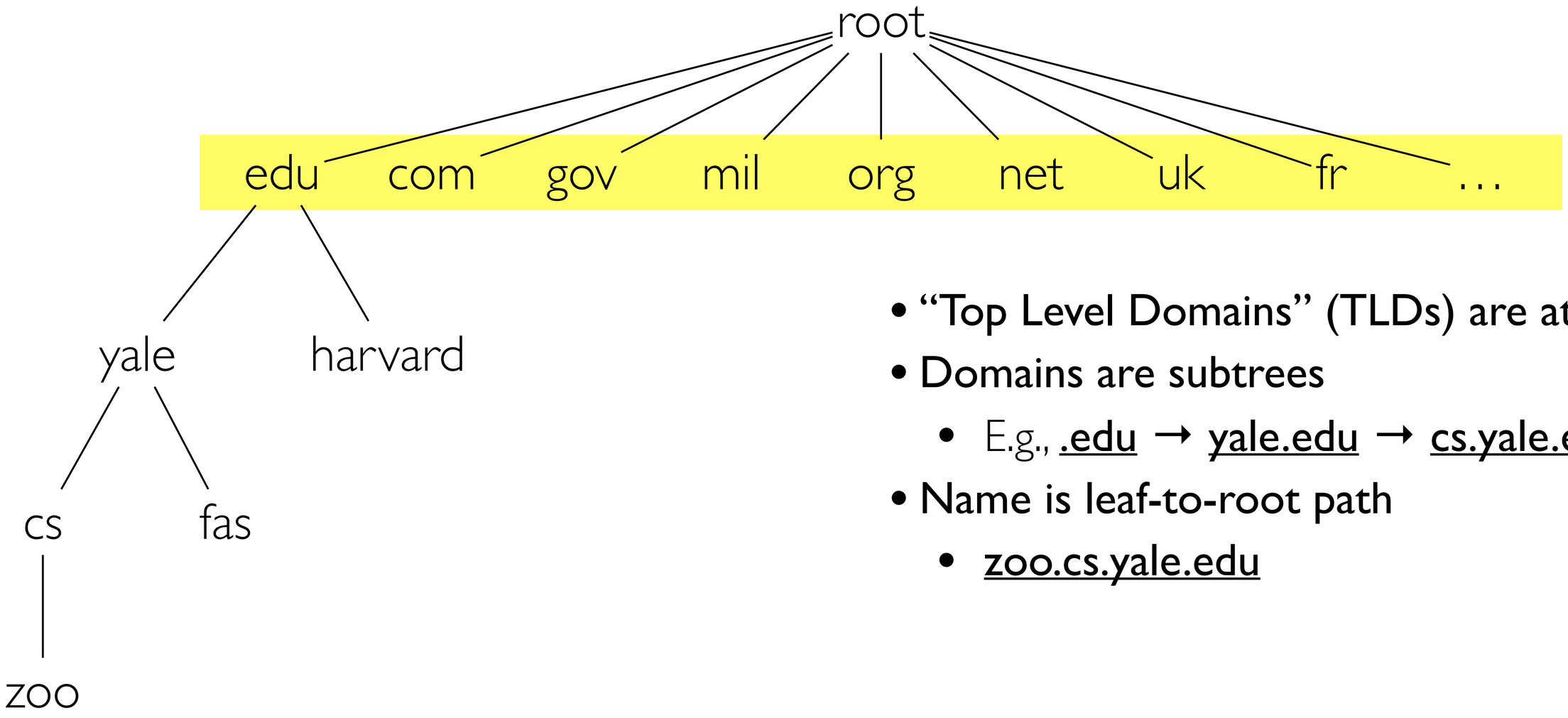

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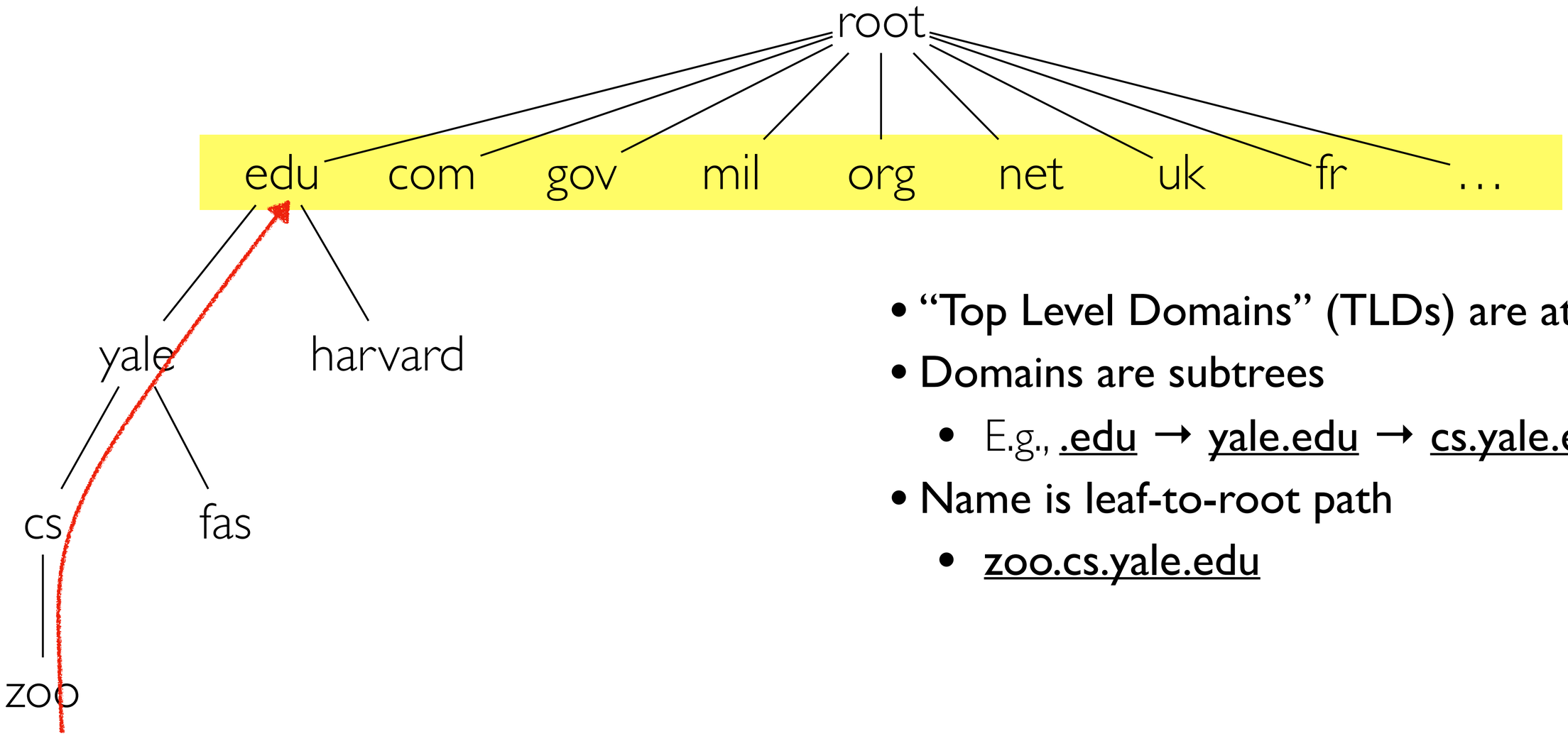

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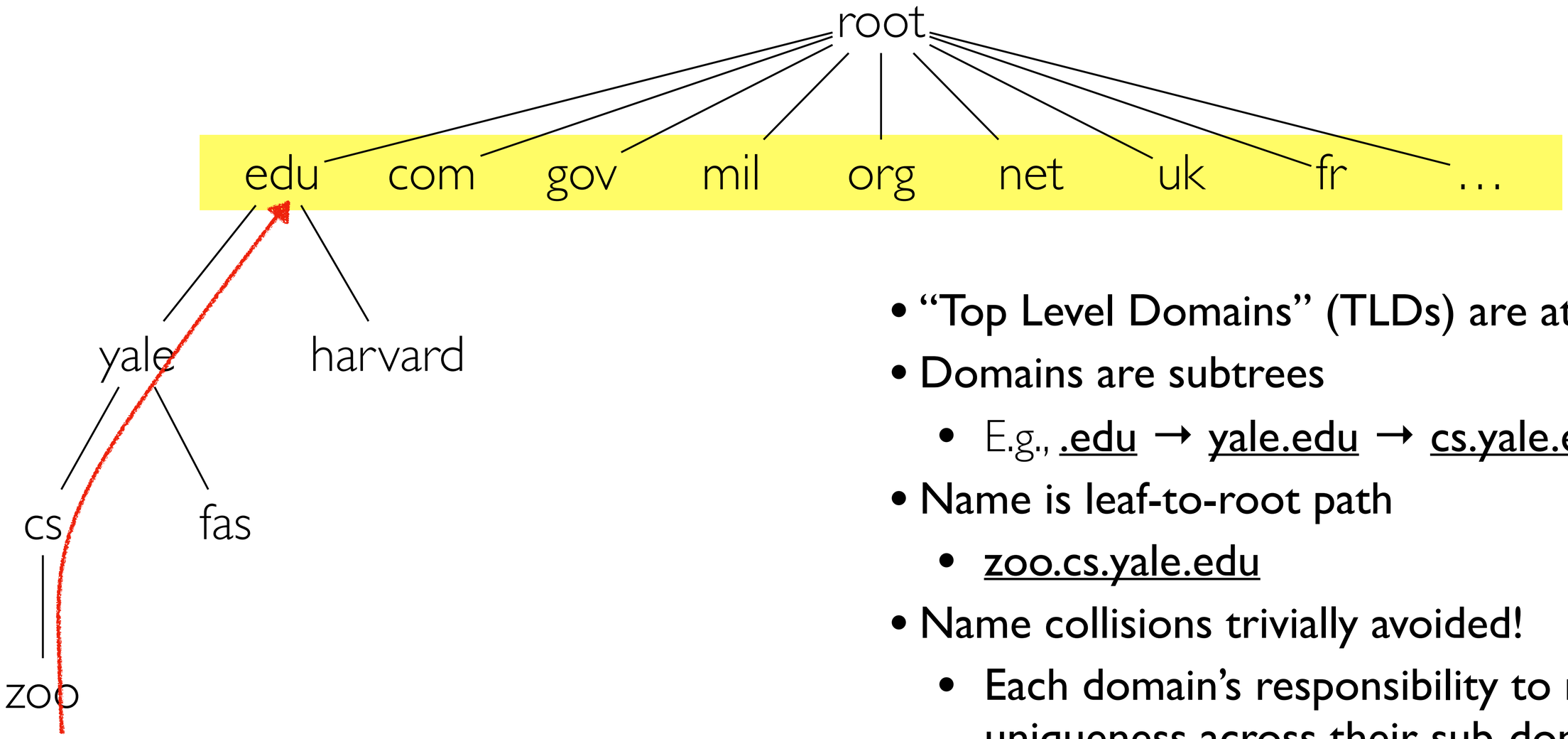

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- Name collisions trivially avoided!
  - Each domain's responsibility to maintain uniqueness across their sub-domains

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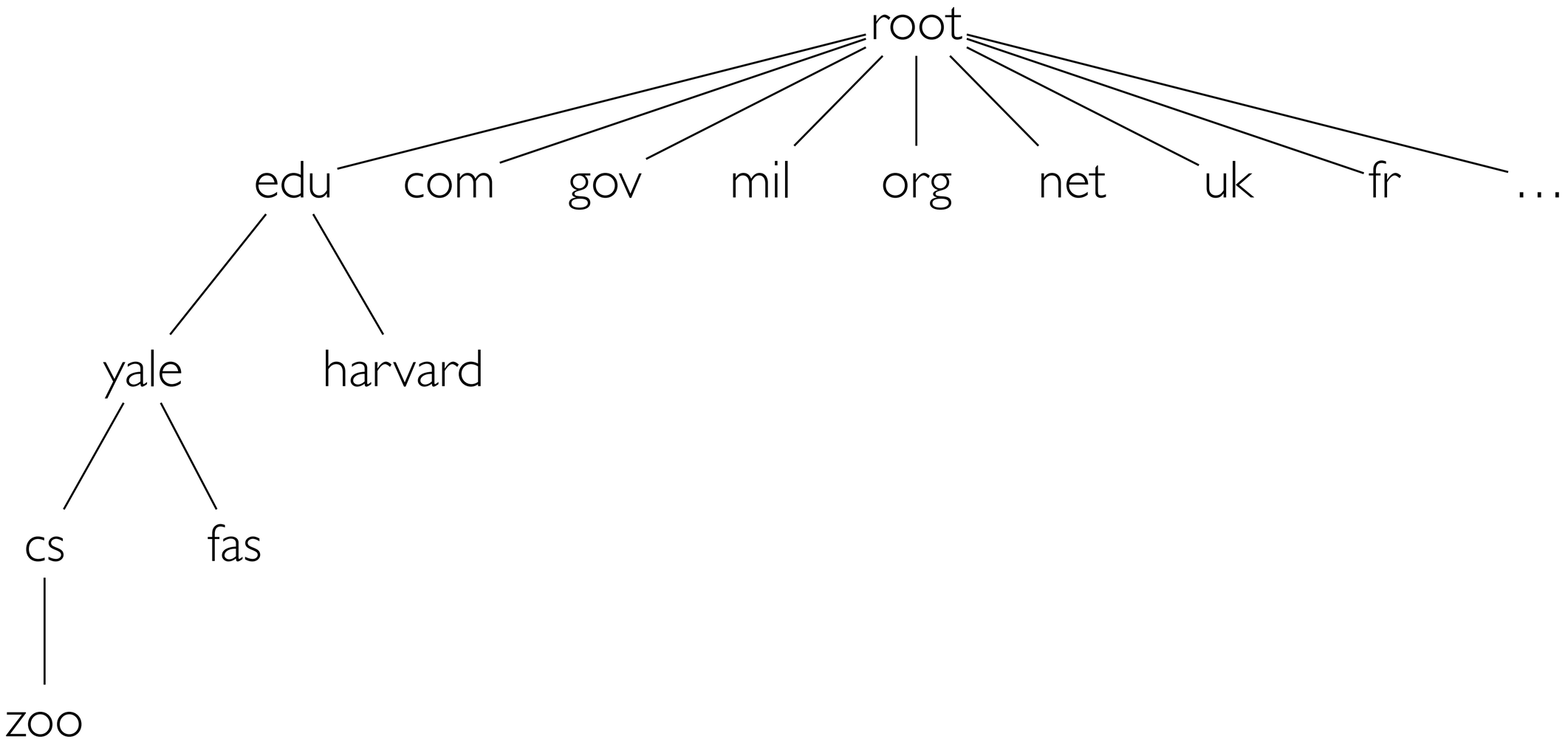

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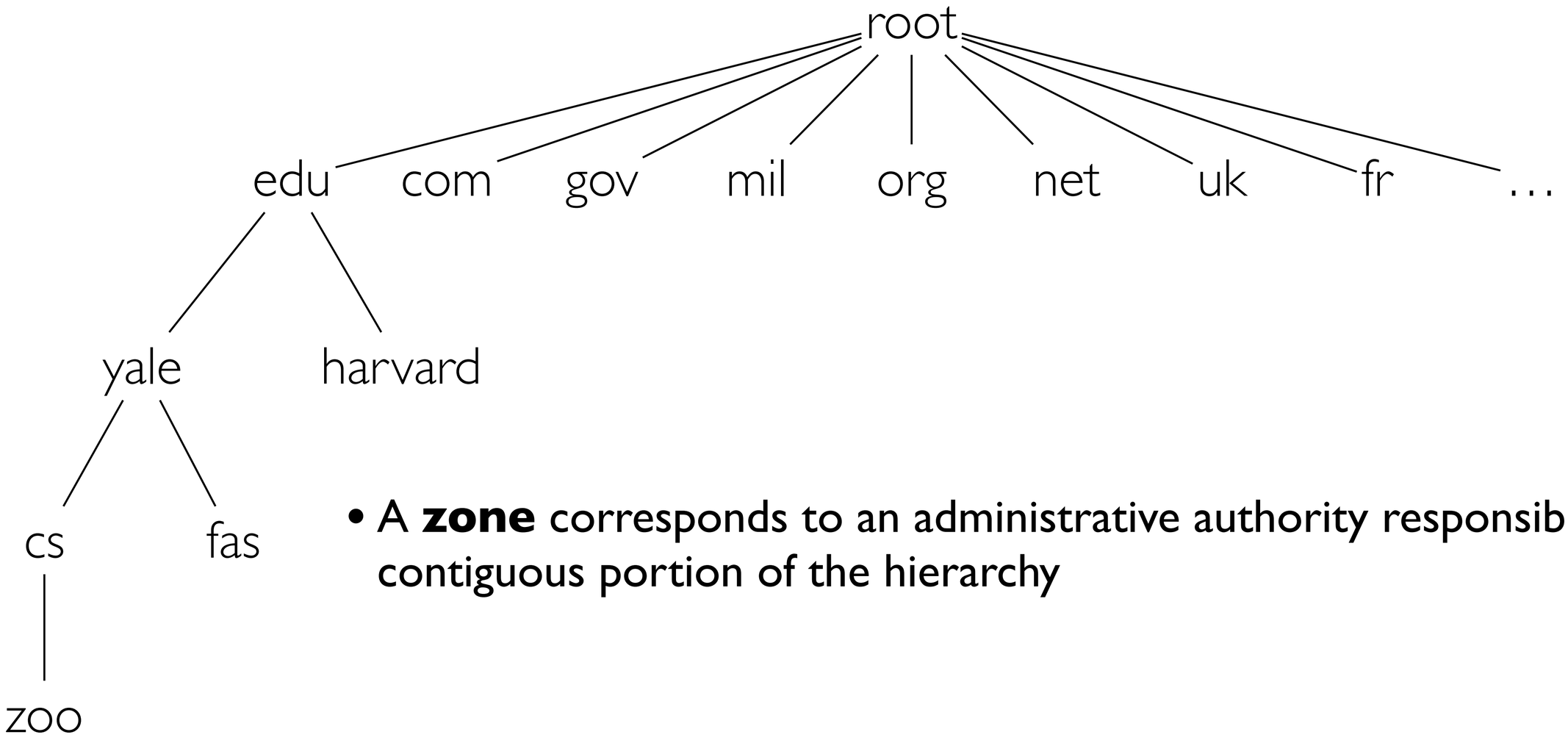

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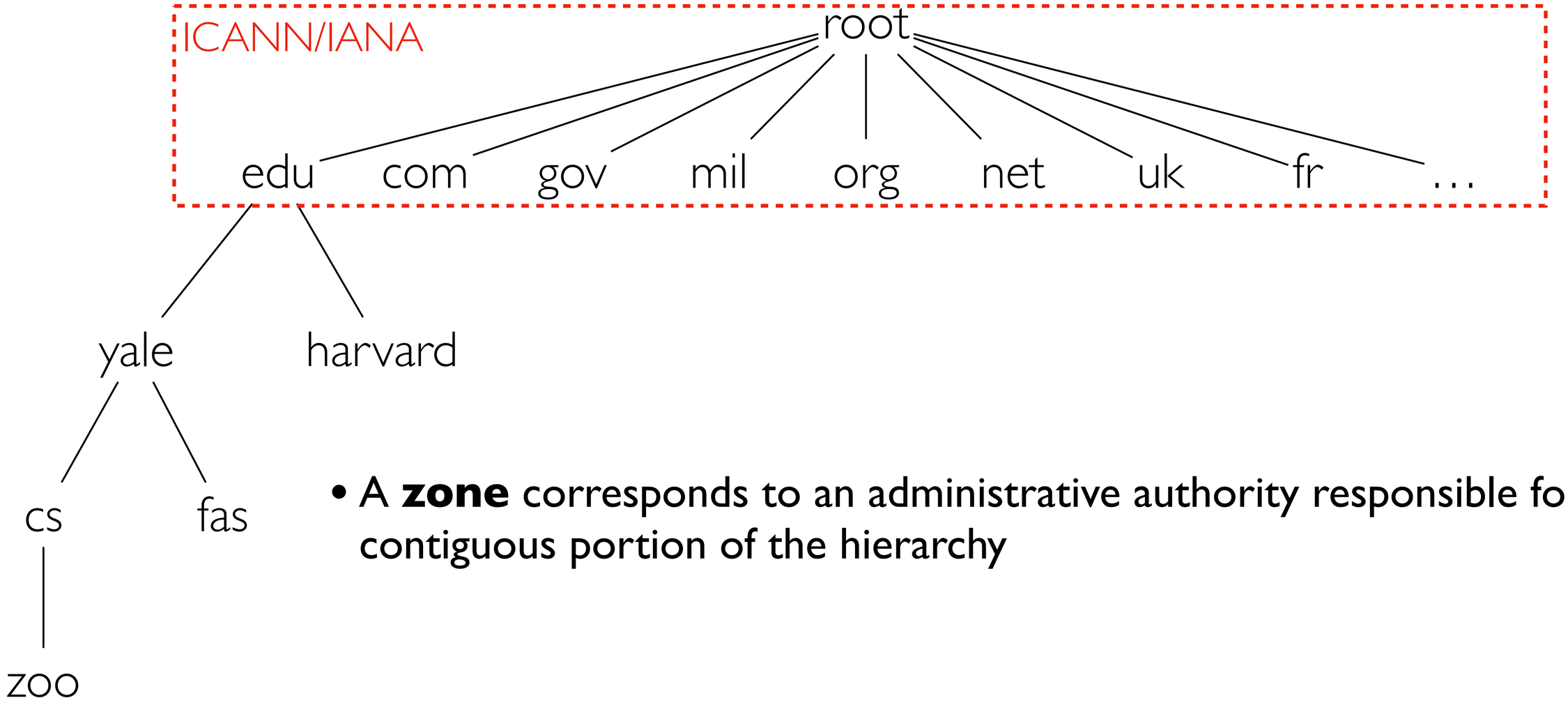

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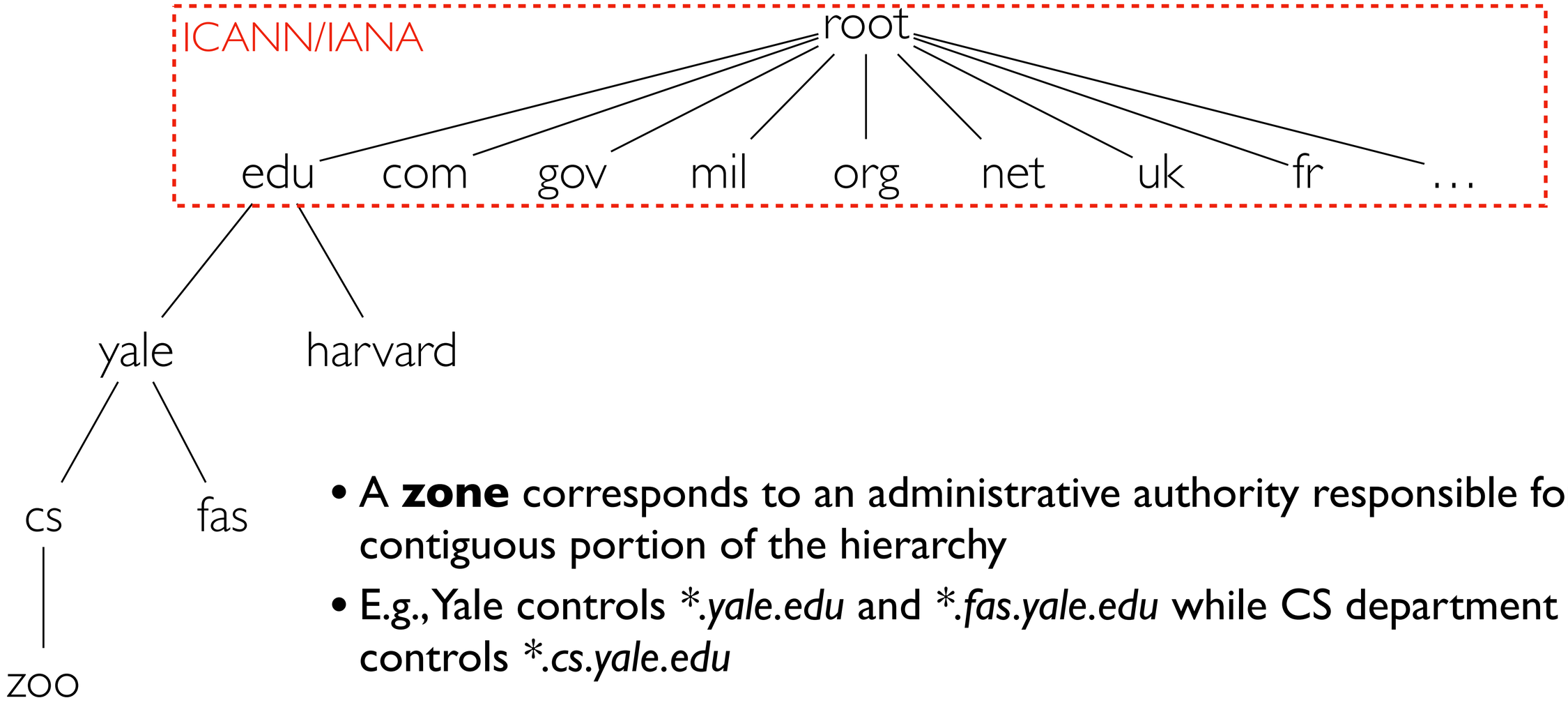

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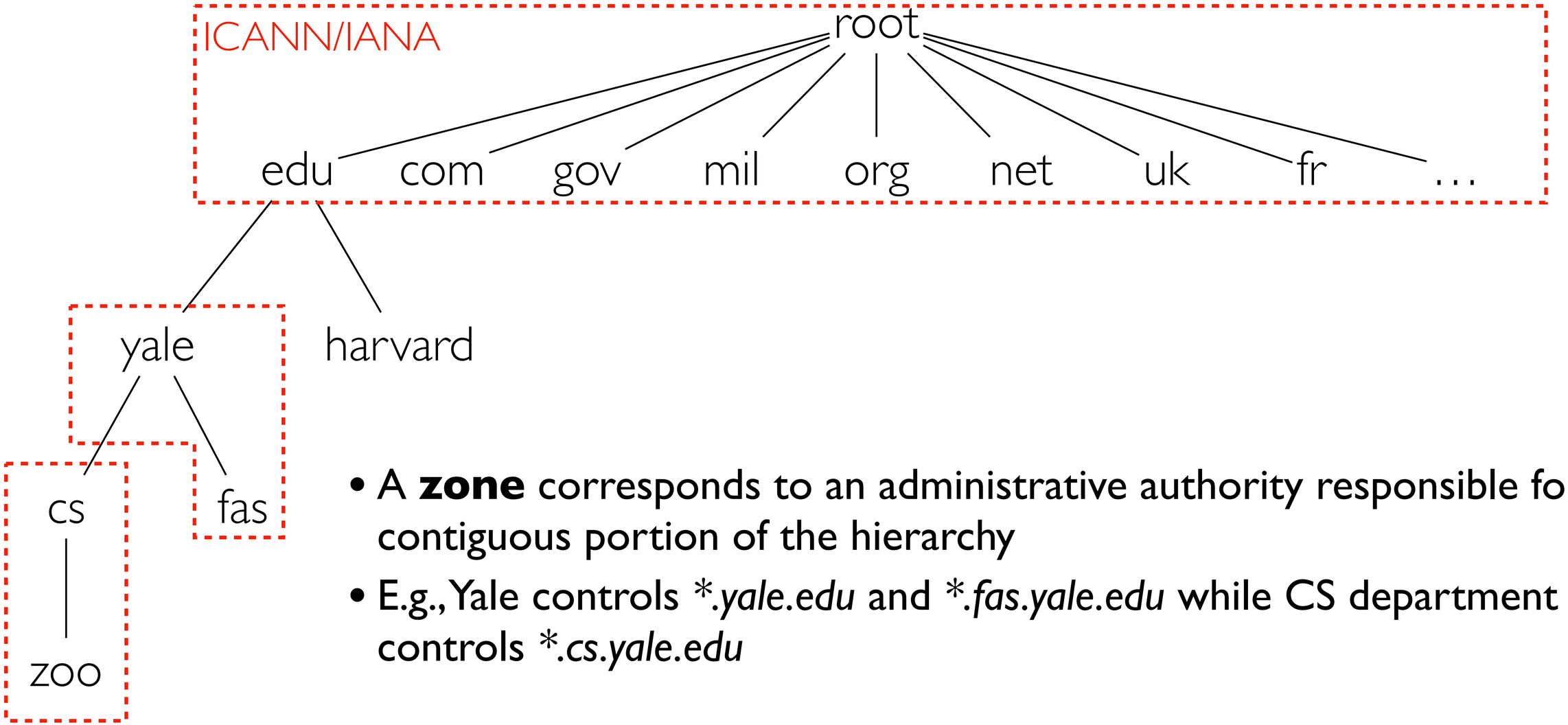

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- **Next Level: Top-Level Domain (TLD) servers**
  - .com, .edu, etc.; managed professionally
  - Store addresses of next level DNS servers **under them…**

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  - Location hardwired into relevant servers
  - Store addresses **all** next level DNS servers…
- **Next Level: Top-Level Domain (TLD) servers**
  - .com, .edu, etc.; managed professionally
  - Store addresses of next level DNS servers **under them…**
- **Bottom Level: Authoritative DNS servers**
  - Store the **actual name-to-address mappings**
  - Maintained by the corresponding administrative authority

Storage Hierarchy

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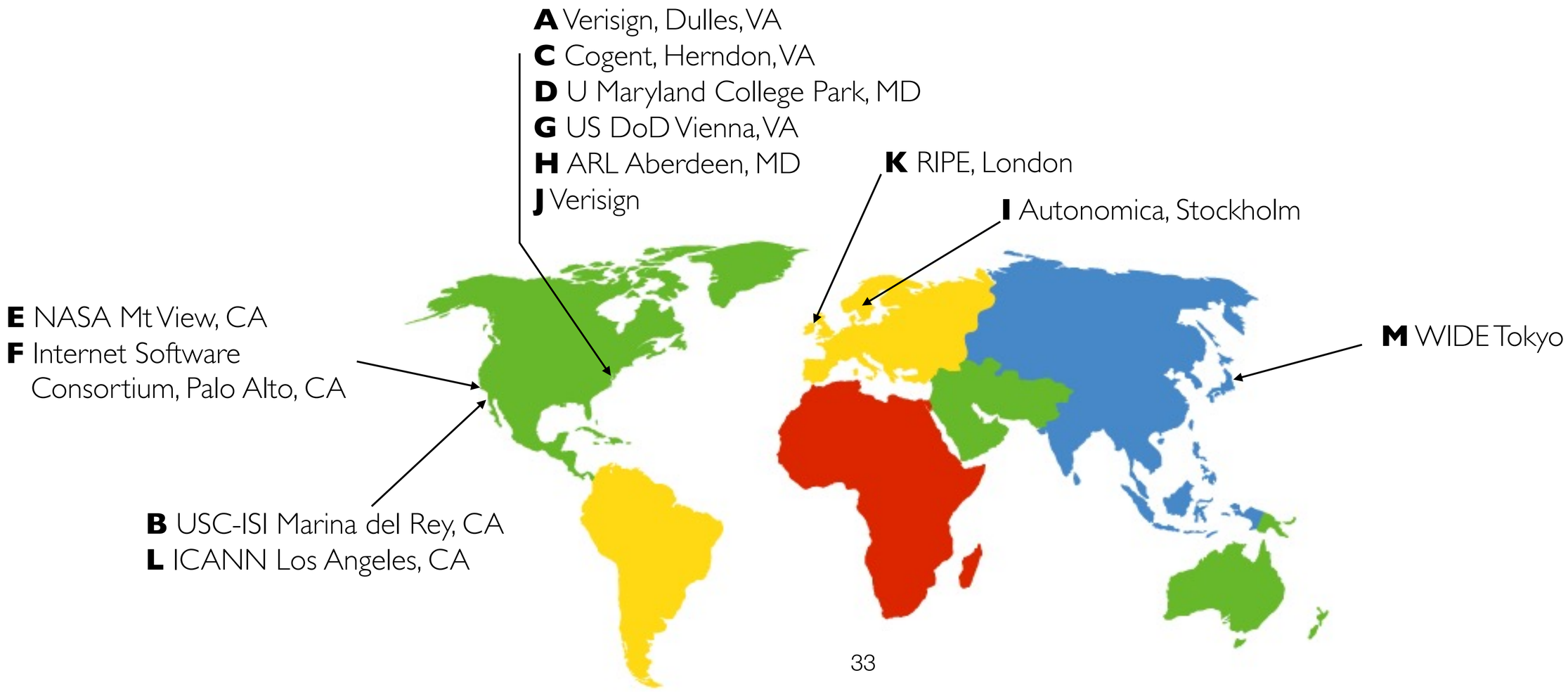
- Each server stores a subset of the total DNS database
- Each server can discover the server(s) responsible for any portion of the hierarchy

DNS Root Servers

- 13 root servers (labeled A-M; see http://www.root-servers)



DNS Root Servers

- 13 root servers (labeled A-M; see http://www.root-servers)
- Replicated via any-casting

A Verisign, Dulles, VA
C Cogent, Herndon, VA
D U Maryland College Park, MD
G US DoD Vienna, VA
H ARL Aberdeen, MD
J Verisign (21 locations)

K RIPE, London (plus 16 other locations)

I Autonomica, Stockholm (plus 29 other locations)

E NASA Mt View, CA
F Internet Software Consortium, Palo Alto, CA (and 37 other locations)

M WIDE Tokyo (plus Seoul, Paris, San Fransisco)

B USC-ISI Marina del Rey, CA
L ICANN Los Angeles, CA

Anycast in a nutshell

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- Routing finds shortest paths to destination

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- Routing finds shortest paths to destination
- What happens if multiple machines advertise the same address?
- The network will deliver the packet to the closest machine with that address
- This is called "anycast"
  - Very robust
  - Requires no modification to routing algorithms

DNS Records

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  - RR is (name, value, type, TTL)

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  - Name = domain
  - Value = name of DNS server for domain

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  - Name = hostname
  - Value = IP address
- Type = NS: (→*Name Server*)
  - Name = domain
  - Value = name of DNS server for domain
- Type = MX: (→*Mail eXchanger*)
  - Name = domain in email address
  - Value = name(s) of mail server(s)

Inserting Resource Records into DNS

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- Example: you just created company “FooBar”

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- **Example: you just created company "FooBar"**
- **You get a block of IP addresses from your ISP**
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- **Register foobar.com at registrar (e.g., GoDaddy)**
  - Provide registrar with names and IP addresses of your authoritative name server(s)
  - Registrar inserts RR pairs into the .com TLD server
    - (foobar.com, dns1.foobar.com, NS)
    - (dns1.foobar.com, 212.44.9.129, A)

Inserting Resource Records into DNS

- **Example: you just created company "FooBar"**
- **You get a block of IP addresses from your ISP**
  - Say 212.44.9.128/25
- **Register foobar.com at registrar (e.g., GoDaddy)**
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  - Registrar inserts RR pairs into the .com TLD server
    - (foobar.com, dns1.foobar.com, NS)
    - (dns1.foobar.com, 212.44.9.129, A)
- **Store resource records in your server dns1.foobar.com**
  - e.g., type A records: (foobar.com, 212.44.9.130, A), (social.foobar.com, 212.44.9.131, A), etc.
  - e.g., type MX records for foobar.com

Using DNS (Client/Application view)

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- **Two components**
  - Local DNS server
  - Resolver software on hosts

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  - Local DNS server
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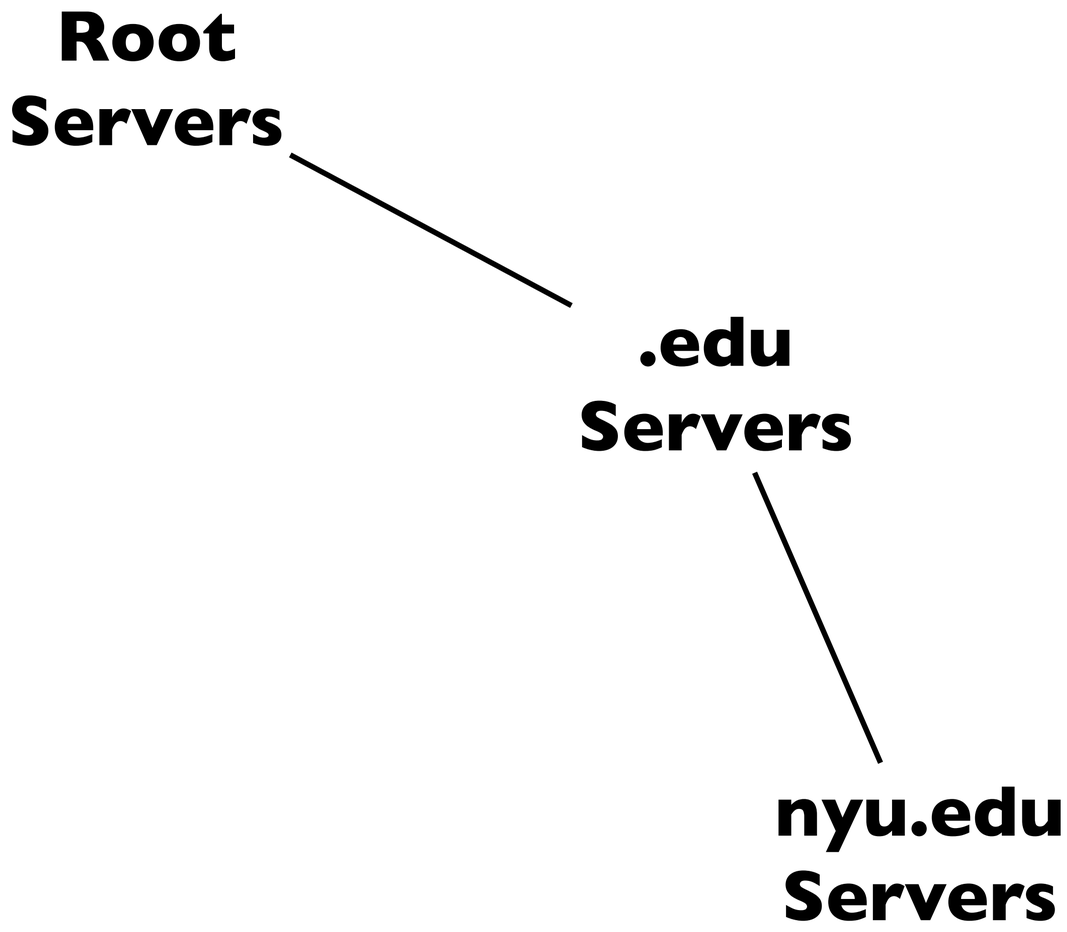
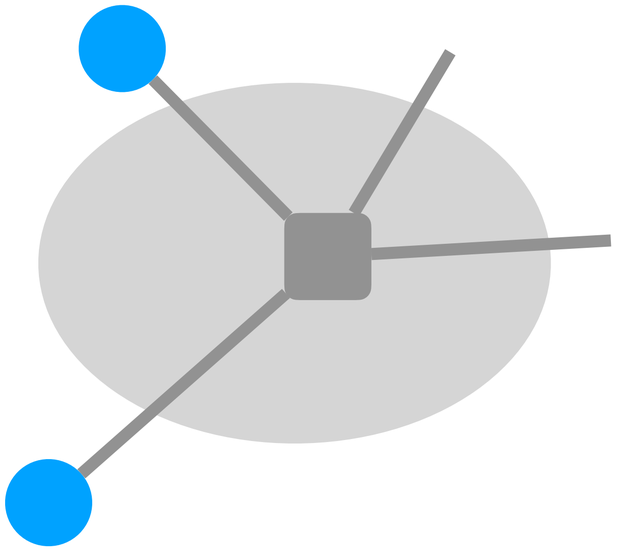
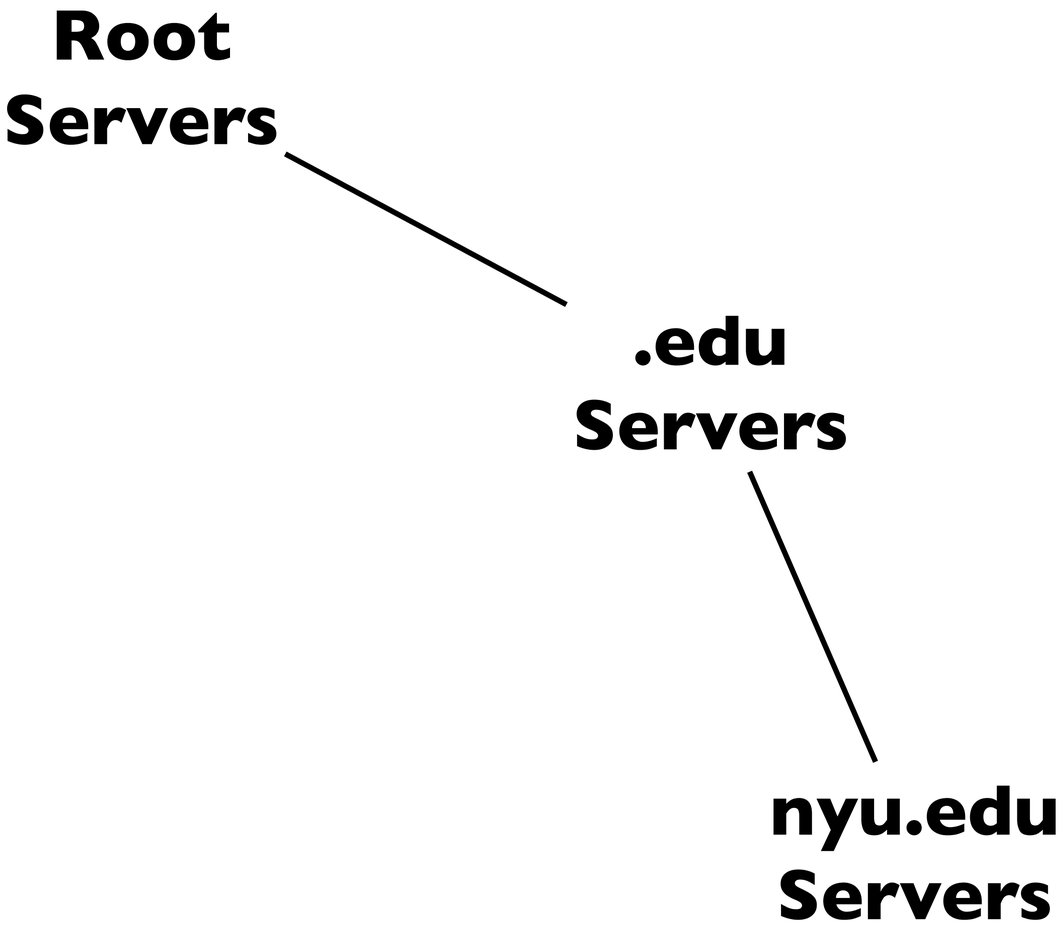
- **Local DNS server ("default name server")**
  - Clients configured with the default server's address or learn it via a host configuration protocol (e.g., DHCP — future lecture)

- **Client application:**
  - Obtain DNS name (e.g., from URL)
  - Triggers DNS request to its local DNS server


Root
Servers
.edu
Servers
nyu.edu
Servers

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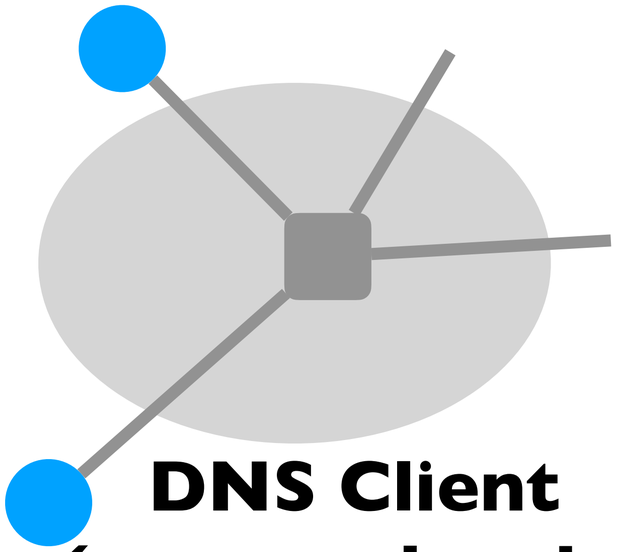

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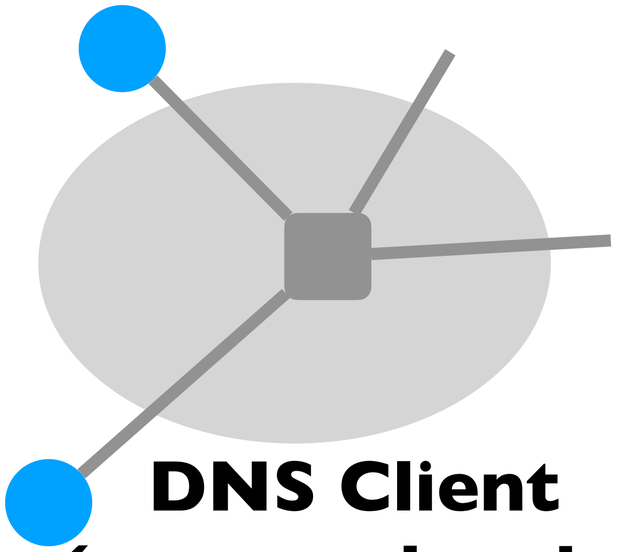

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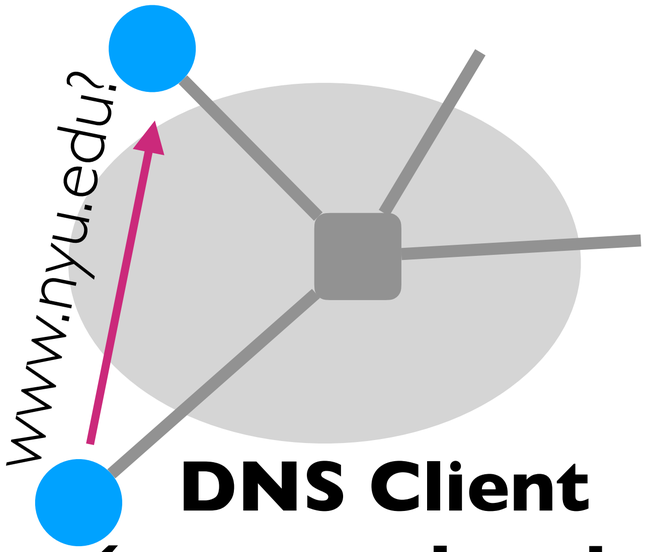

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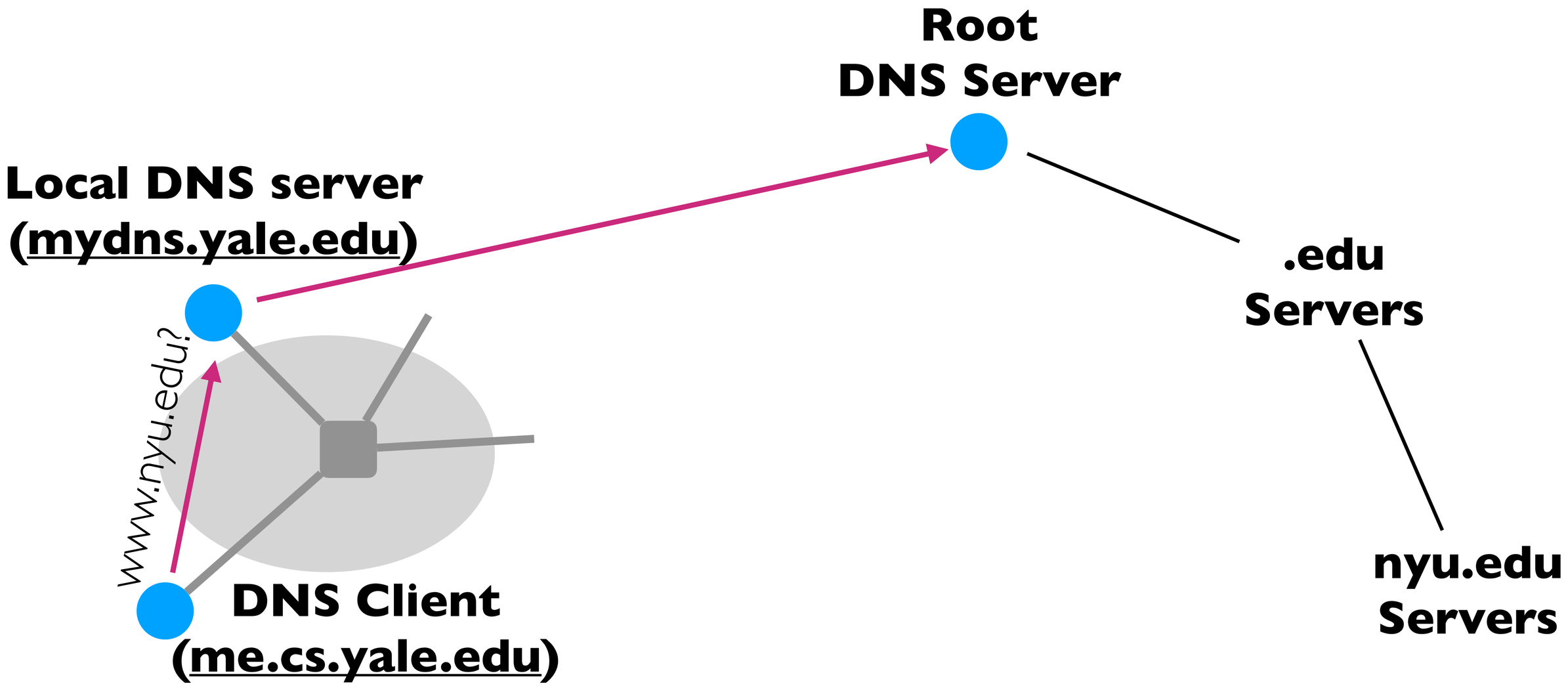
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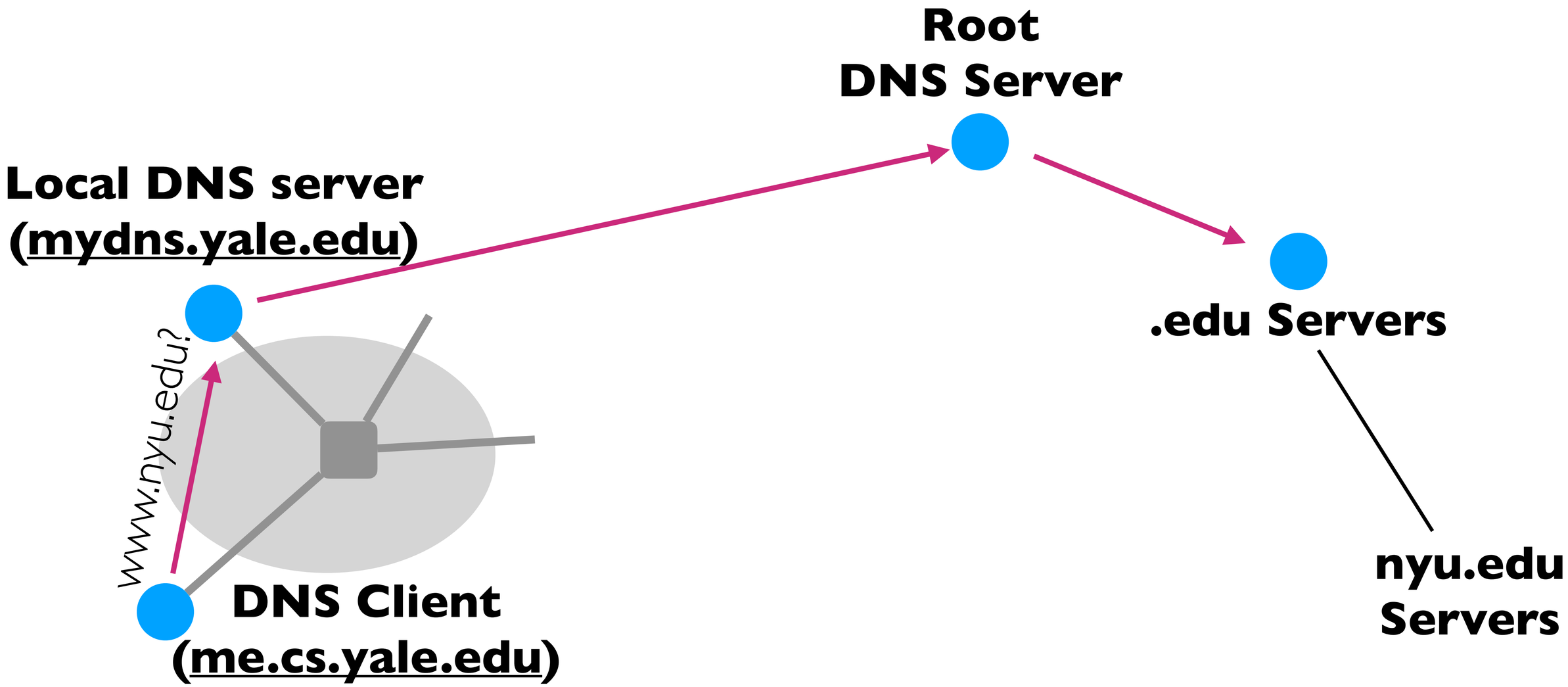
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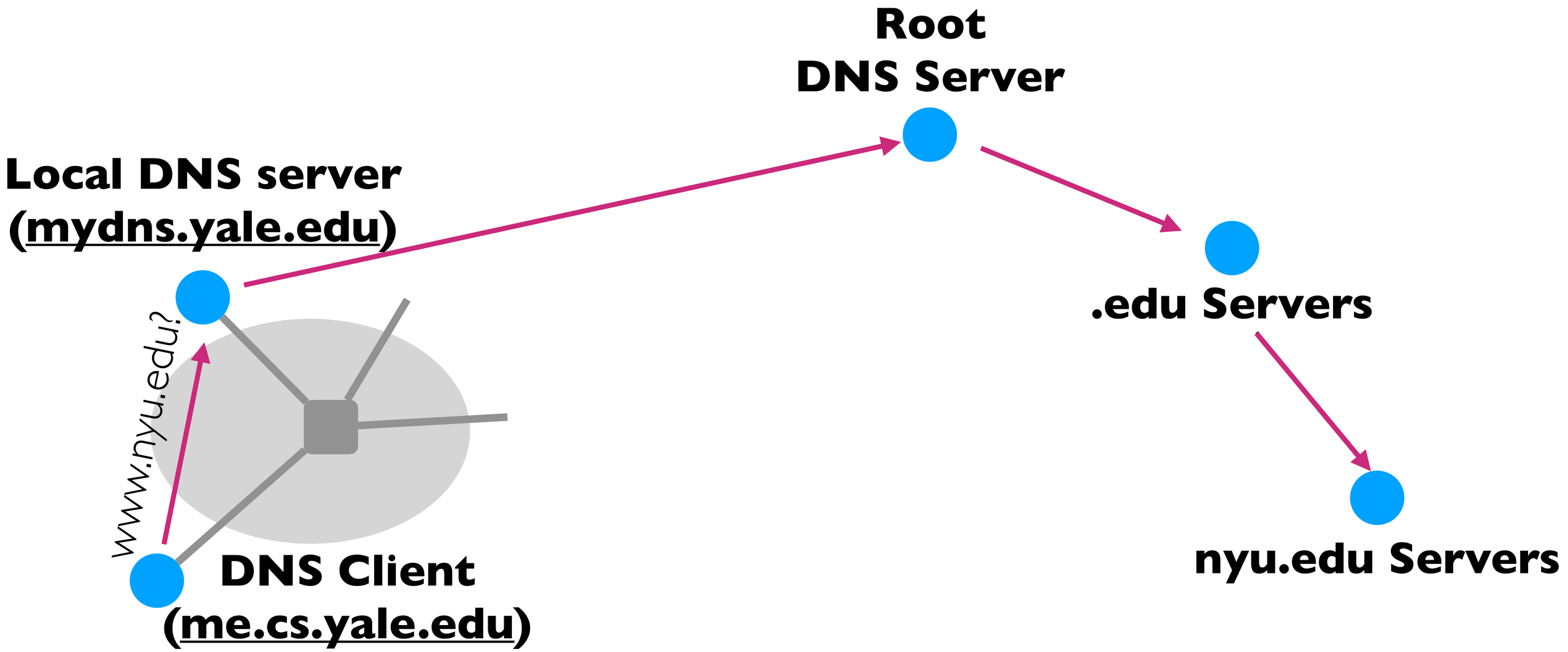
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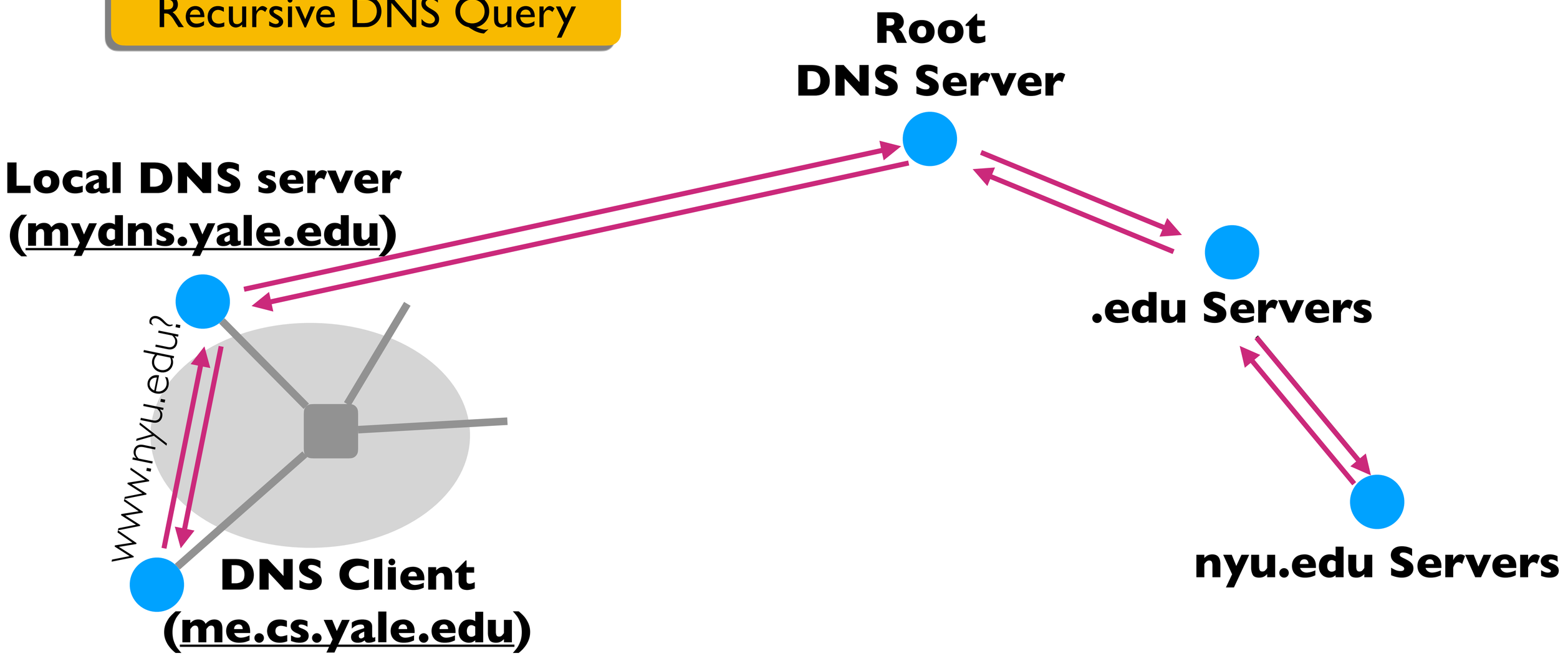
Recursive DNS Query



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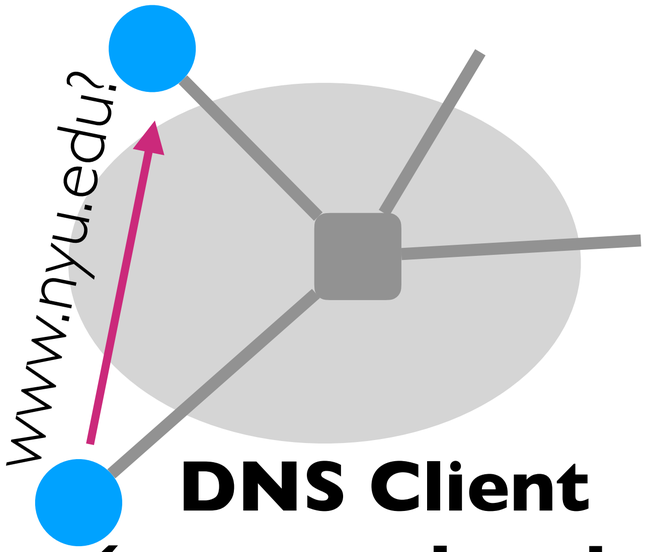

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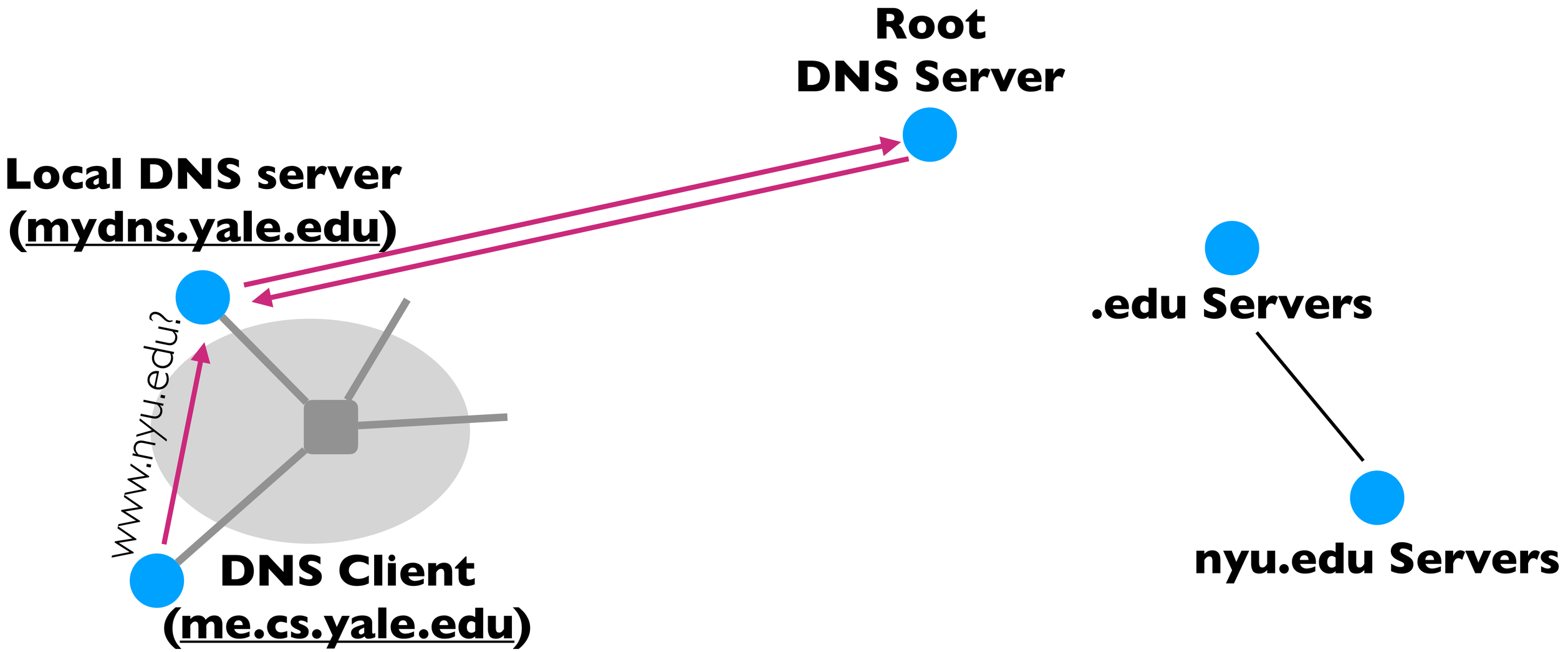
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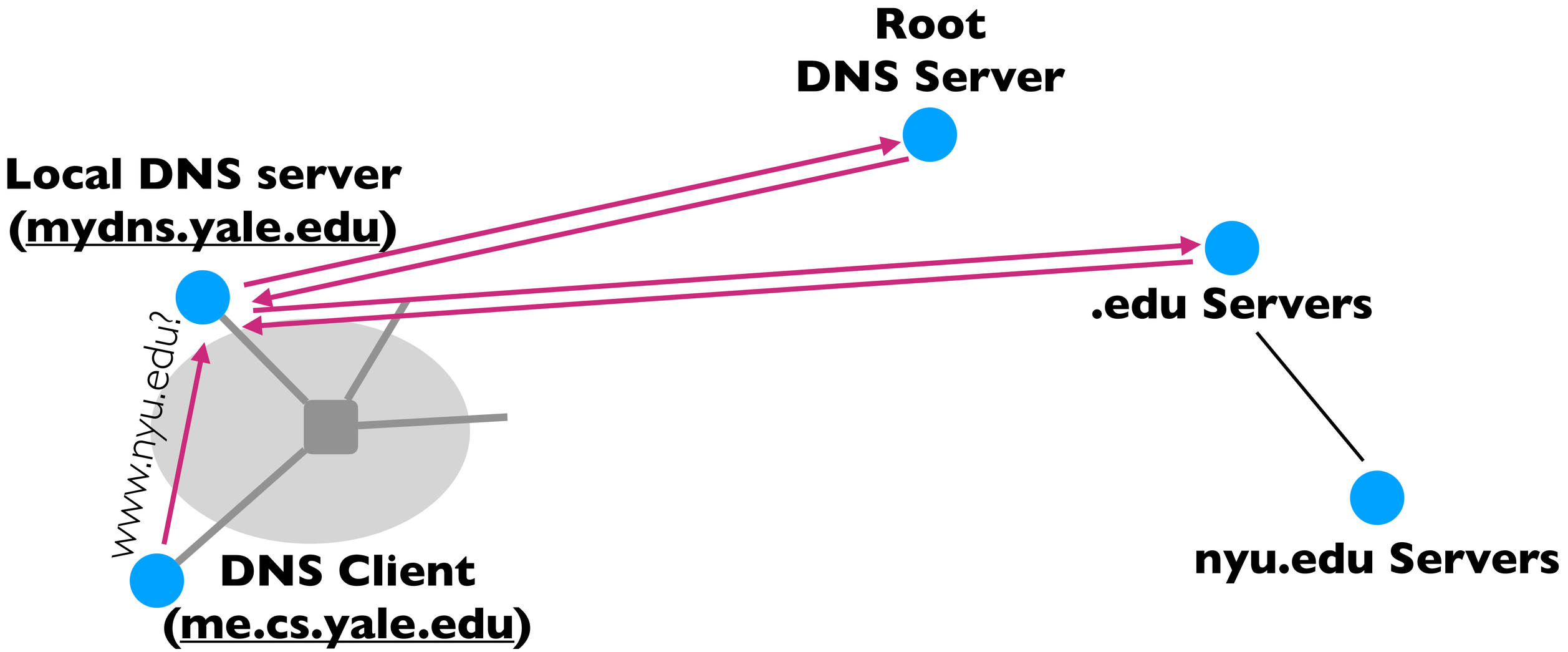
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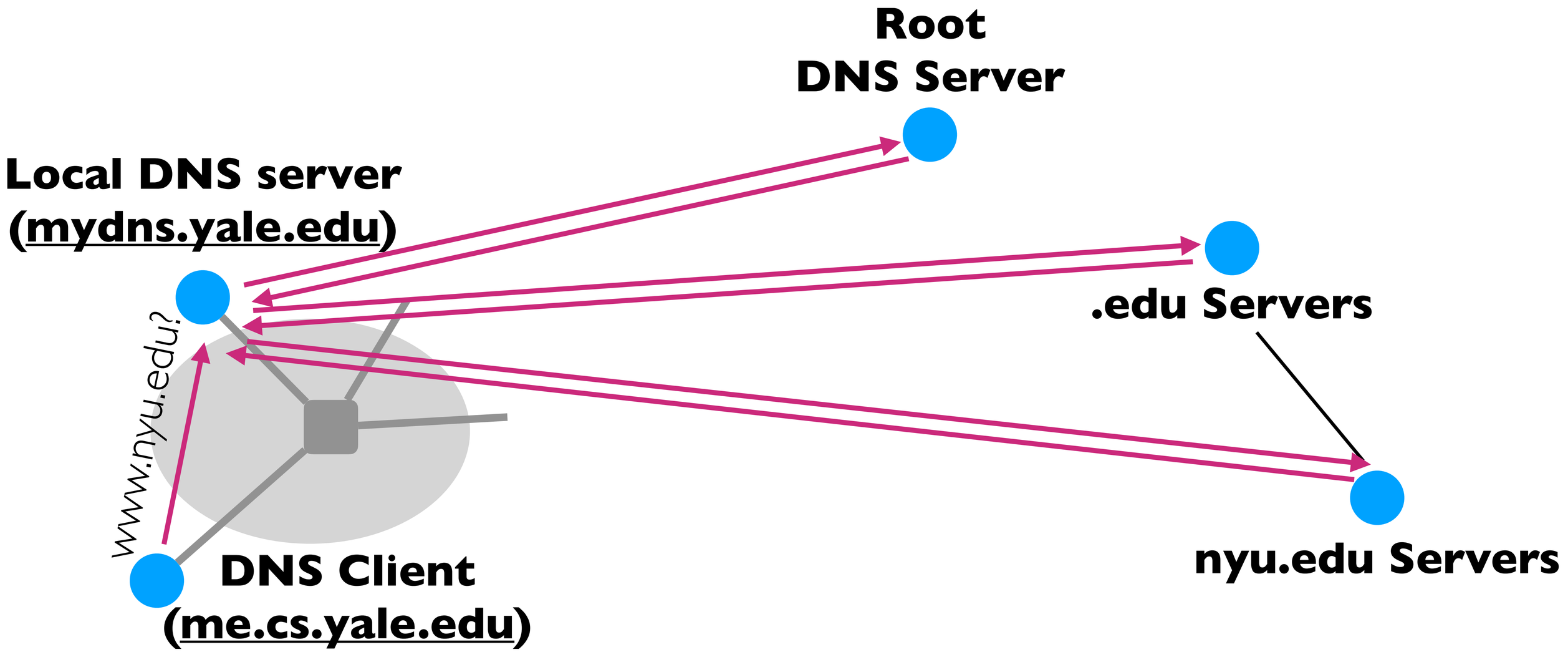
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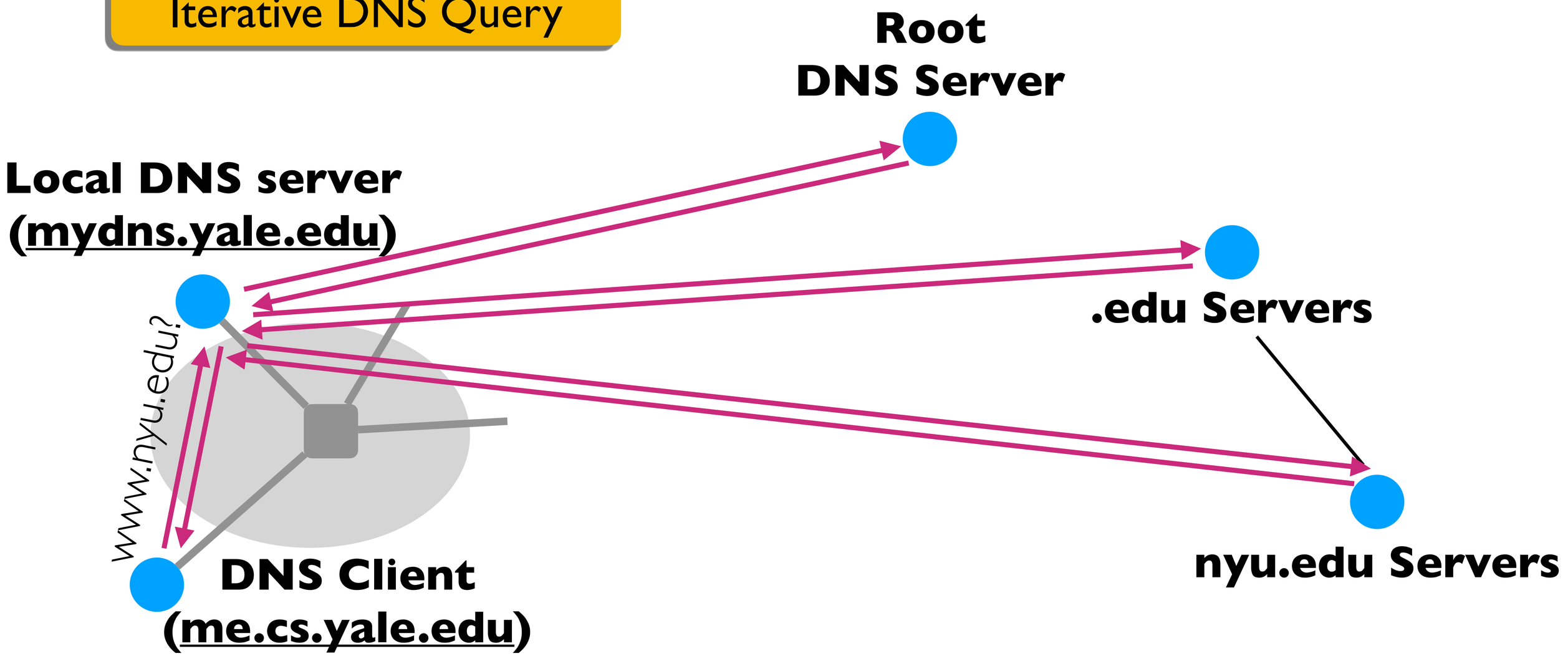
Iterative DNS Query



DNS Protocol

DNS Protocol

- Query and Reply messages; both with the same message format
  - *See text for details*

DNS Protocol

- **Query and Reply messages; both with the same message format**
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- **Client-Server Interaction on UDP Port 53**
  - Spec. supports TCP too, but not always implemented

Goals: How are we doing?

- Scalable
  - Many names
  - Many updates
  - Many users creating names
  - Many users looking up names
- Highly available
- Correct
  - No naming conflicts (uniqueness)
  - Consistency
- Lookups are fast

Per-domain Availability

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- **Try alternate servers on timeout**
  - *Exponential backoff* when retrying same server

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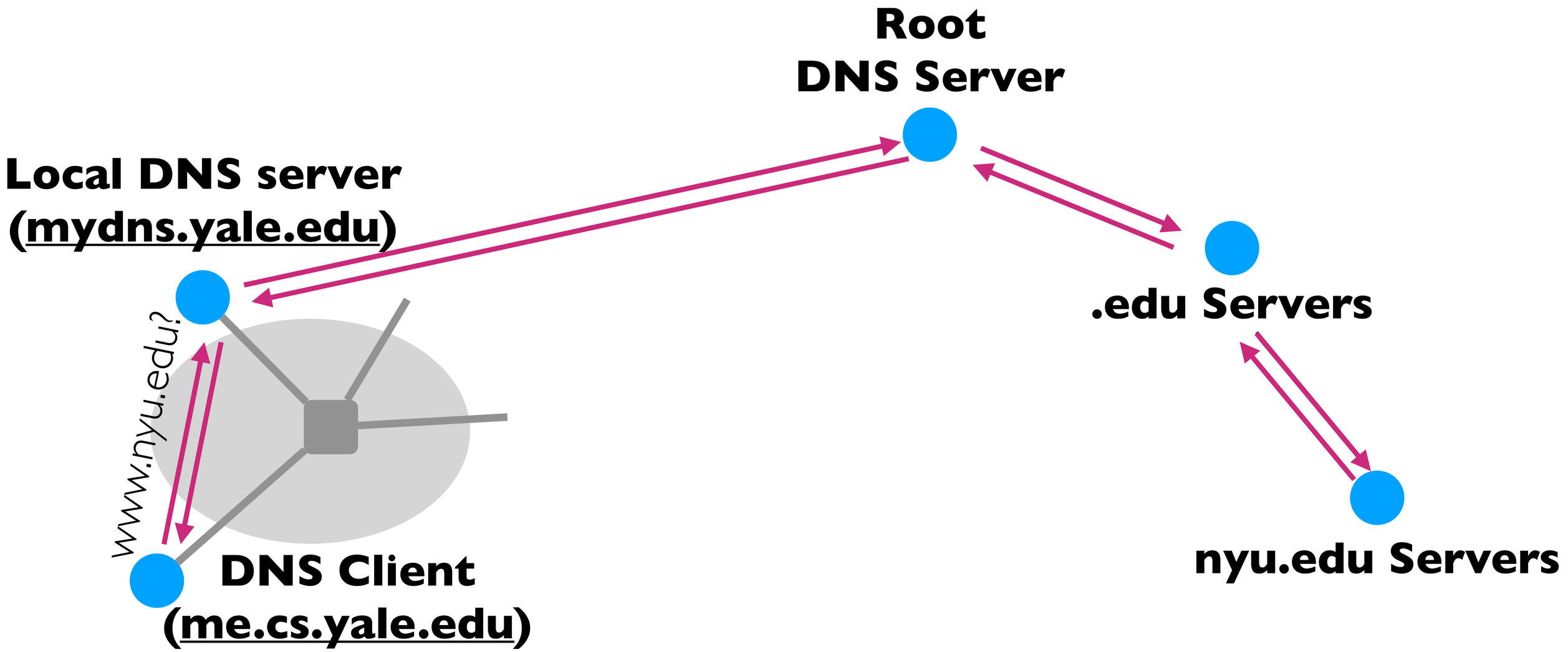
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DNS Server
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- Reduces load at all levels

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- Reduces load at all levels
- Reduces delay experienced by DNS client

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  - DNS servers cache responses to queries
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- **Why caching is effective**
  - The top-level servers very rarely change
  - Popular sites visited often → local DNS server often has the information cached

Negative Caching

Negative Caching

- **Remember things that don't work**
  - Misspellings like *www.cnn.comm* and *www.cnnn.com*
  - These can take a long time to fail the first time
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- **Negative caching is optional**

Time to put your malicious hats on…

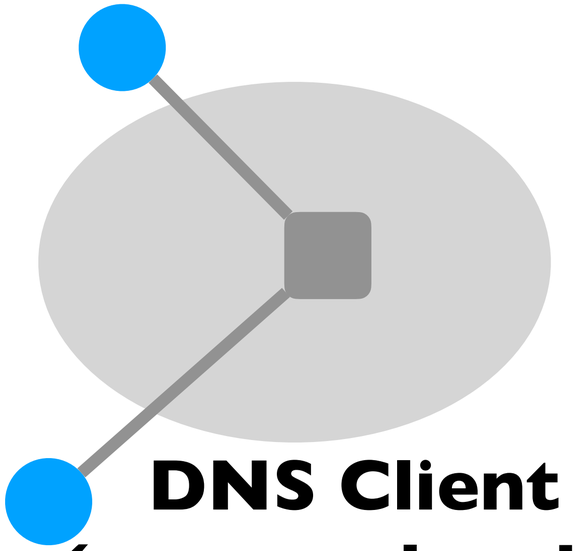
How can one attach DNS?

Root
DNS Server

.edu Servers

nyu.edu Servers

Local DNS server (mydns.yale.edu)



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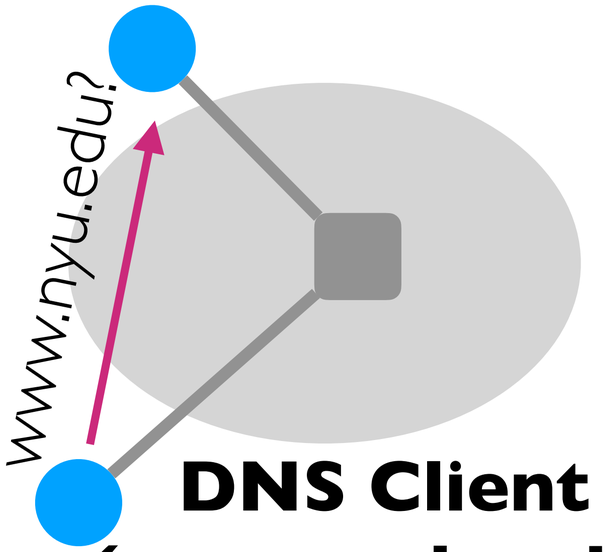

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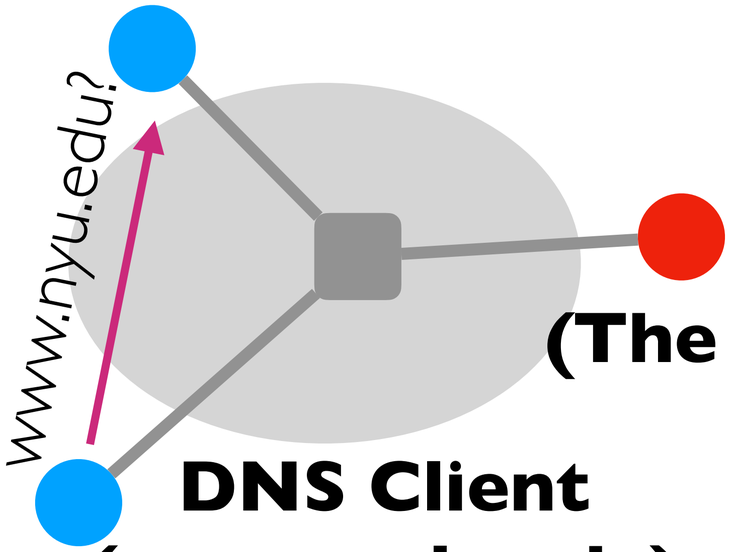

Persa
(The impersonator)

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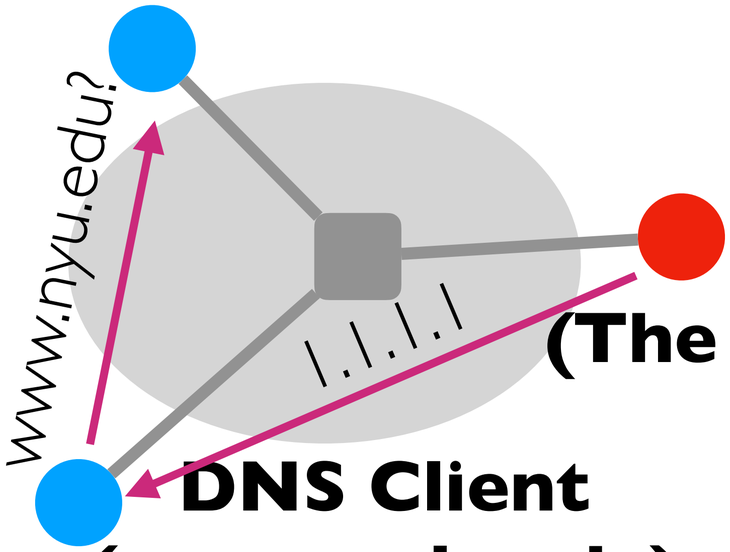

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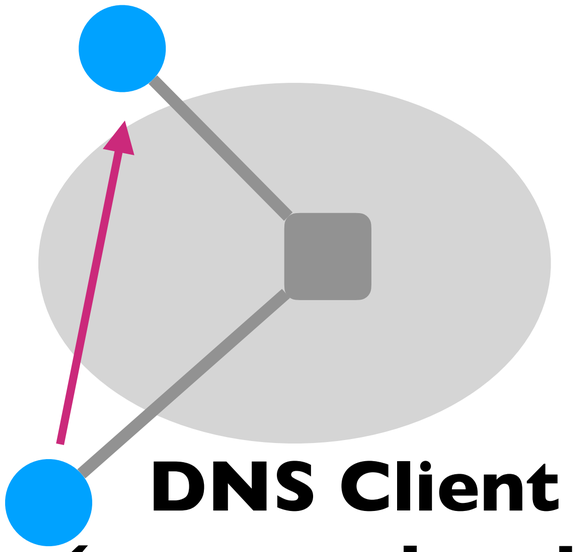

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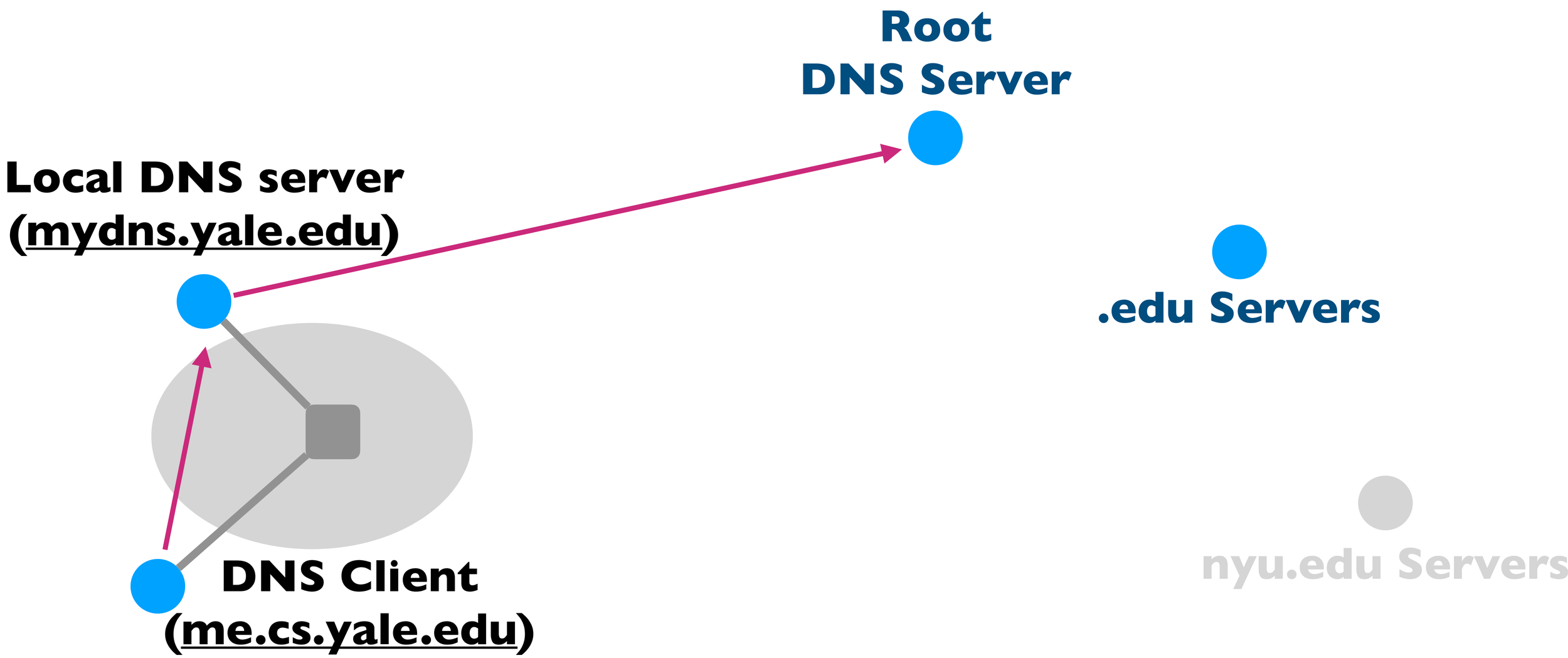
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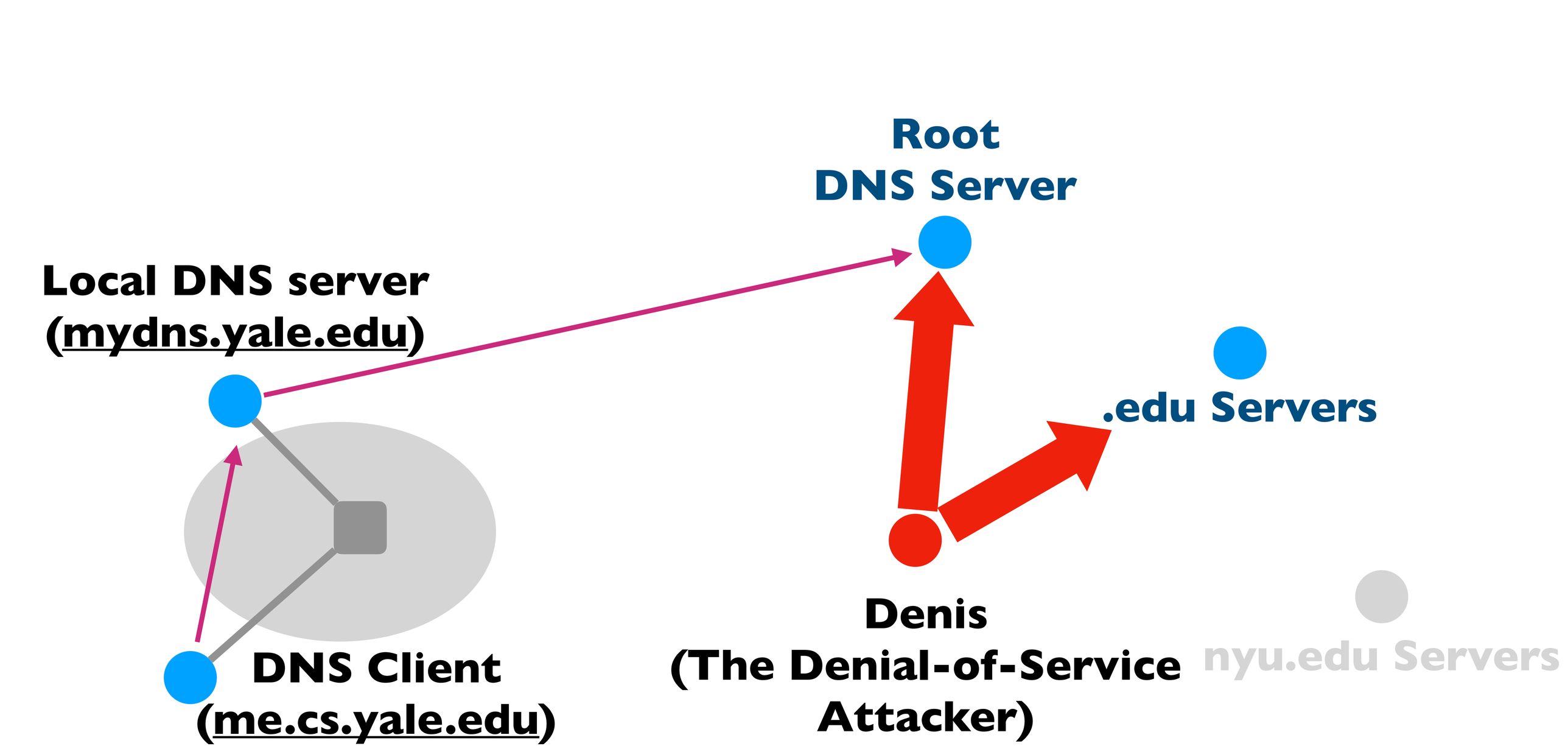
Root
DNS Server
Local DNS server
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Denis
(The Denial-of-Service
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- **Impersonate the local DNS server**
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- **Denial-of-service the root or TLD servers**
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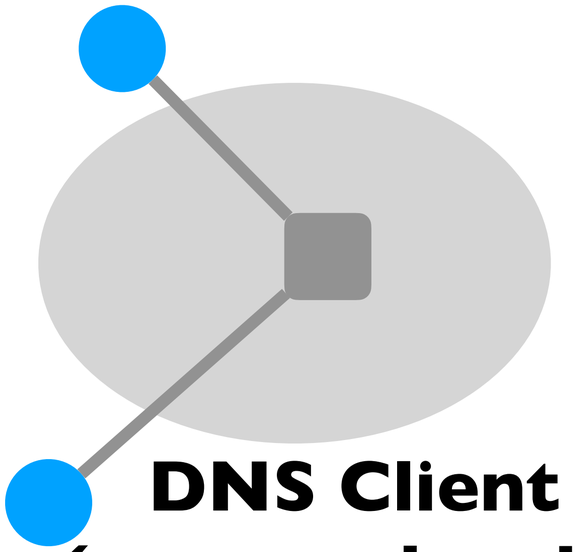

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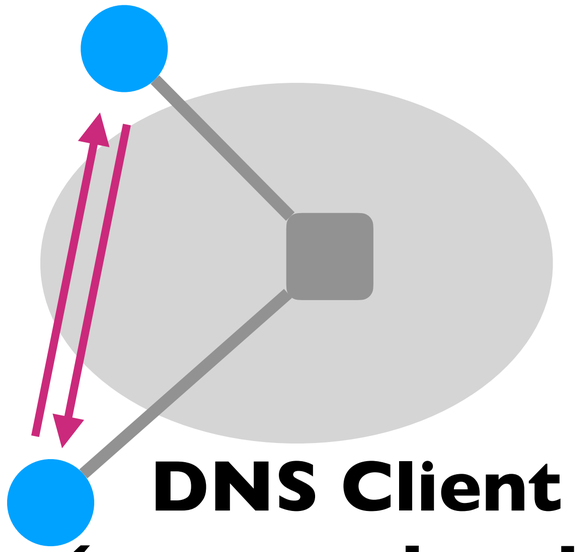

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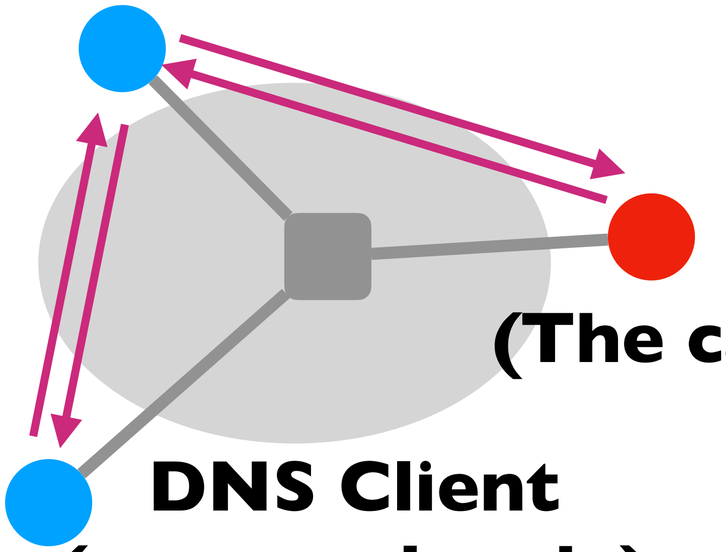

Cacha
(The cache poisoner)

DNS Client
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- **Impersonate the local DNS server**
  - Give the wrong IP address to the DNS client
- **Denial-of-service the root or TLD servers**
  - Make them unavailable to the rest of the world
- **Poison the cache of a DNS server**
  - Increase the delay experienced by DNS clients

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- “Fate sharing” for network failures
- Reasonable trust model
- Caching lends scalability, performance

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- Multiple names for the same addresses
  - E.g., many services (mail, www, ftp) on same machine

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  - Enables load-balancing
- Multiple names for the same addresses
  - E.g., many services (mail, www, ftp) on same machine
- Allowing "host" names to evolve into "service" names