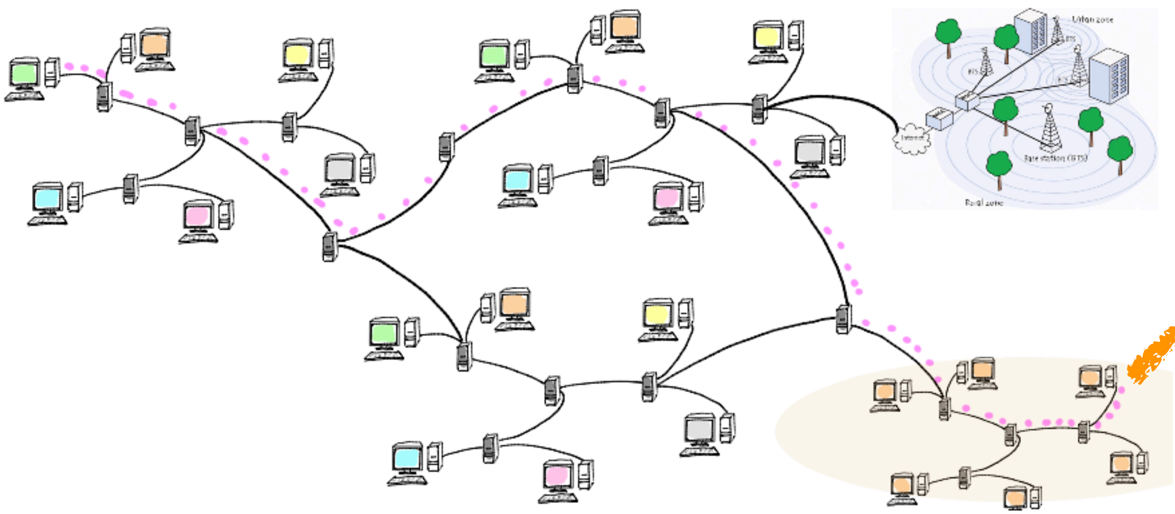
University of Illinois at Urbana-Champaign
Dept. of Electrical and Computer Engineering

ECE 101: Exploring Digital Information Technologies

The Internet
(part 2 of 3)

Review: Sending Data Packets Across the Internet!

Once it's all connected,
- you can **send packets of bits**
- **to any machine on the Internet**!



How?

You **just need an IP address**!

Here's one for **`ece.illinois.edu`**

Every Computer Has a Unique IP Address

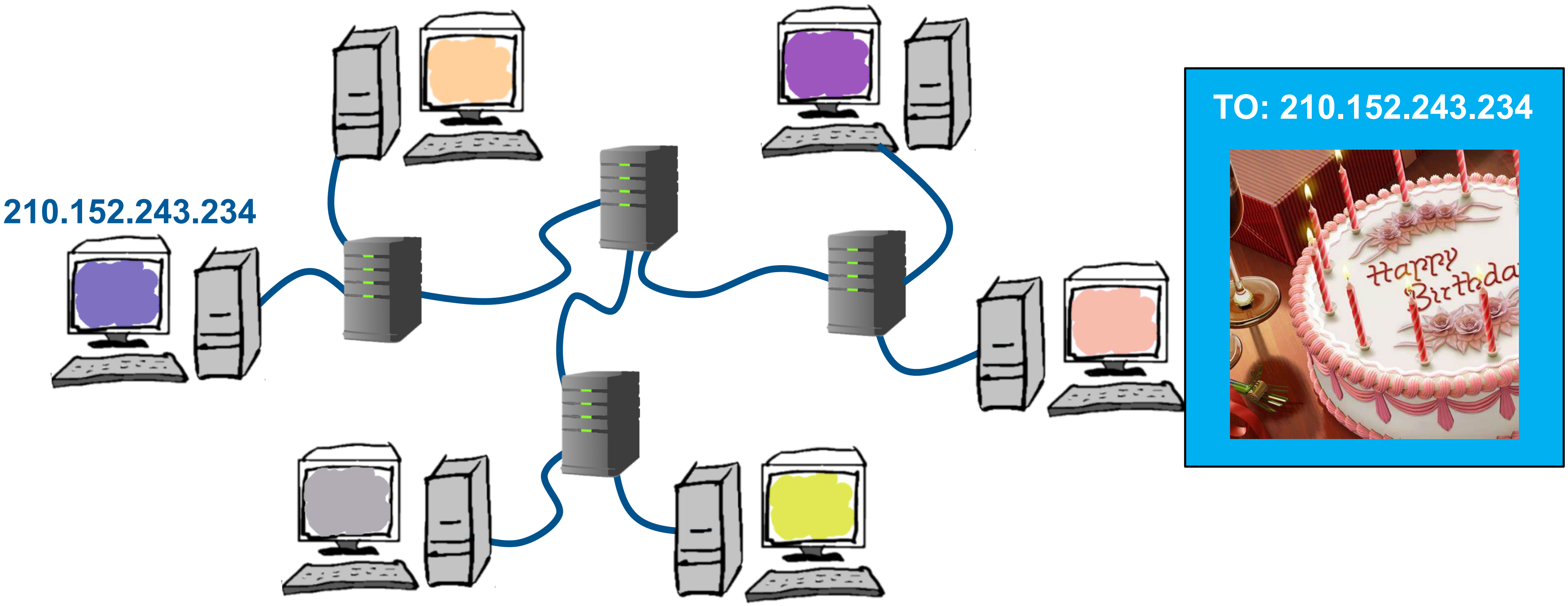
An Internet Protocol (**IP**) **address**

- **is 4 Bytes** (32 bits) … i.e. IPV4
- Humans write **130.126.151.19**,
- but in the computer, it's
- **10000010 01111110 10010111 00010011**
- (without the spaces).

Every computer in the Internet **has an IP address**.*

*Sort of. Today, a household usually shares one public address.

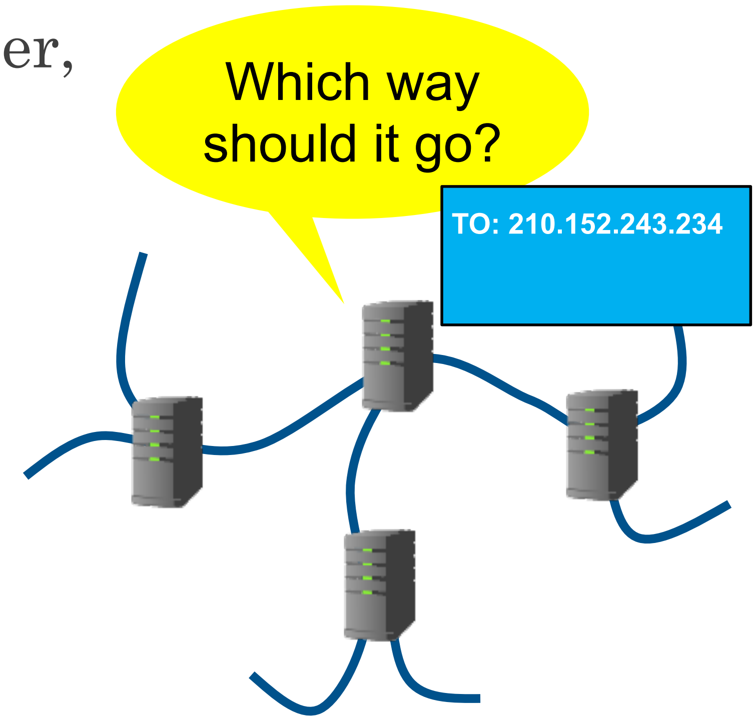
Hierarchical Network



How do the Routers know where to forward Data Packets

When a **data packet arrives** at a router,
- the **router must decide**
- **on which** outgoing link/network **interface**
- **to forward** the packet.

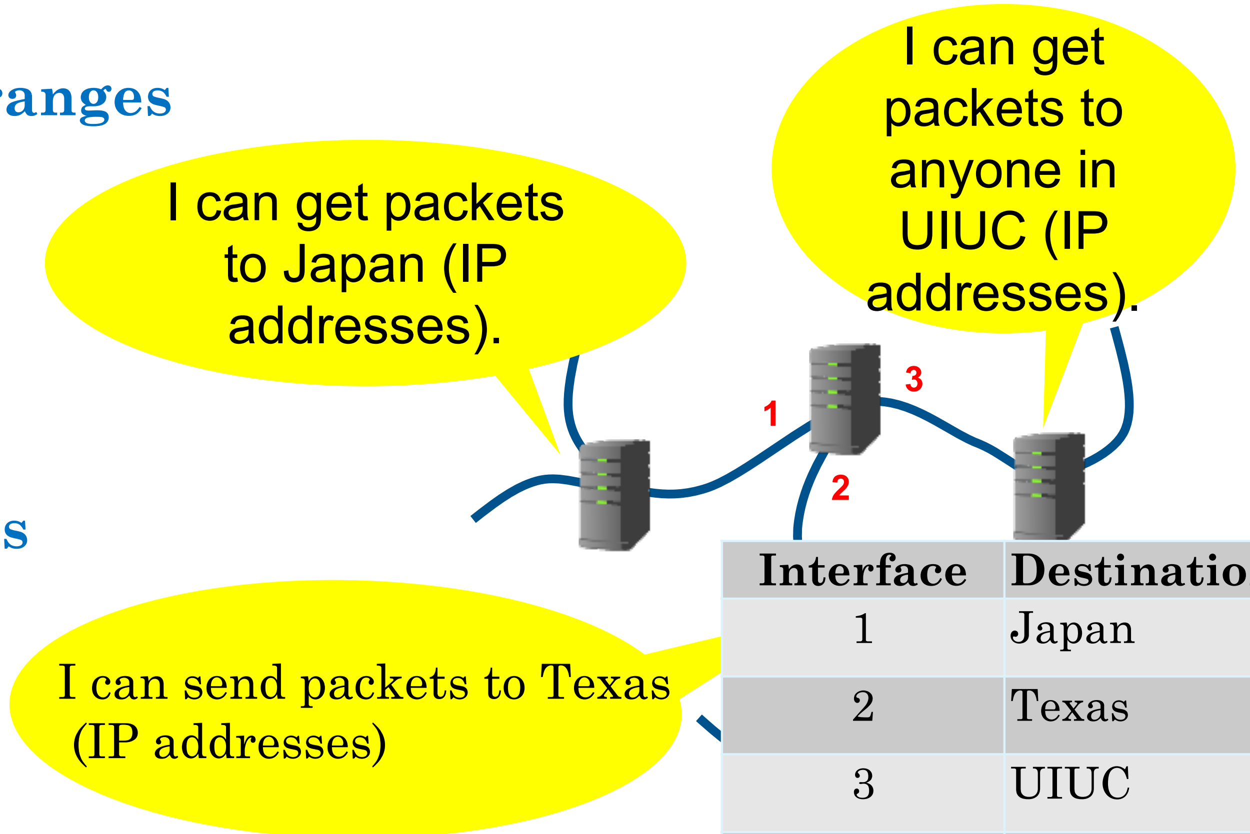
The router looks at two things:
1. destination IP address in packet,
2. and its forwarding table (also called a routing table).



Routers keep updated Routing Tables

Routers periodically
- **advertise IP address ranges that they can reach**
- to their other links,
- as if they are gossiping, who knows whom!!

A **forwarding table maps**
- **IP addresses into**
- **interface numbers**
- (1, 2, or 3, for example).

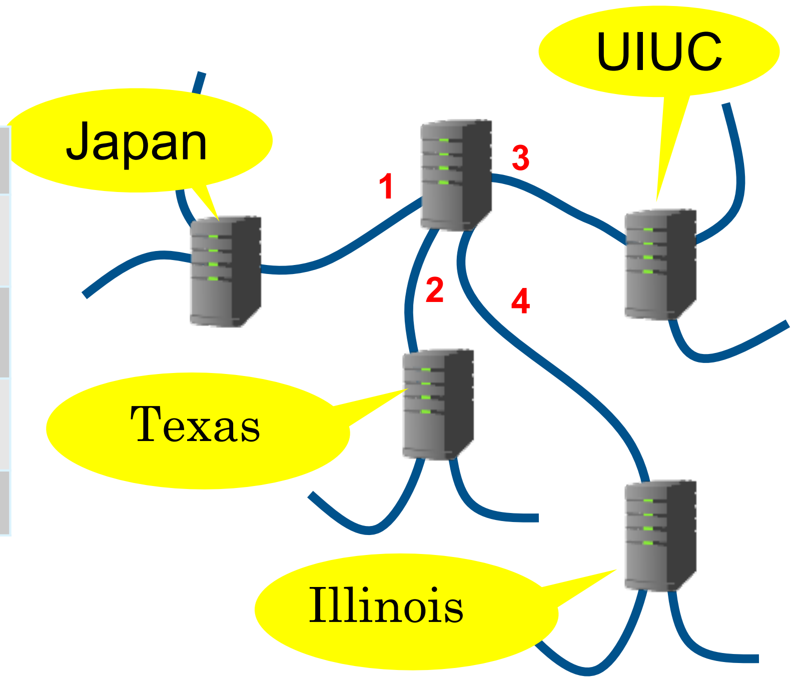


Interface	Destination
1	Japan
2	Texas
3	UIUC

Let's Route

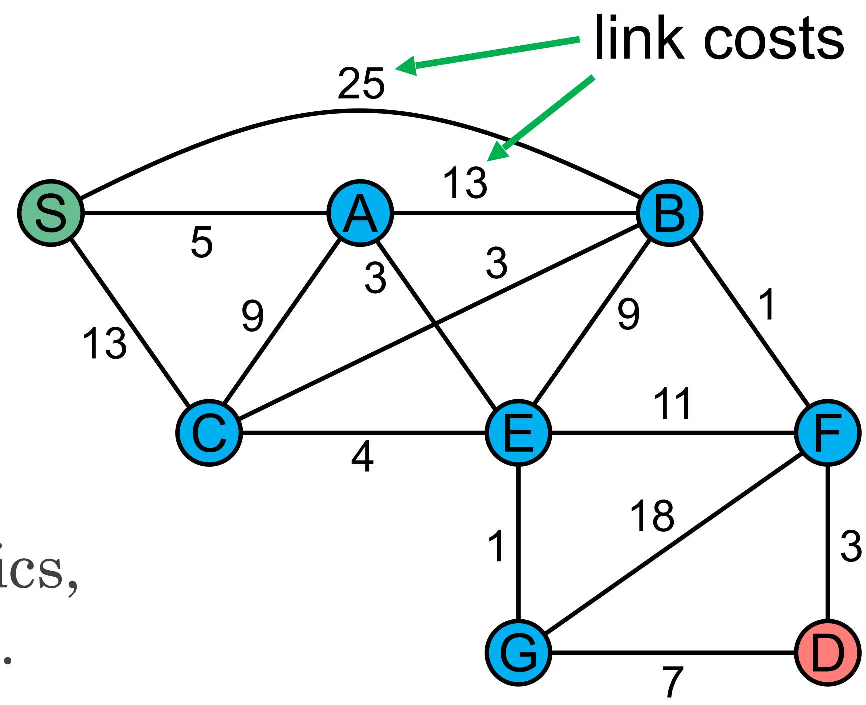
- A packet arrives for Northwestern University (in Chicago, IL, USA).
- **Which interface?**
- A packet arrives for Tokyo University (in Tokyo, Japan).
- **Which interface?**
- A packet arrives for UIUC.
- **Which interface?**
- Usually, the **more specific answer is chosen**.

Interface	Destination
1	Japan
2	Texas
3	UIUC
4	Illinois



Network Graph for Routing

How to get from S to D?



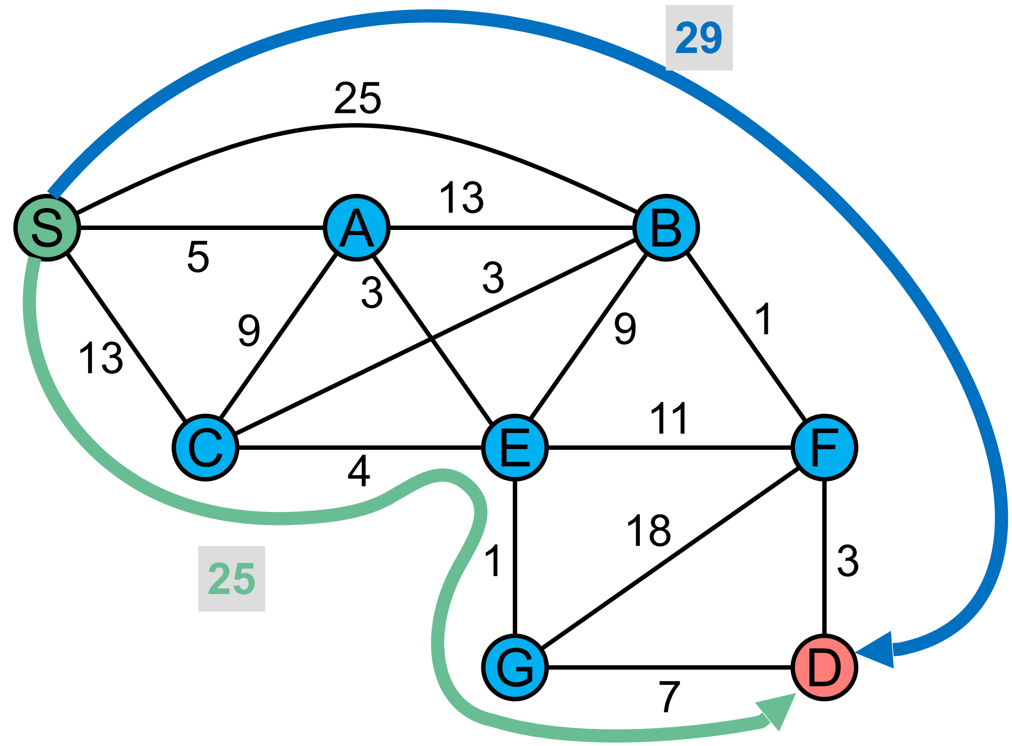
Link cost may reflect
- length (delay),
- link capacity,
- congestion (queueing delay),
- any combination of those metrics,
- or just the router's preferences.

Computing Cost of a Path

How to get from S to D?

The **cost of a path** is
- the **sum of the costs**
- **of** the **links** in the path.

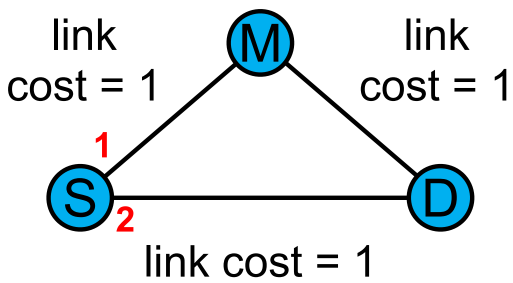
And the **desired path is** the path with the **smallest cost**.



To construct a forwarding table,
- a router must **decide**
- **which path to follow**
- to reach each other node.

Let's Find Routes Together!

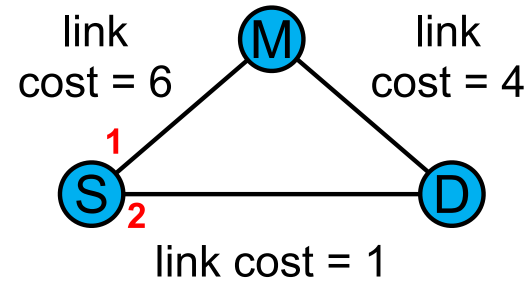
Complete the forwarding table for the node S.



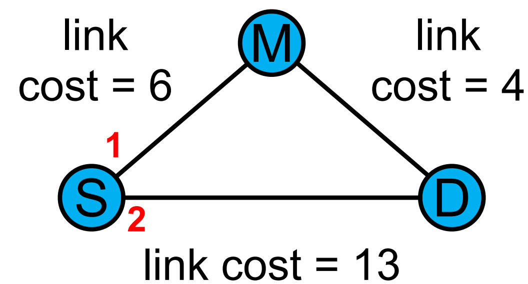
dest	interface
D	2
M	1

(Compute cost by "hops": all link costs are 1)

dest	interface
D	2
M	2



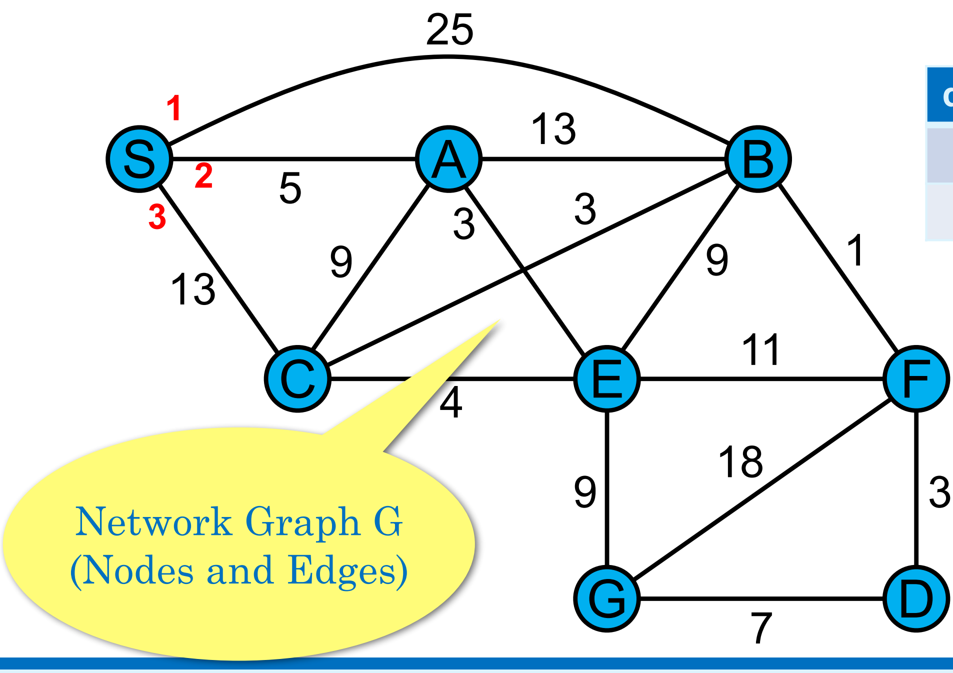
dest	interface
D	1
M	1



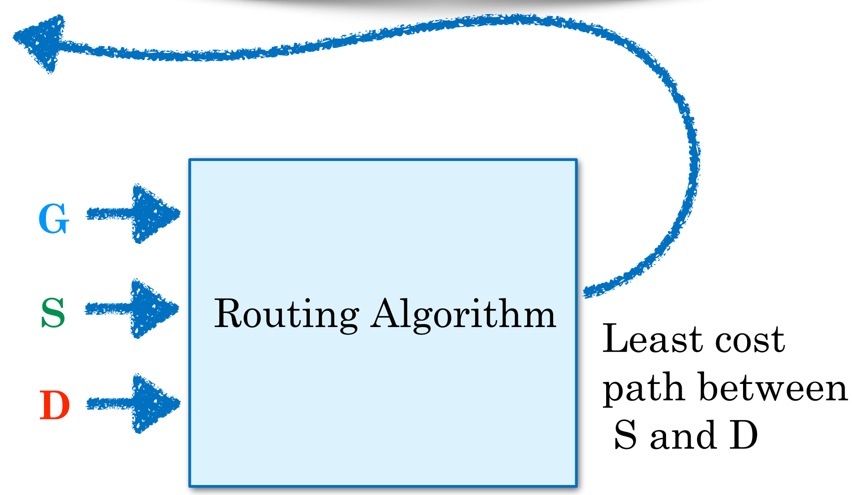
Here's a challenge …

Complete the forwarding table for **destination node D** from the **source node S**.

The computer will do it for you!!



dest	interface
D	?
…	…

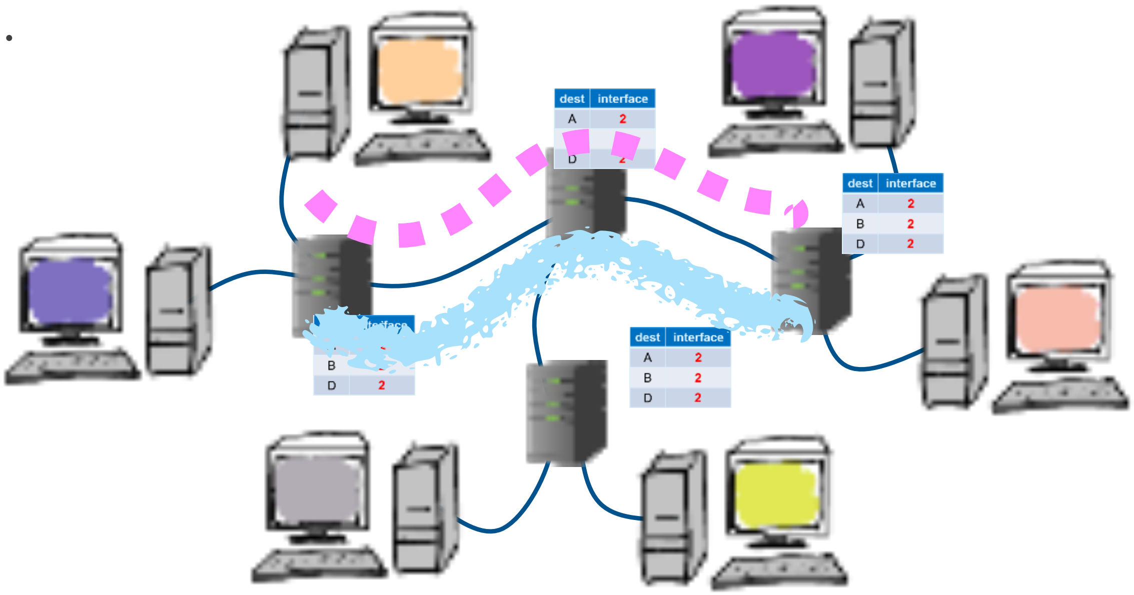


Data and Control Planes

Routers forward **packets**.
- Packets containing data are said to pass **through the data plane**.

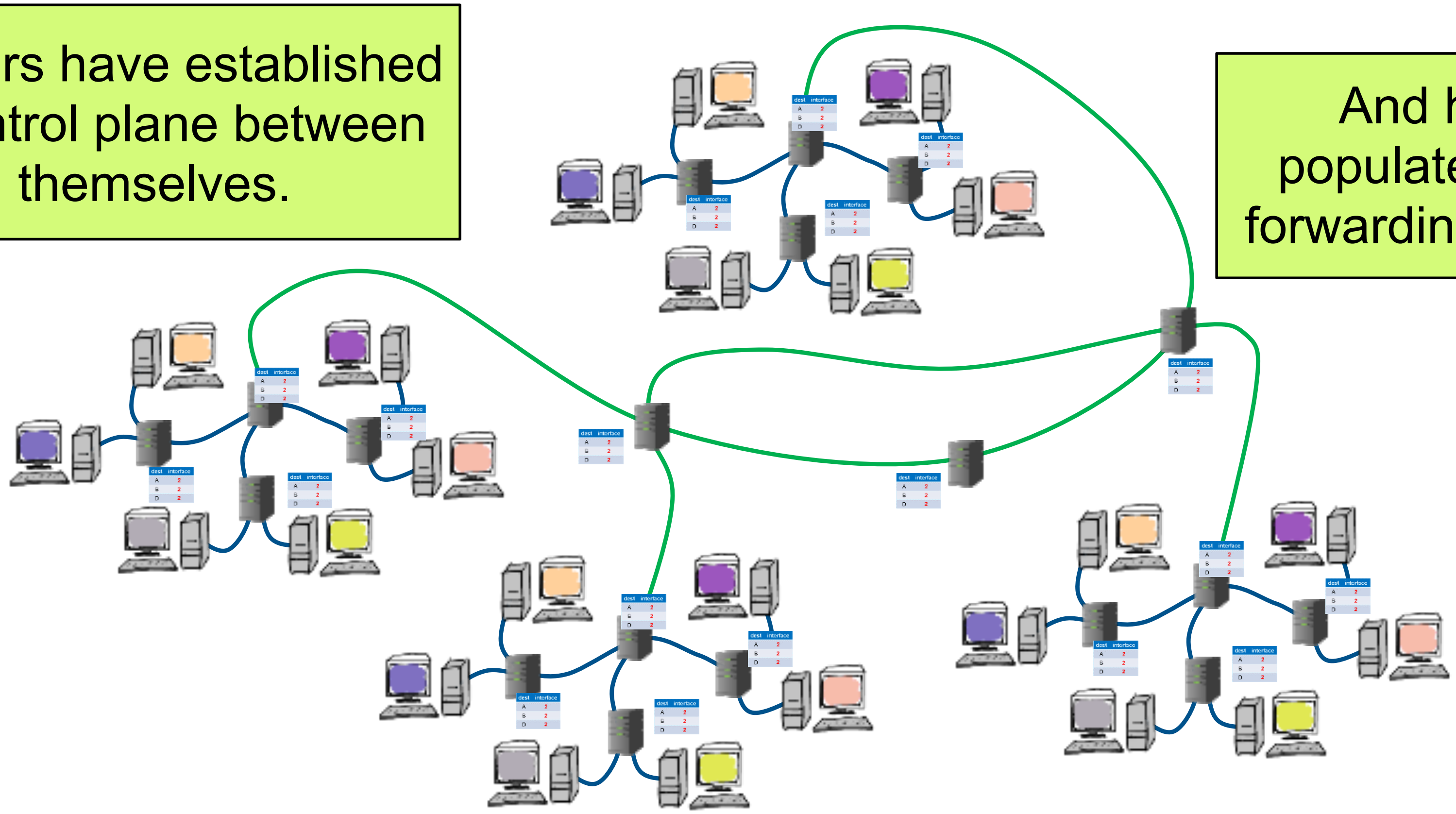
Routers exchange **information about routes** available to them.
- These coordination messages travel **through the control plane**.

The two planes
- use the same physical network
- but are logically separate.



Internet Plumbing's Ready: Routing and Forwarding

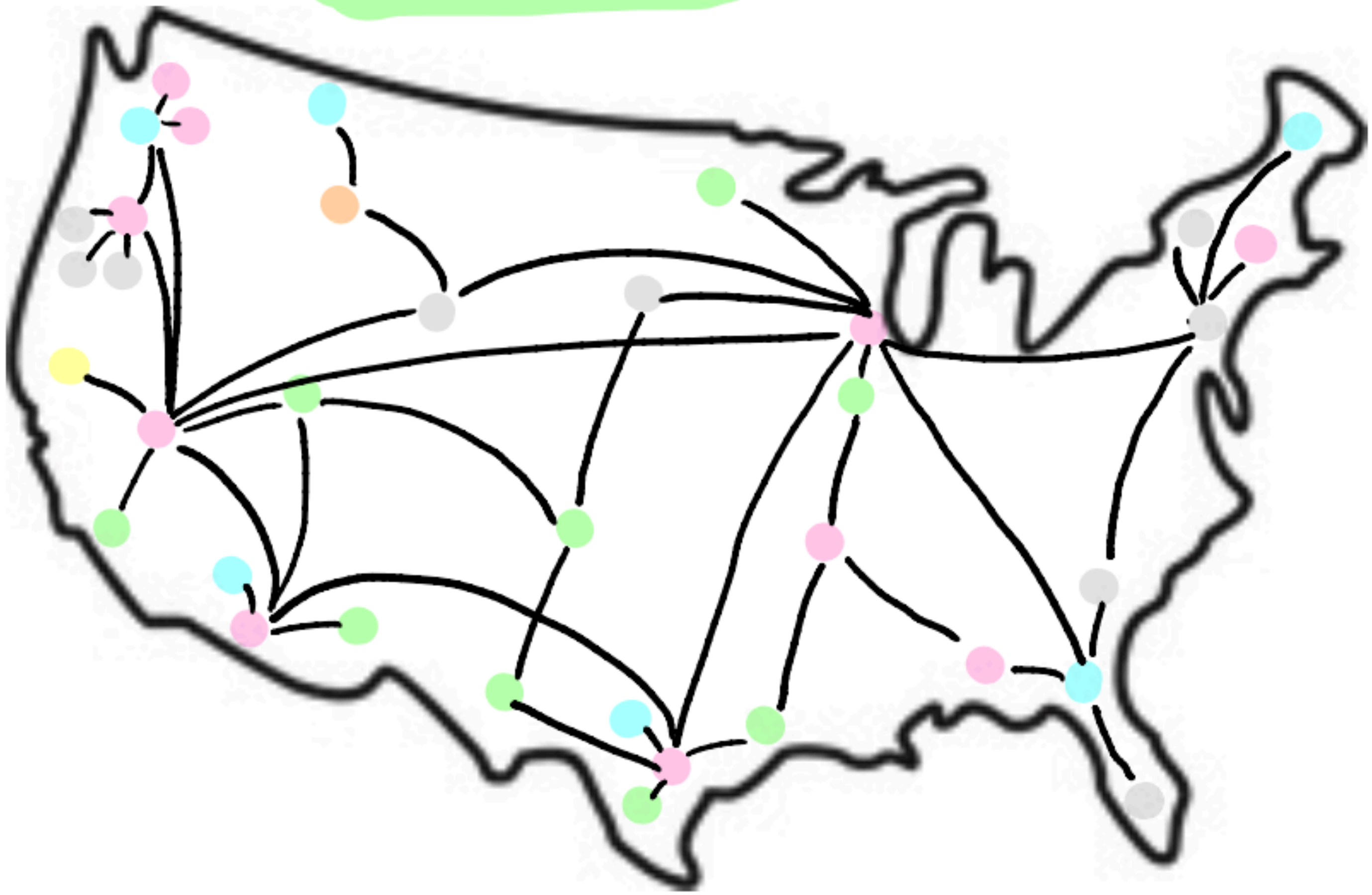
Routers have established a control plane between themselves.



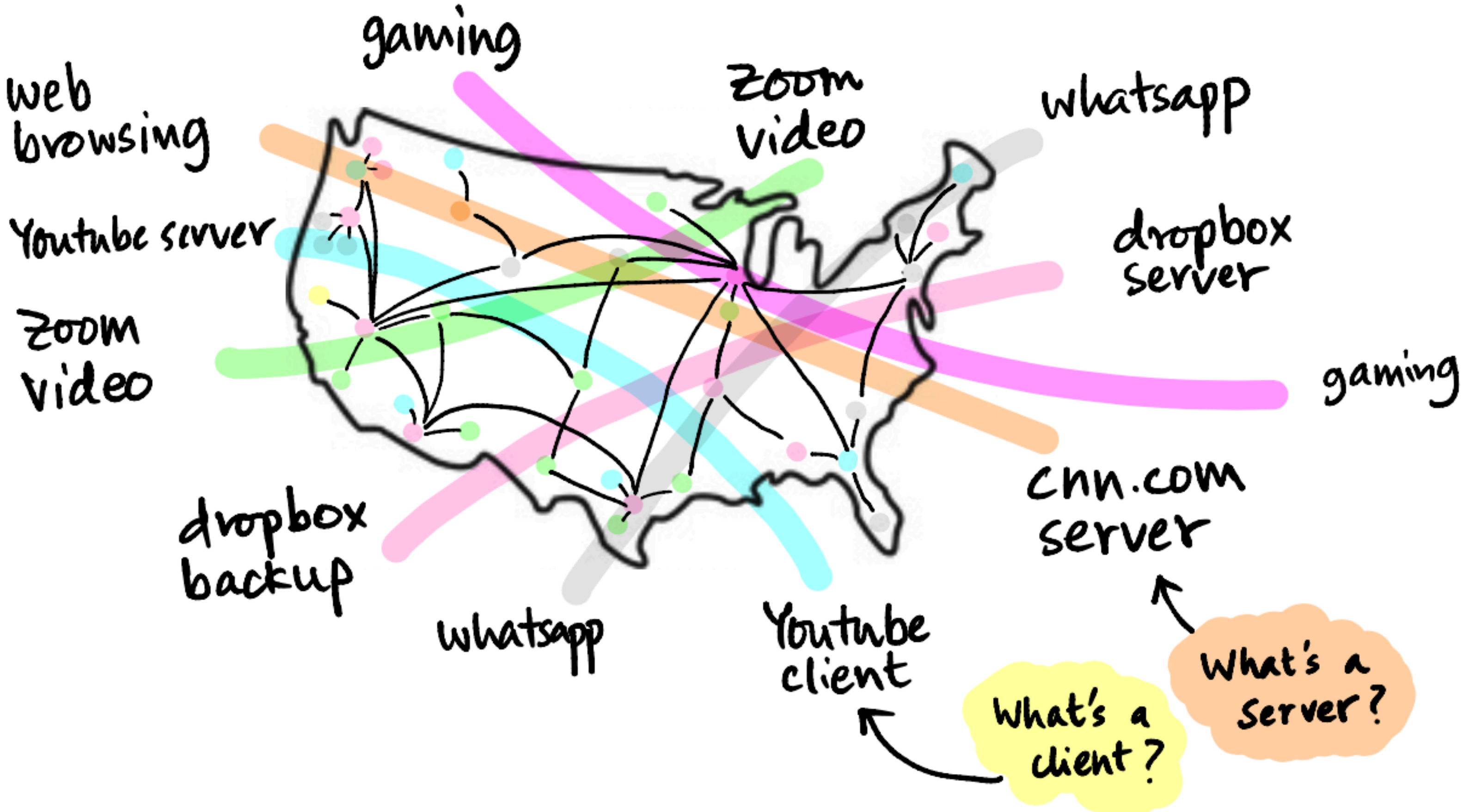
And have populated their forwarding tables.

The airports are ready, and flights can link them

Now what?



Applications running on the "edge"

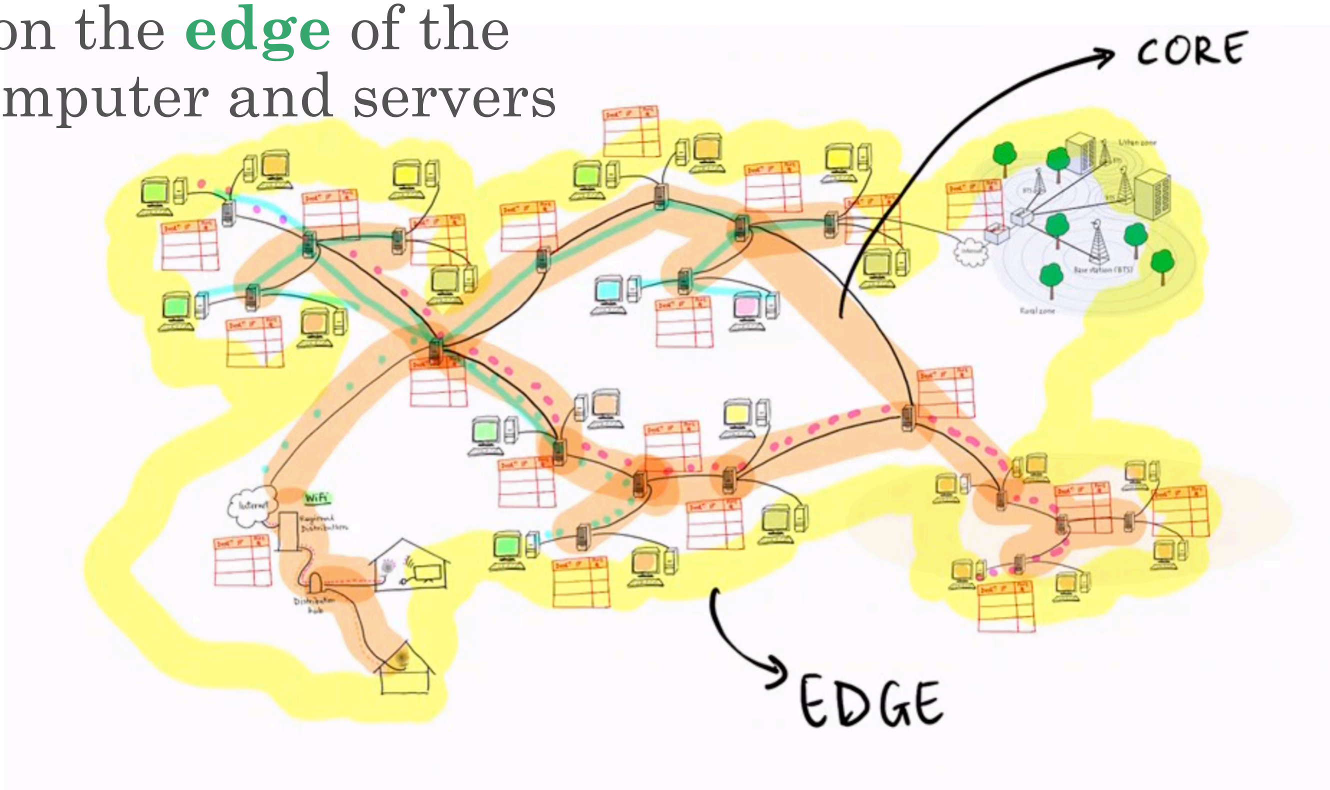


The Edge and the Core of the Internet

Applications operate on the **edge** of the network, where your computer and servers are connected.

Everything else
- all of the routers,
- all of the rest of the hierarchy,
- the plumbing of the Internet,

…these form the **core of the Internet**.



Application: Web Browser

You are planning a vacation.

So you open your browser and type "lonelyplanet.com" (for example).

Somewhere across the Internet is a **server**—maybe in Dublin—that has the Lonely Planet homepage.

Your browser sends a **request** to the Lonely Planet server.

The server sends a **response** with the page back to your browser.

HTTP: An Application Protocol for Browsing the Web

The computers participating in the exchange

- your browser on **your laptop** and
- the lonely planet **server**,
- must use the same **protocol**.

The protocol **used for web browsing is**

Hyper-Text Transfer Protocol (**HTTP**)

HTTP Requests and Responses Use Human-Readable Text

So what does your computer actually send?

English sentences?

"Please give me the web page at lonelyplanet.com."

No!

Like most computer protocols,

- **HTTP has rules**
- about how to request
- and receive information.

HTTP is more friendly, though—it does **use human-readable sequences of bytes** (text).

Contents of an HTTP Request

A HTTP request

- (like your browser sends) has
- a command (GET),
- a web page name (/index.html)
- a protocol specification (HTTP/1.0),
- and some options.

```
GET /index.html HTTP/1.0
User-Agent: Mozilla/4.0
Host: lonelyplanet.com
(more options, ending blank line)
```


Contents of an HTTP Response (Successful)

A HTTP response

- (returned from a web server to your browser) has
- a protocol specification (HTTP/1.0),
- an error code (200 OK),
- some options,
- and the web page itself (in HyperText Markup Language, HTML).

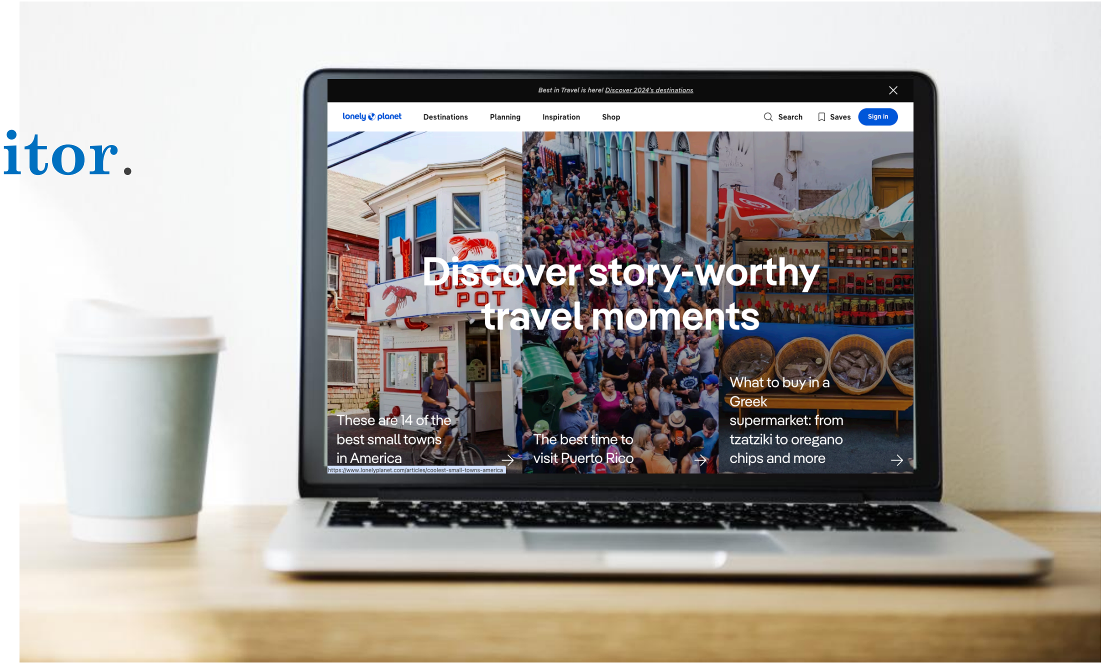
```
HTTP/1.0 200 OK
Date: Fri, 9 Sep 2022 16:20:23 GMT
Server: Apache/2.2.15
(more info)

Bits for the web page (in HTML)!
```

When Browser Receives HTTP Response, It Renders Page

When your **browser**
- receives the web page,
- it **renders** it **on your monitor**.

Usually, the browser
- **simultaneously makes requests**
- **for images, videos, and other things**
- embedded in the page.



Data Packets

really just a sequence of **bits**.

The request and response are sent as **data packets**

Control Bits/Packet Header **Data Payload**

Request

Protocol Name	Version	Browser	…	Name of webpage
1010…01	10	10011		10001010 10001000 10000101 10001011 10000111

Response

Protocol Name	Version	Server	…	Contents of the webpage
1010…01	10	11001		1011010 11001000 10100001 11101011 10111111 1000010 10001000 10000101 10001011 10000111 … 1011011 10101000 10000101 11111011 11000111

Where to send the packet?

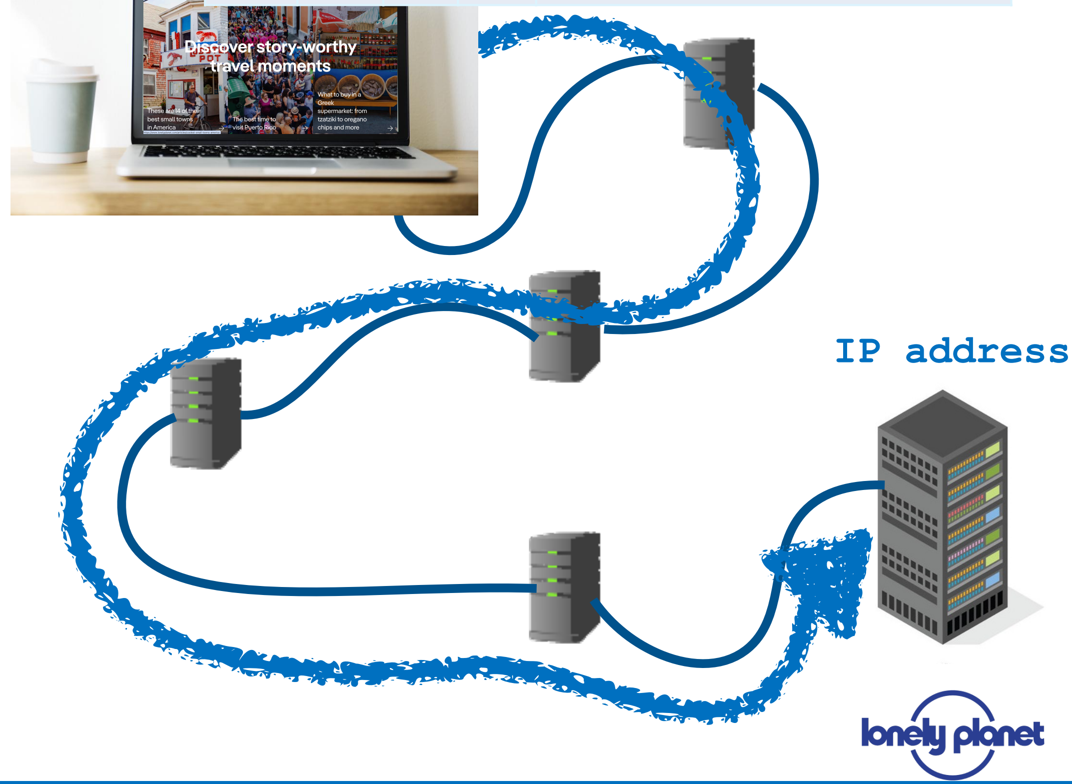
Protocol Name	Version	Browser	…	Name of webpage
1010…01	10	10011		10001010 10001000 10000101 10001011 10000111

Your browser prepares the **request** data packet to be sent.

Where do you send it to? What do you need to send it?

Do you have to know the addresses of all the servers everywhere?

No. You use the **DNS**



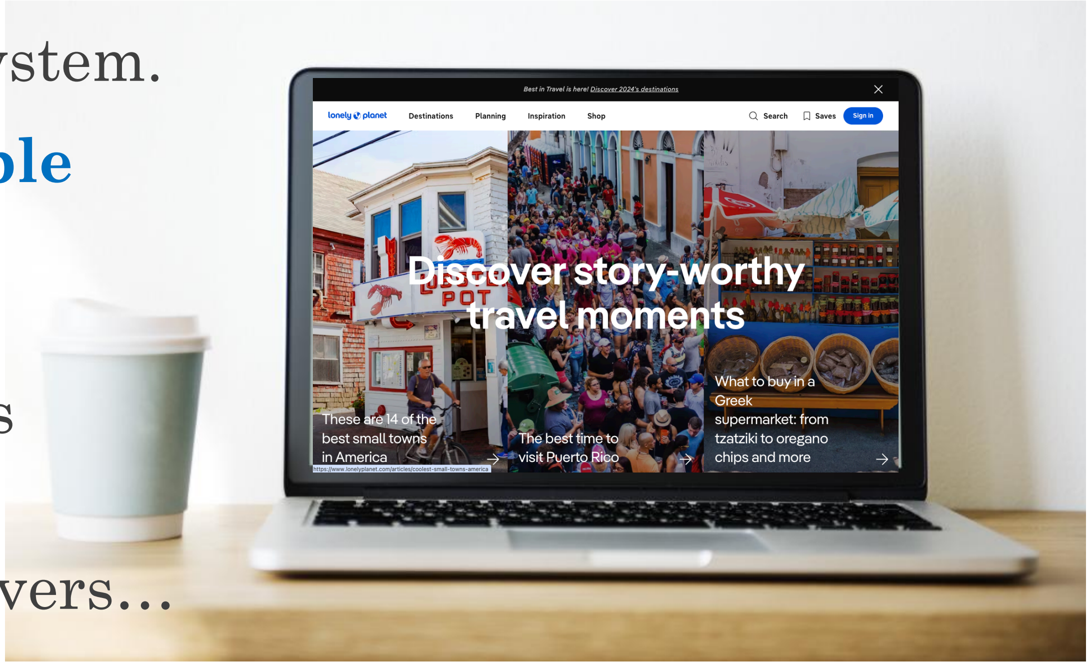
DNS Translates Human-Readable Names to IP Addresses

DNS, or the Domain Name System.

It **translates human-readable names** like lonelyplanet.com **into IP addresses**.

There are 13 DNS root servers around the world.

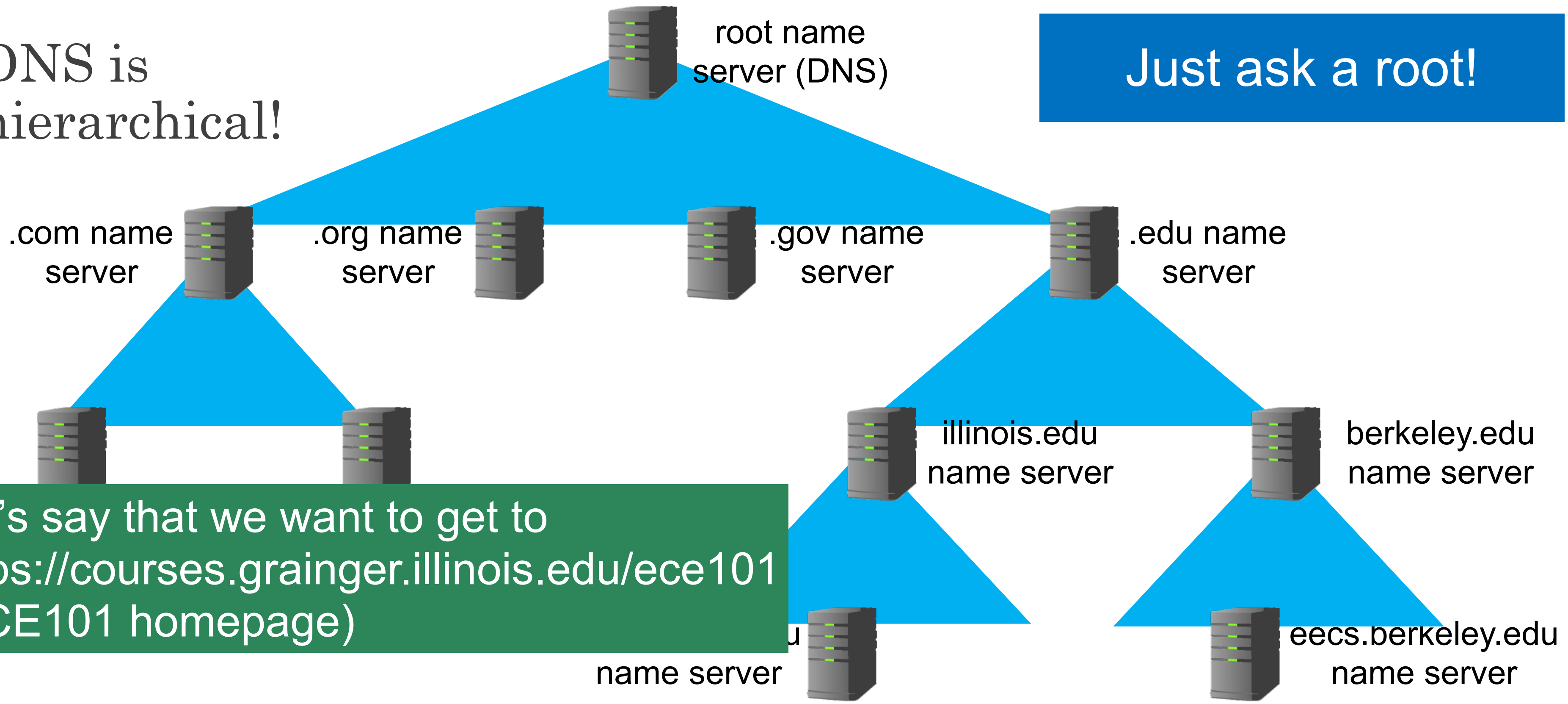
Billions of people using 13 servers…



Domain Name System (DNS) Server Hierarchy

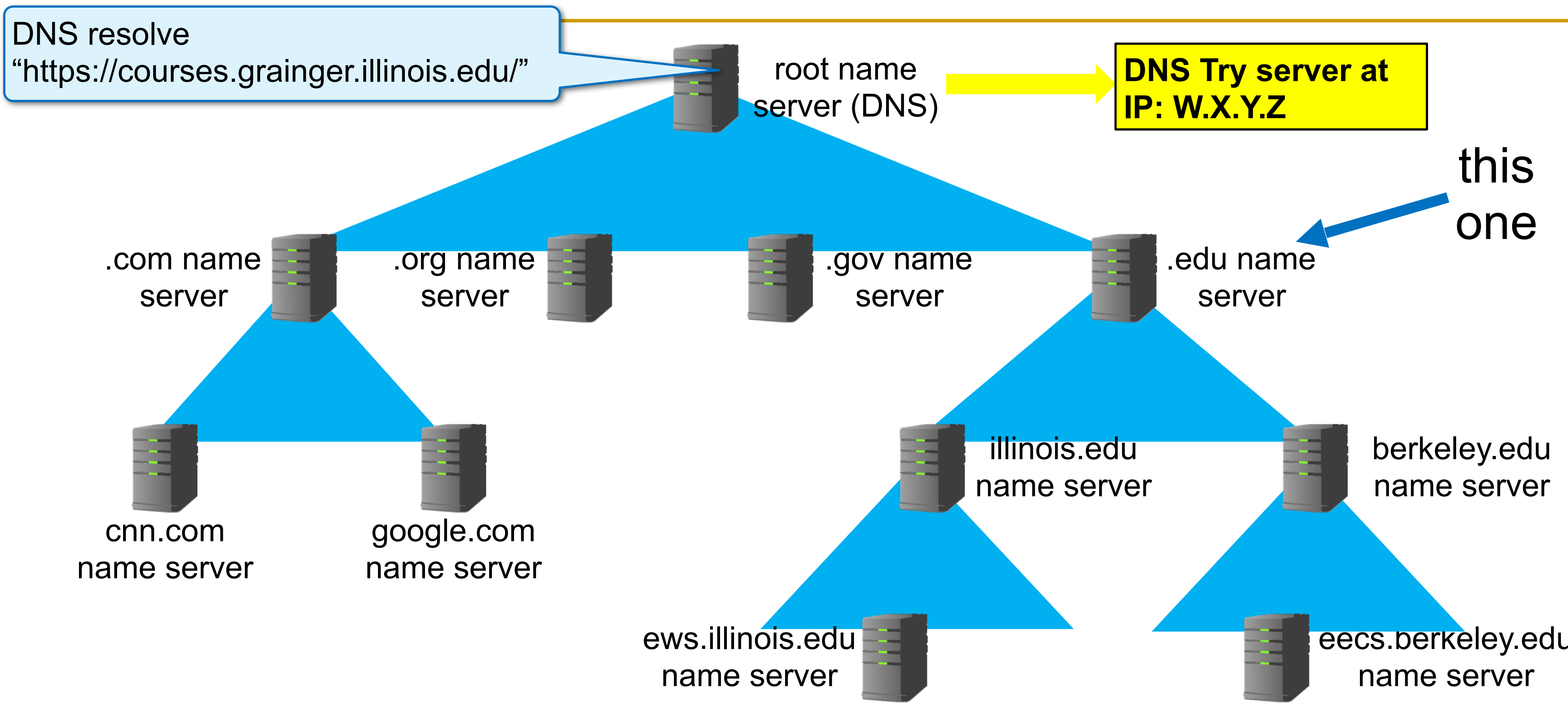
DNS is hierarchical!

Just ask a root!

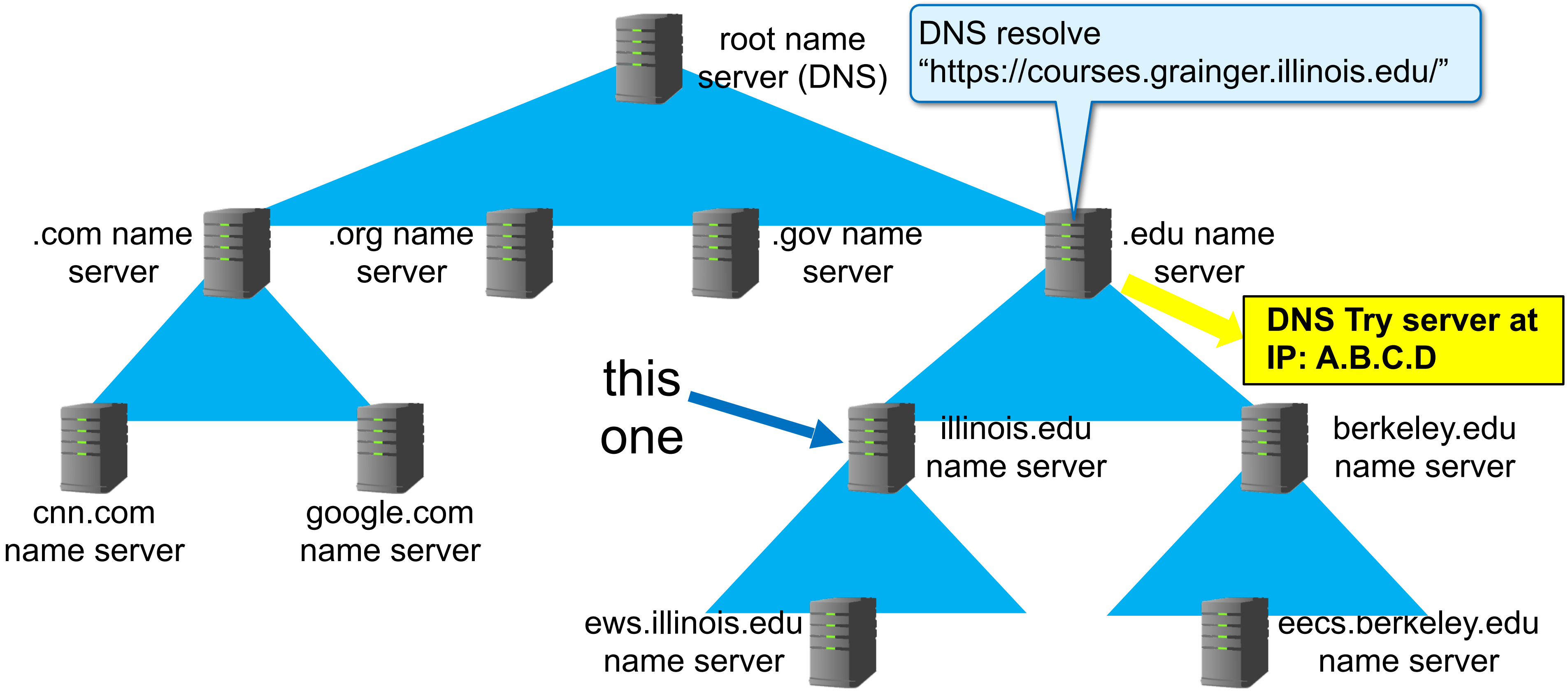


Let’s say that we want to get to https://courses.grainger.illinois.edu/ece101 (ECE101 homepage)

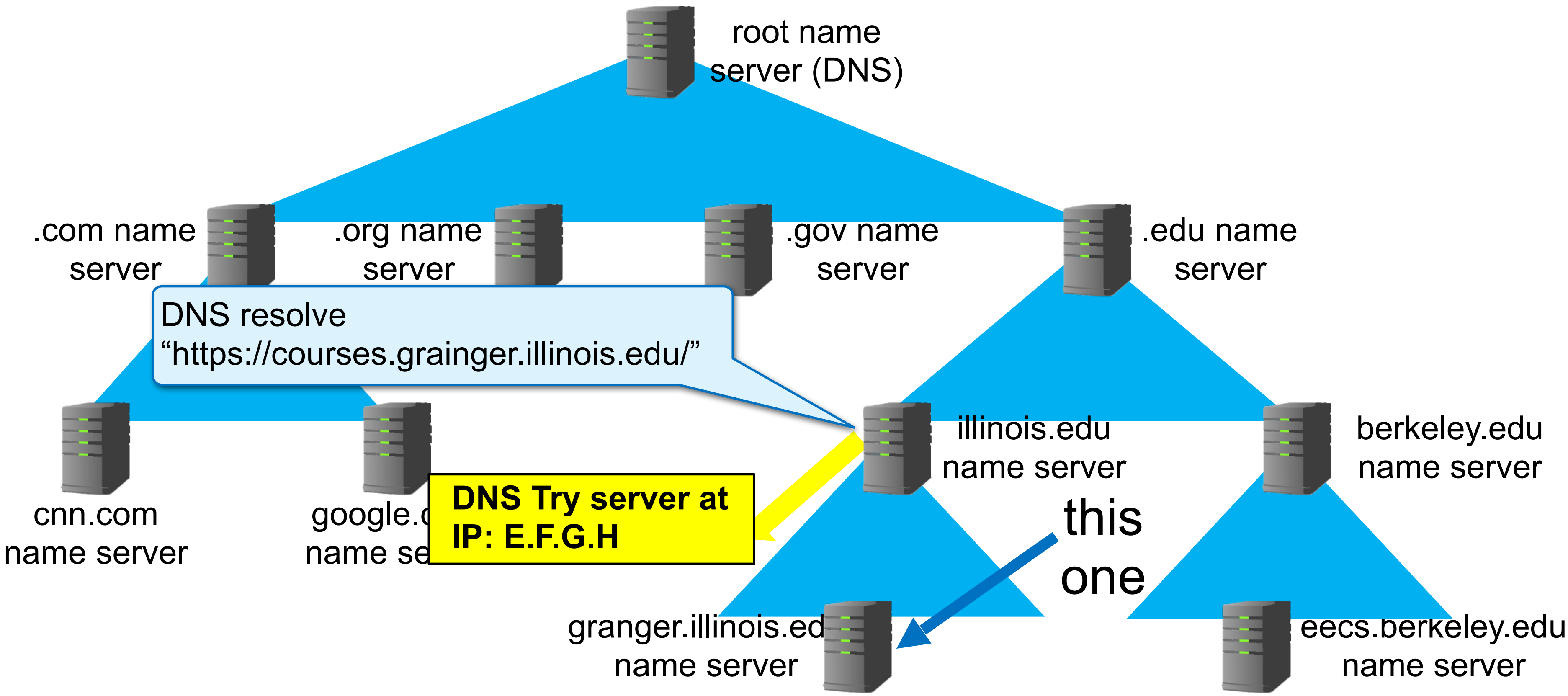
DNS Lookups Start Logically at the Root



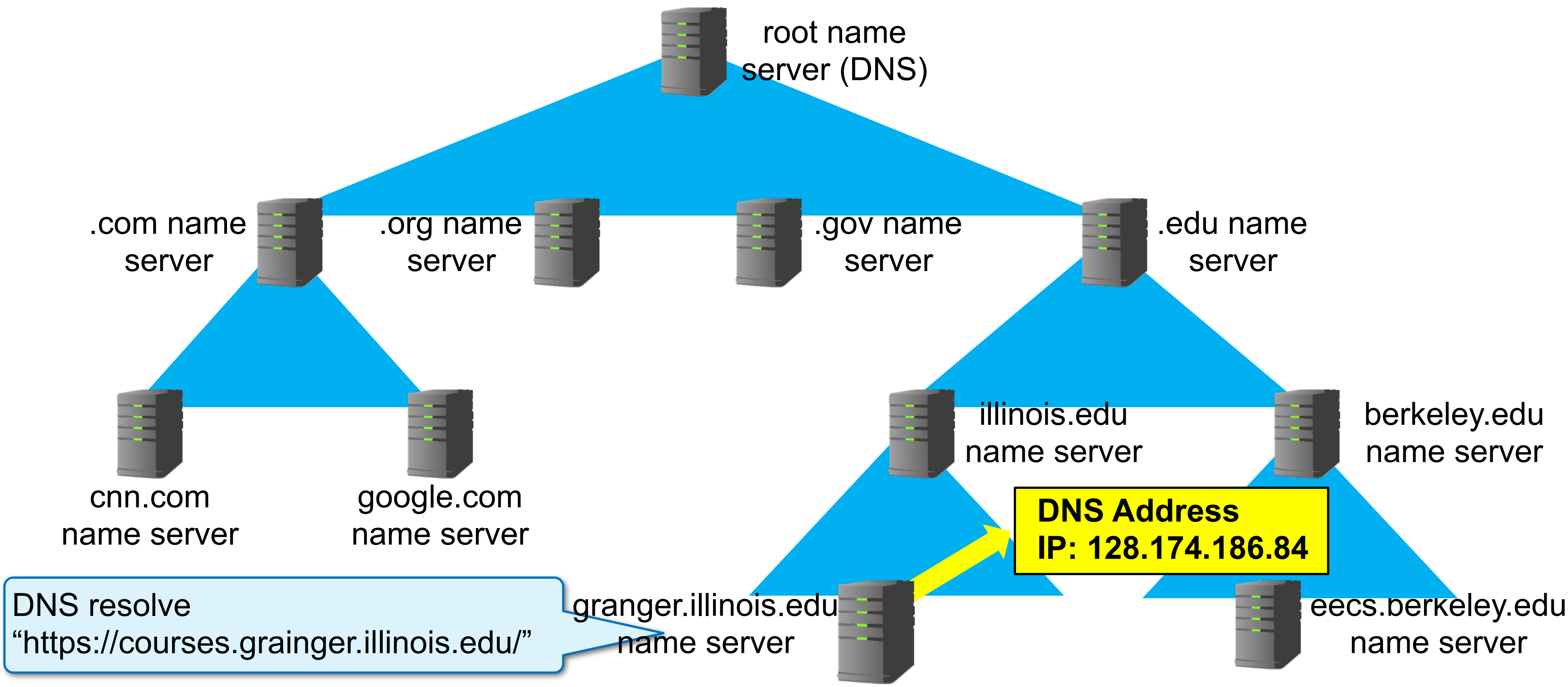
DNS Lookups Iterate Until an Answer is Found



DNS Keeps Chugging Along



Until, Finally, an Answer!

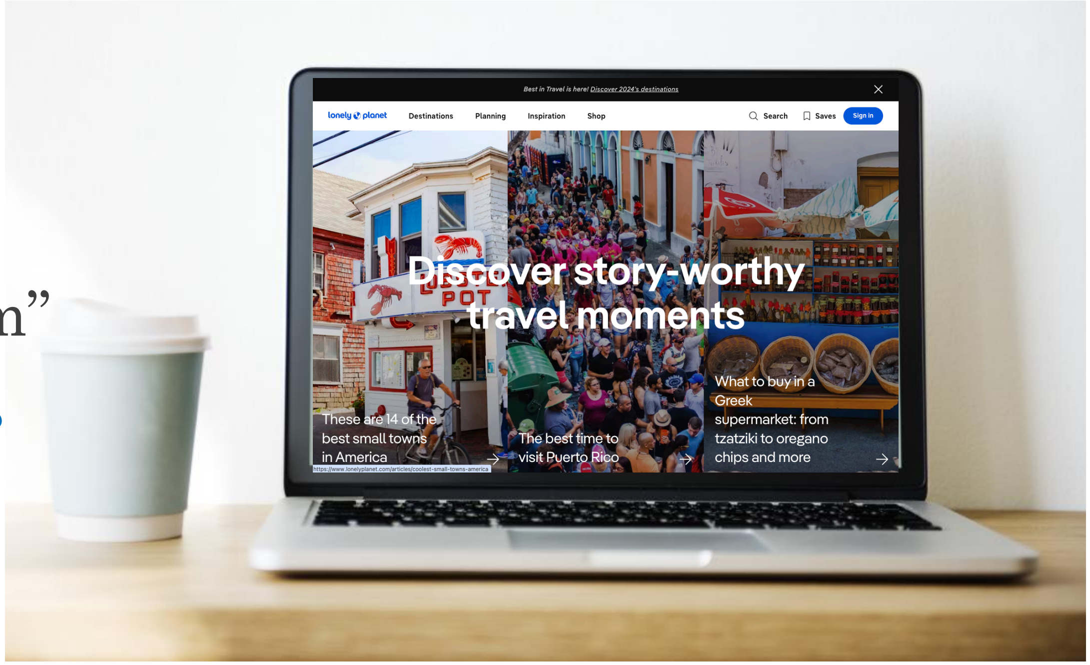


DNS Provides the IP Address for lonelyplanet.com

Back to our example…

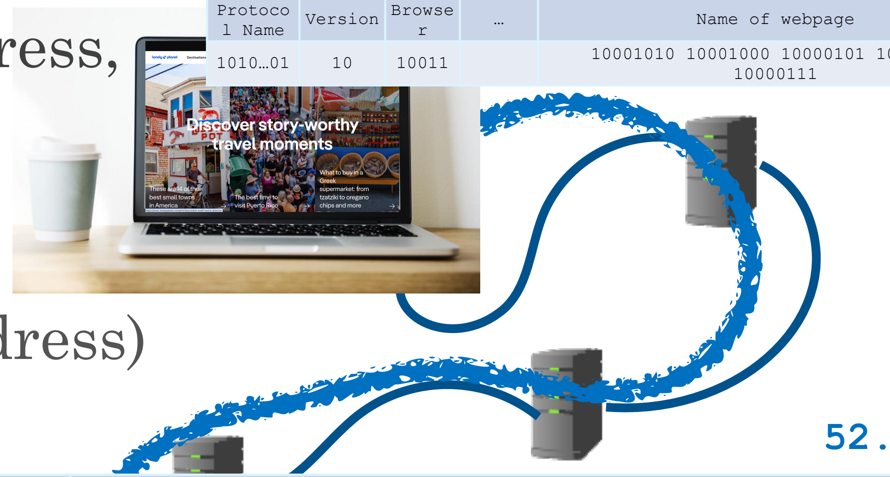
Your web browser wants to connect to "lonelyplanet.com"

It **queries DNS and obtains an IP address**: 52.84.52.66.

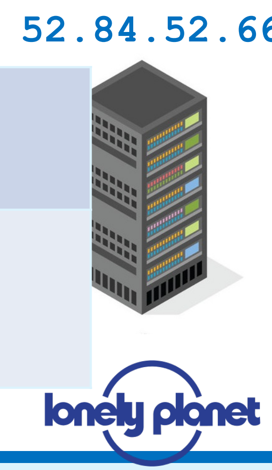


Send the request off …

Once the browser has the IP address,
- it can add it to the data packet
- as **destination IP**
- in packet header **control bits,**
- also add **source IP** (return address)
- and **send**



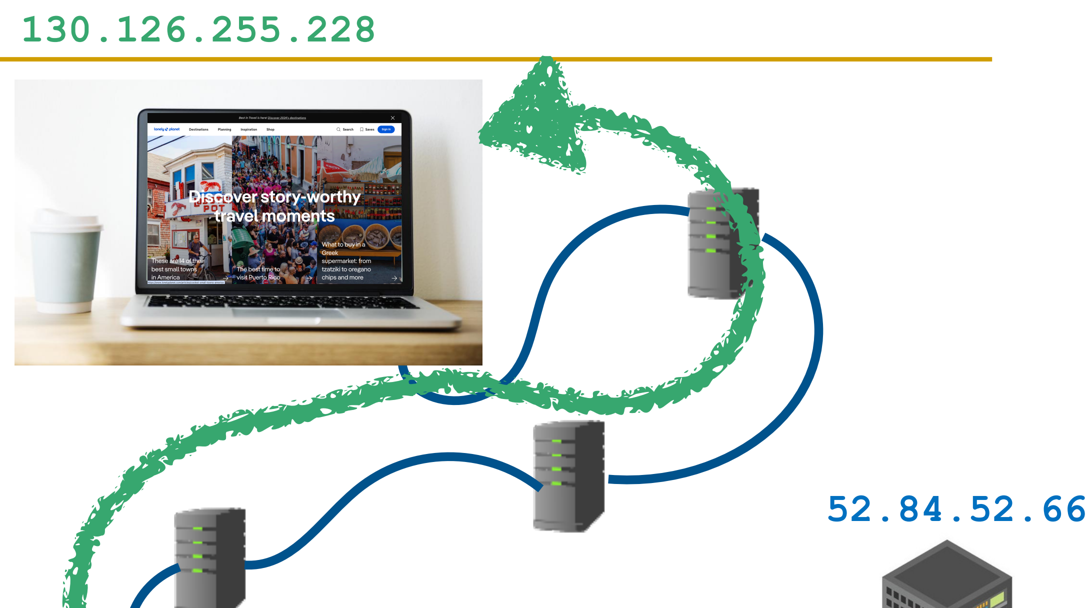
Protocol Name	Version	Browser	…	Name of webpage
1010…01	10	10011		10001010 10001000 10000101 10001011 10000111



Destination IP	Source IP	Protocol Name	Version	Name of webpage
00110100 01010100 00110100 01000010	10000010 01111110 11111111 11100100	1010…01	10	10001010 10001000 10000101 10001011 10000111

Get back a response …

Once the server receives the request,
- it puts the webpage
- in a data packet
- and sends it back to your browser



Destination IP	Source IP	Protocol Name	Version	…	Contents of the webpage
10000010 01111110 11111111 11100100	00110100 01010100 00110100 01000010	1010…01	10		1011010 11[illegible]01000 10100001 11101011 10111111 1000010 10001000 10000101 100[illegible]1011 100[illegible]0111 … 1011011 10101000 10000101 11111011 11000111

Terminology You Should Know from These Slides

- edge (of Internet)
- core (of Internet)
- Applications
- HyperText Transfer Protocol (HTTP)
- HTTP request and response
- Data packet
- Control bits/packet header
- Data Payload
- Domain Name Service (DNS)

Concepts You Should Know from These Slides

- how a web browser finds and renders a page for you
- why you need a protocol
- uses of packet header: IP addresses, protocol commands (example: HTTP GET)
- what service DNS provides and how it works