How the Internet Works

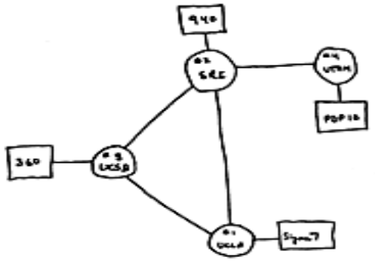
(in 1 hour)

Professor Nick McKeown
1964

"*A network to survive nuclear attack.*"

Paul Baran

Four nodes connected
(UCLA, SRI, UCSB, Utah)

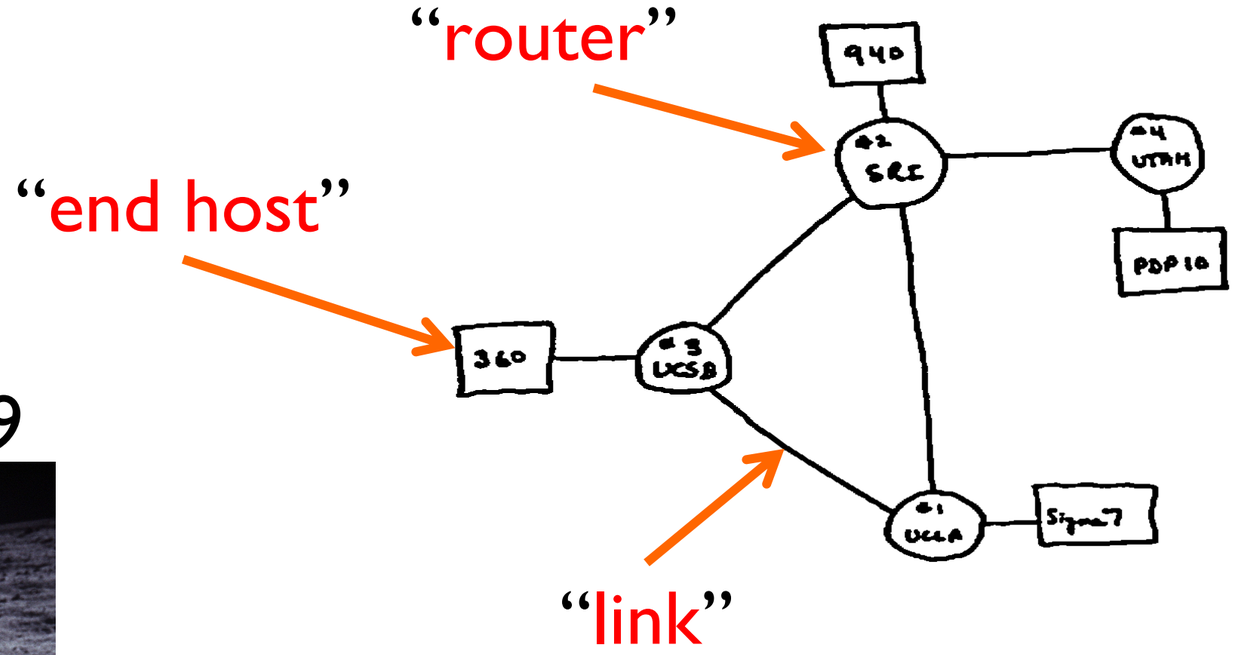


US Government starts
"ARPANET" project

1st network
connects two
computers

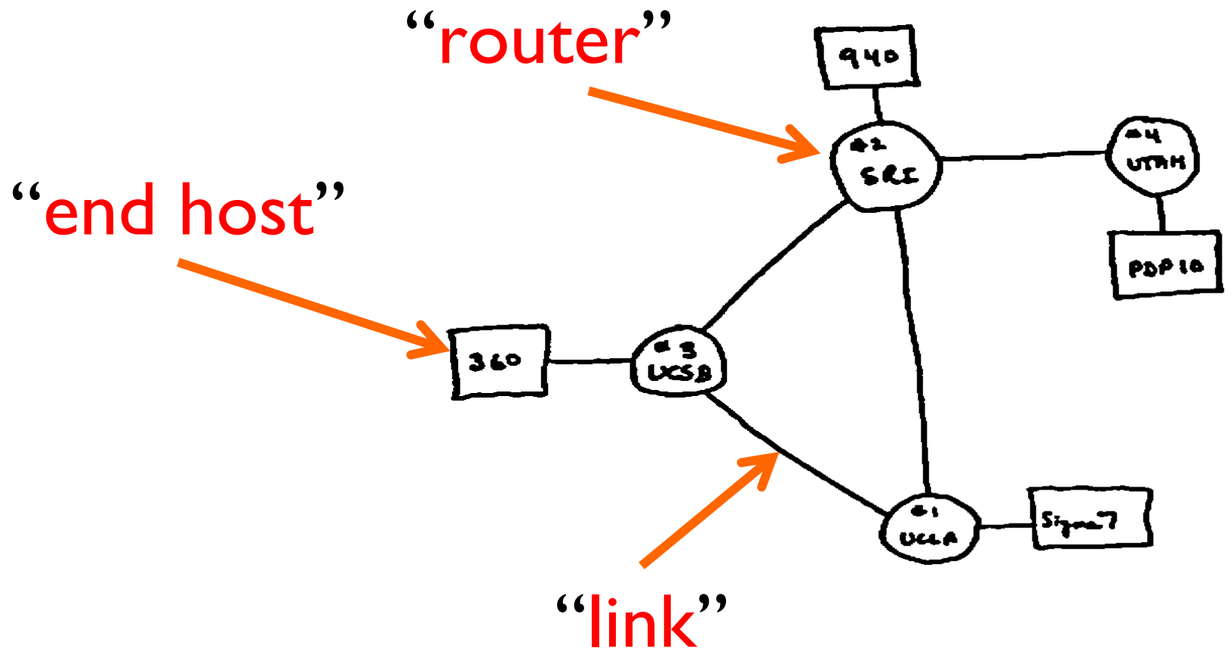
1964 1965 1966 1968 1969

The Internet in 1969



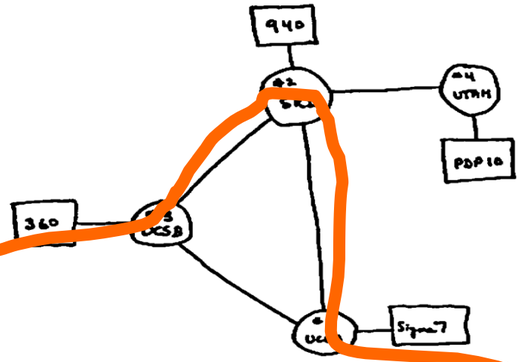
Also in 1969

What did they use it for?



1. Sending files between scientists: "*Here is a big file of astronomy data!*"
2. Email: "*Where shall we have lunch today?*"
3. Remote login to another computer.

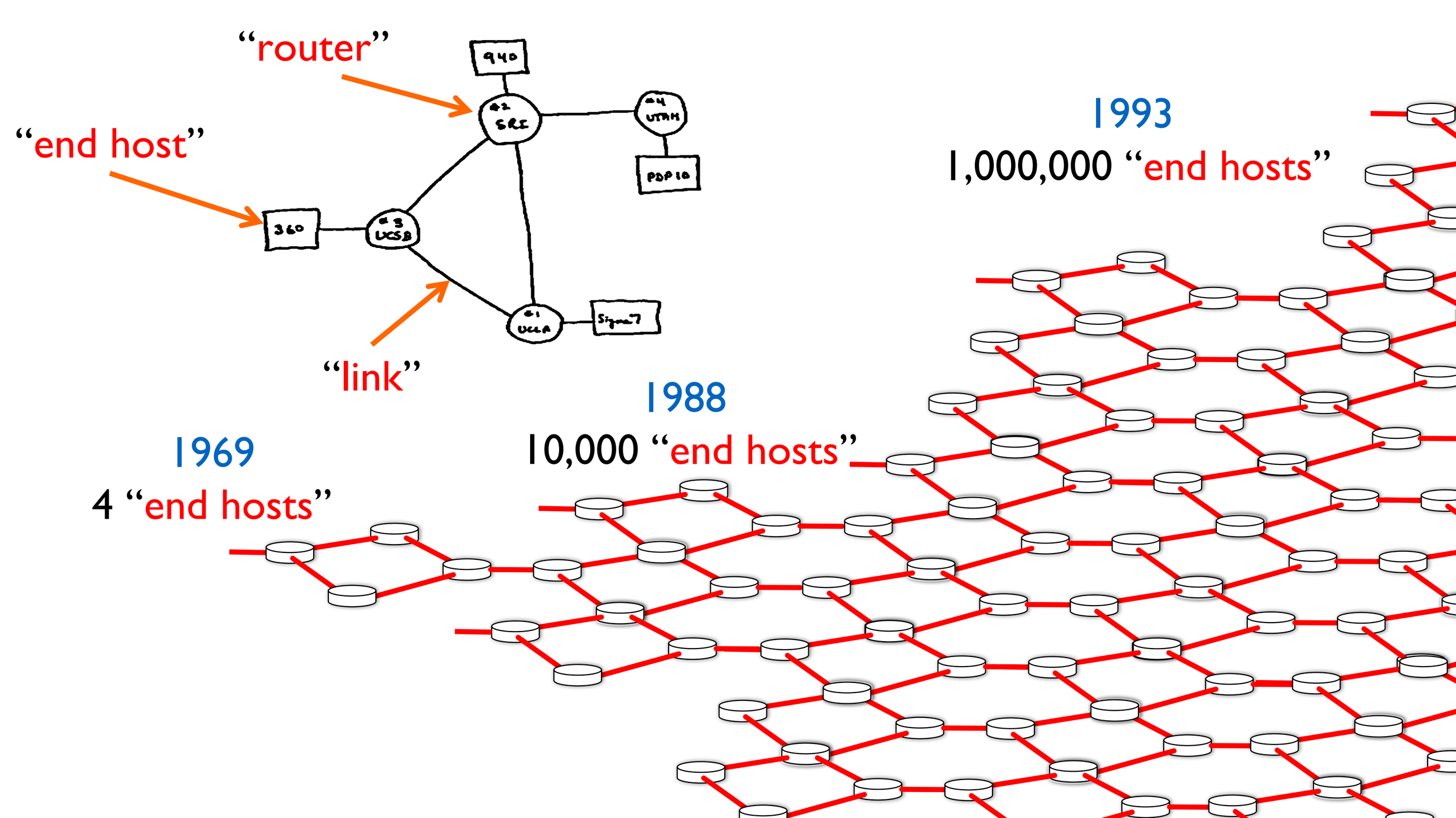
1971



First email typed here

"QWERTYUIOP"

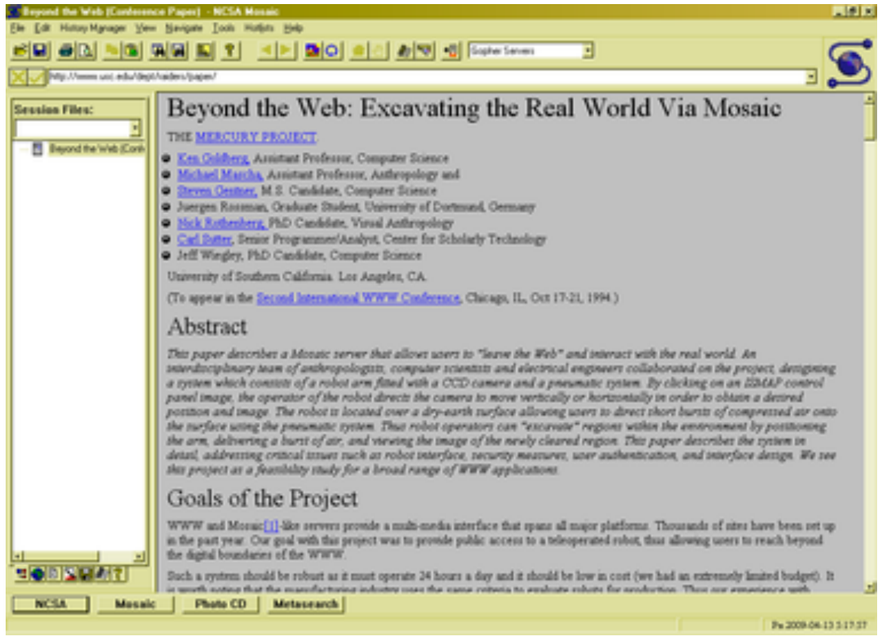
…and printed here


"router"
"end host"
"link"
940
#2 SRI
#4 UTAH
PDP10
360
#3 UCSB
#1 UCLA
Sigma7
1969
4 "end hosts"
1988
10,000 "end hosts"
1993
1,000,000 "end hosts"

Then in 1993 something
REALLY BIG
happened!!!

1993: The first web browser (Mosaic)

Marc Andreessen

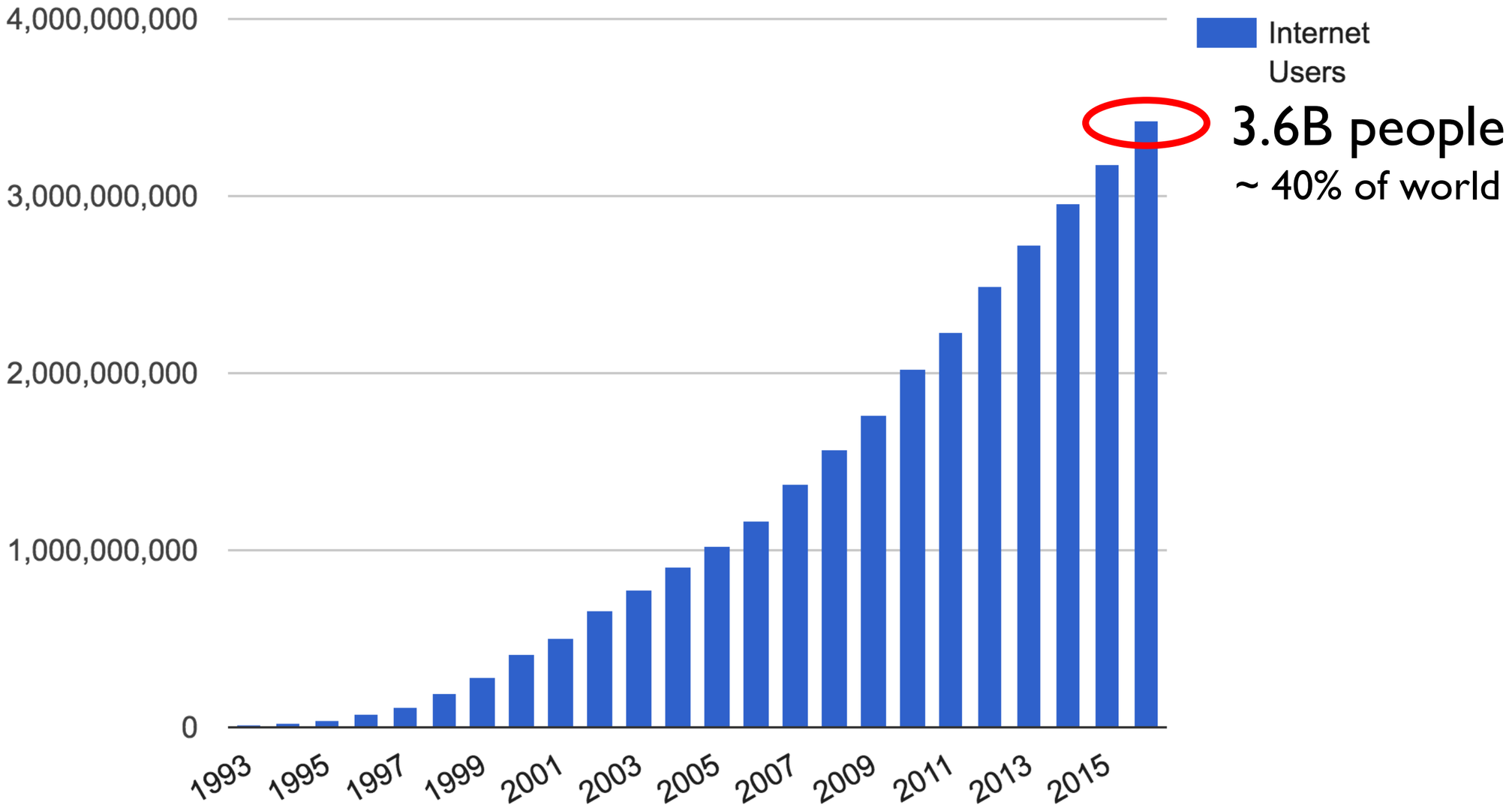


1993

President
Süleyman Demirel

President
Bill Clinton

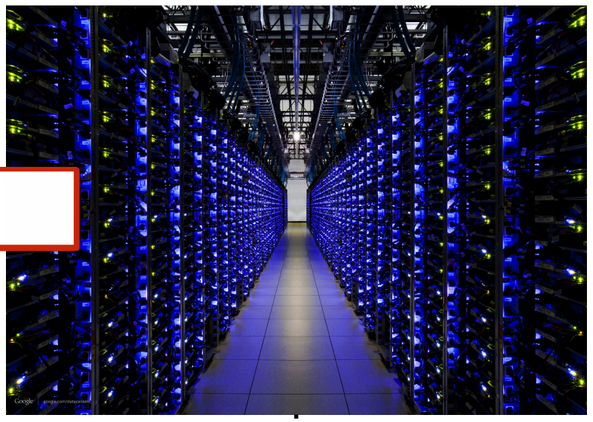
The number of Internet users in the world

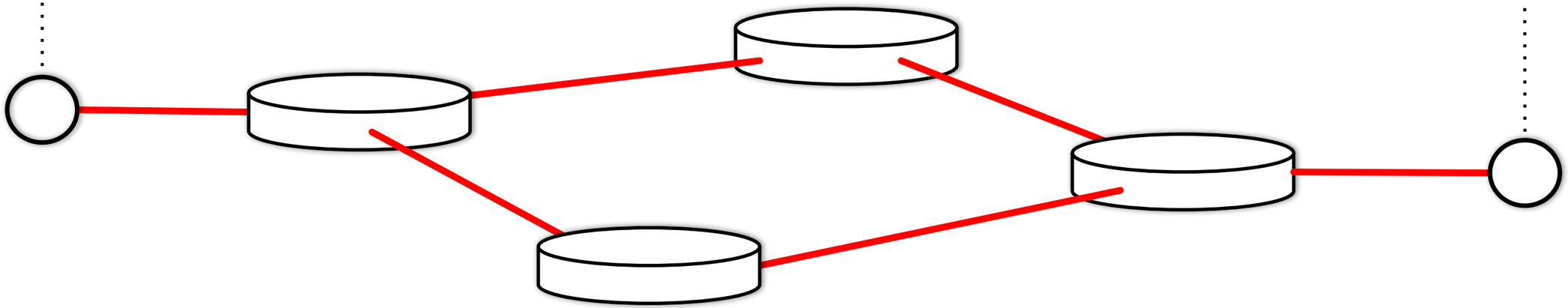


Source: http://www.internetlivestats.com/

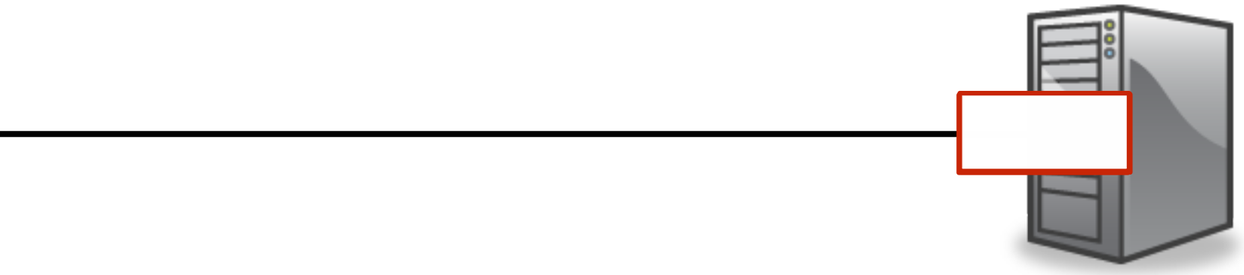
How does it all work?

Google YouTube facebook

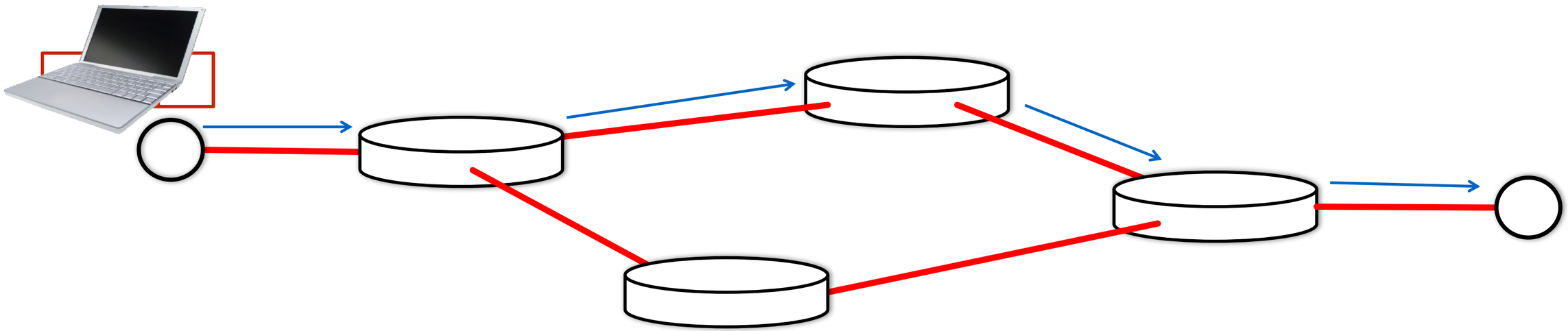


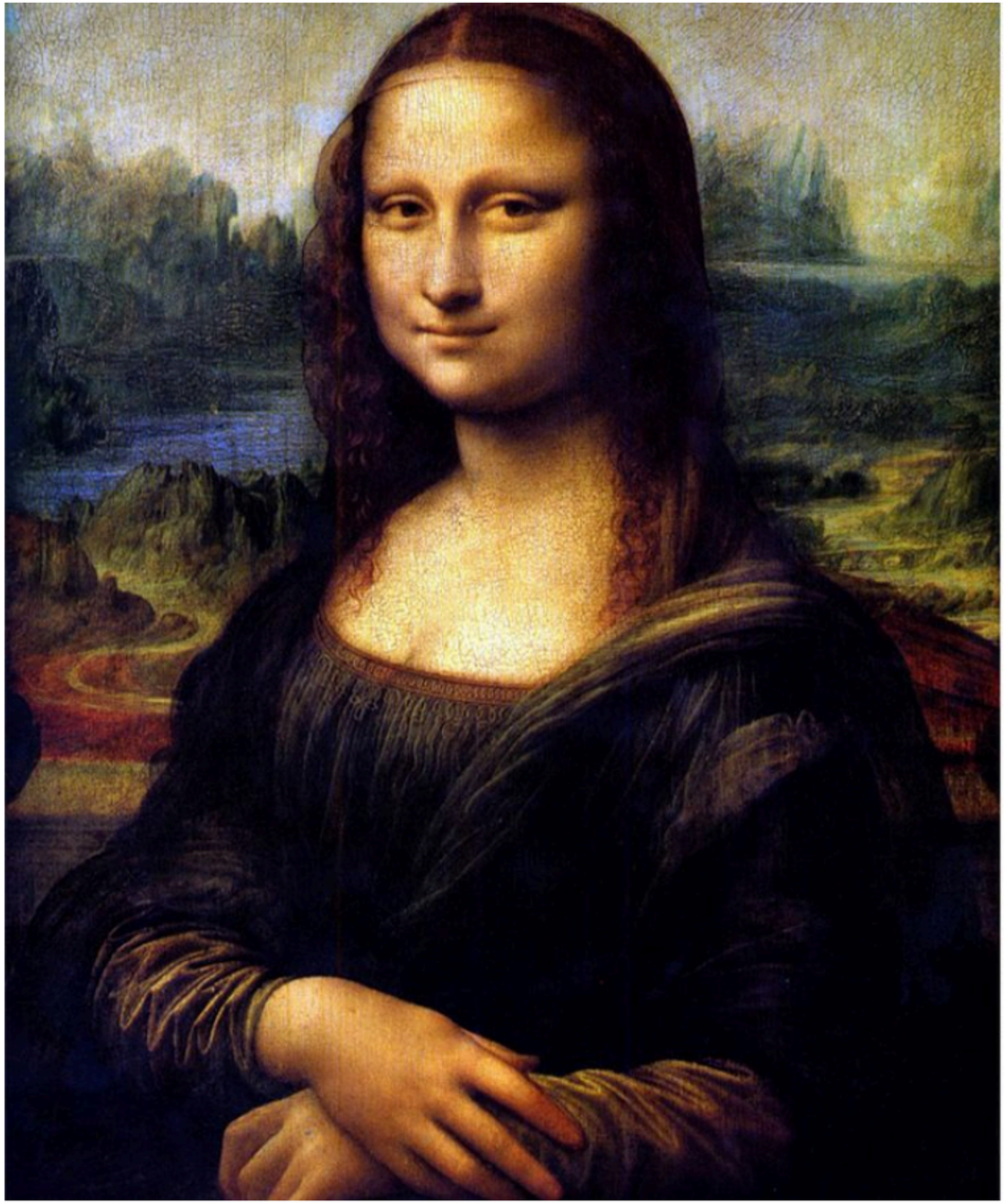


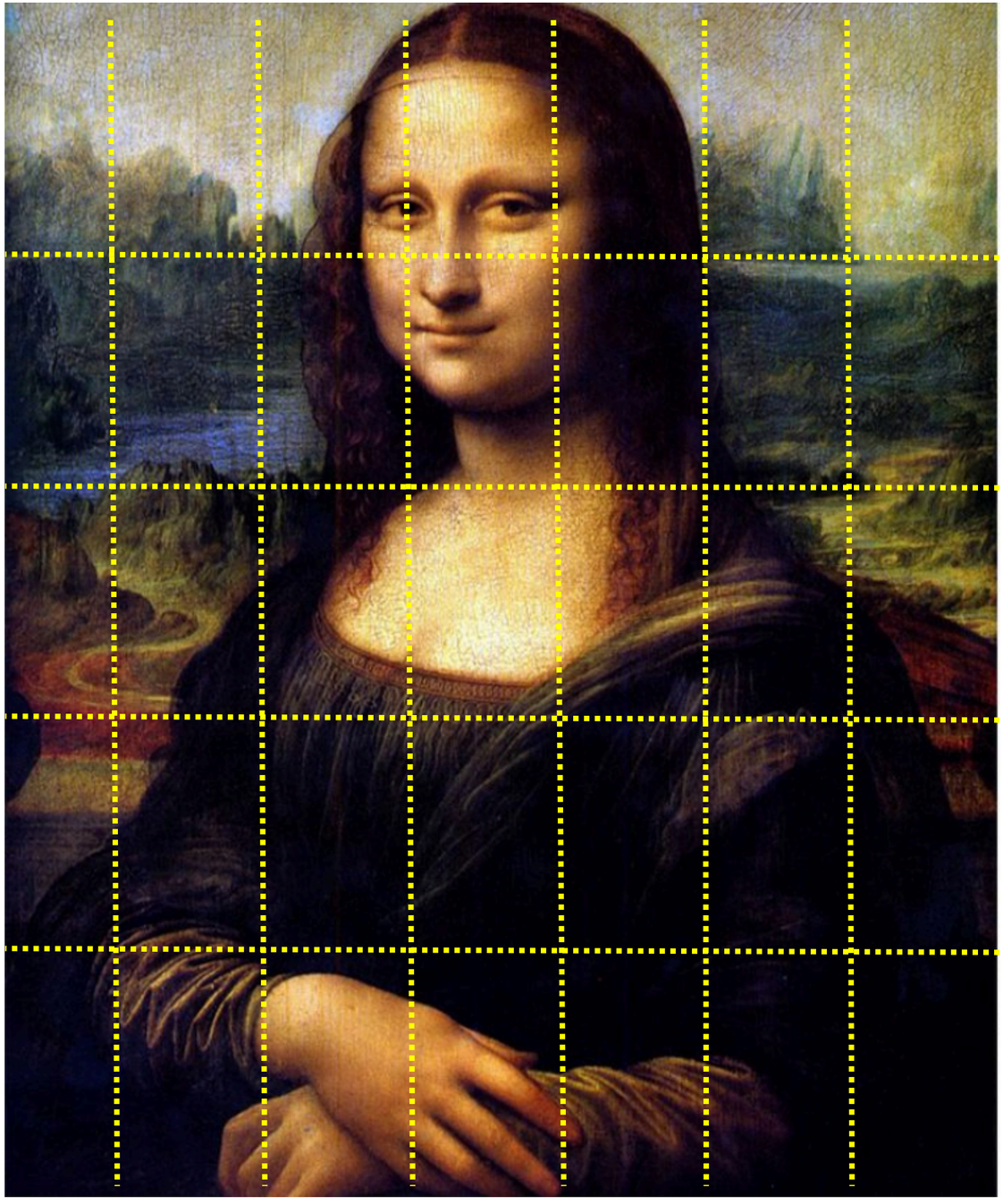
My Java Program

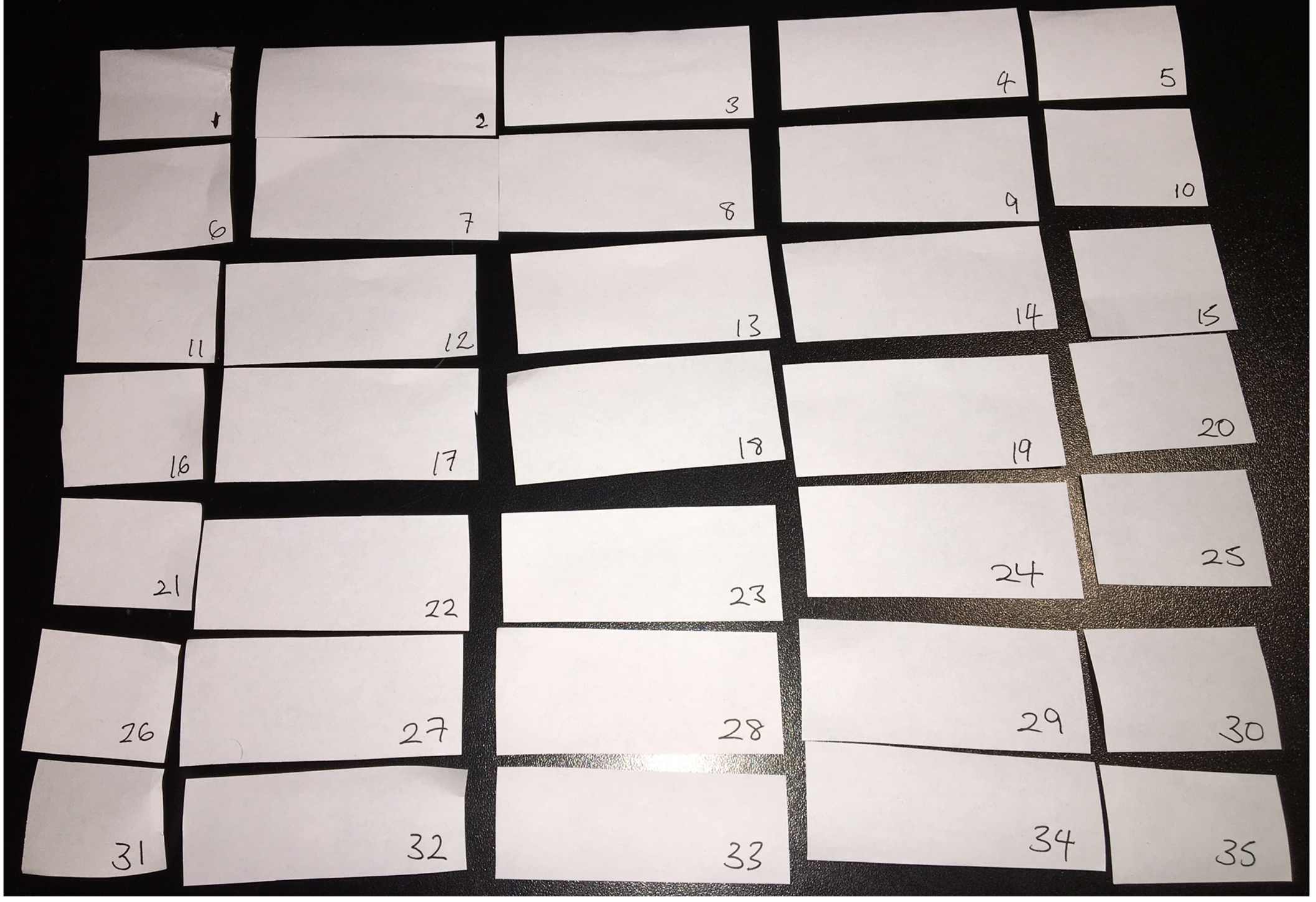


Someone else's Java Program





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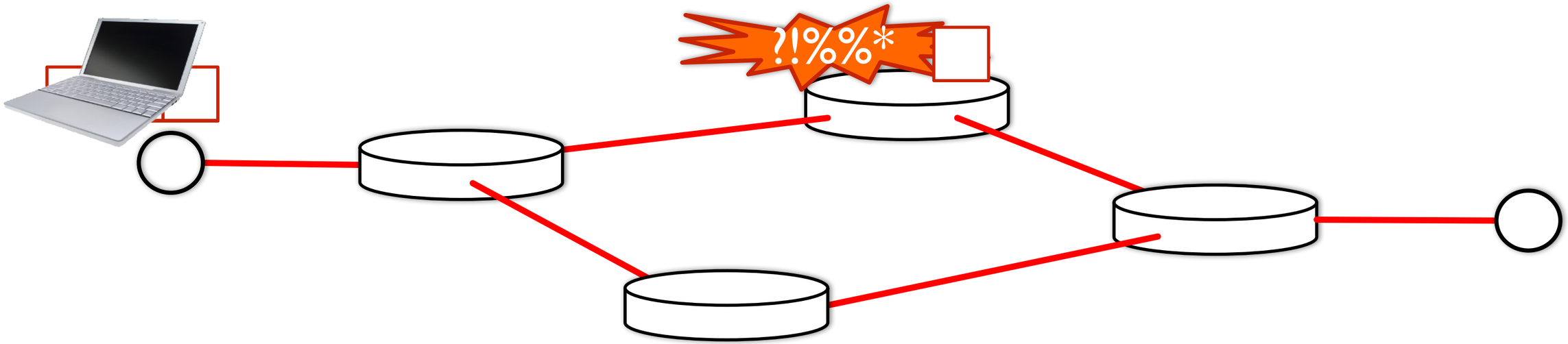
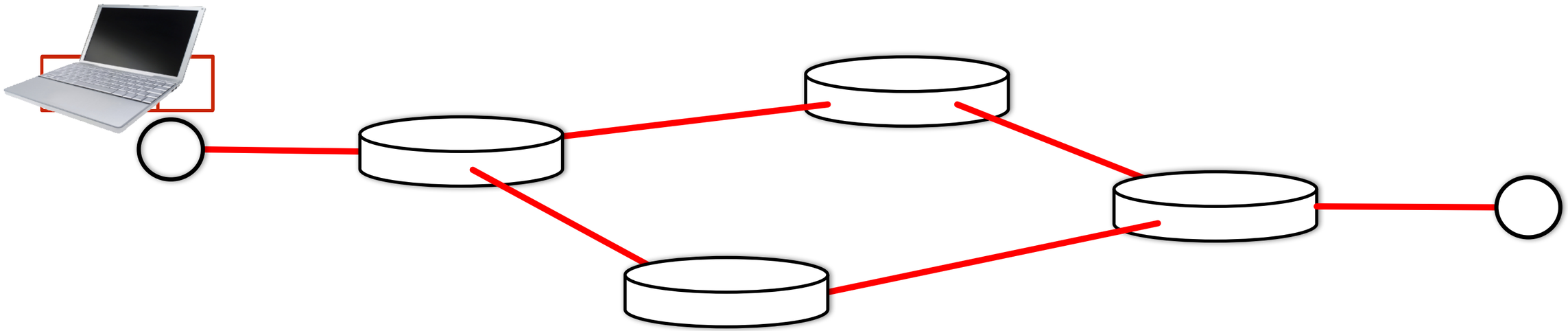
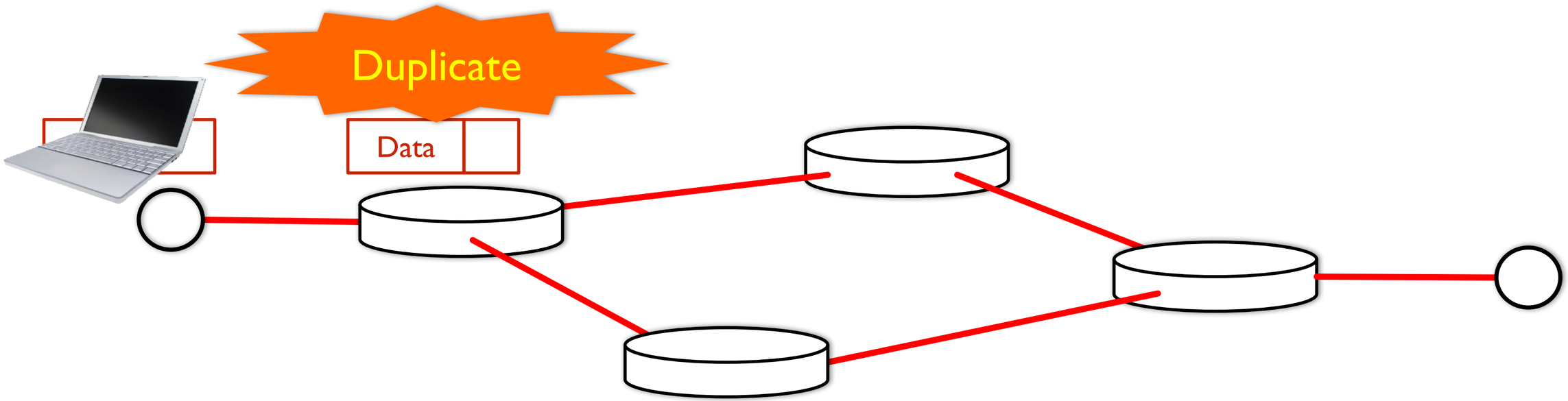
Packets may be damaged



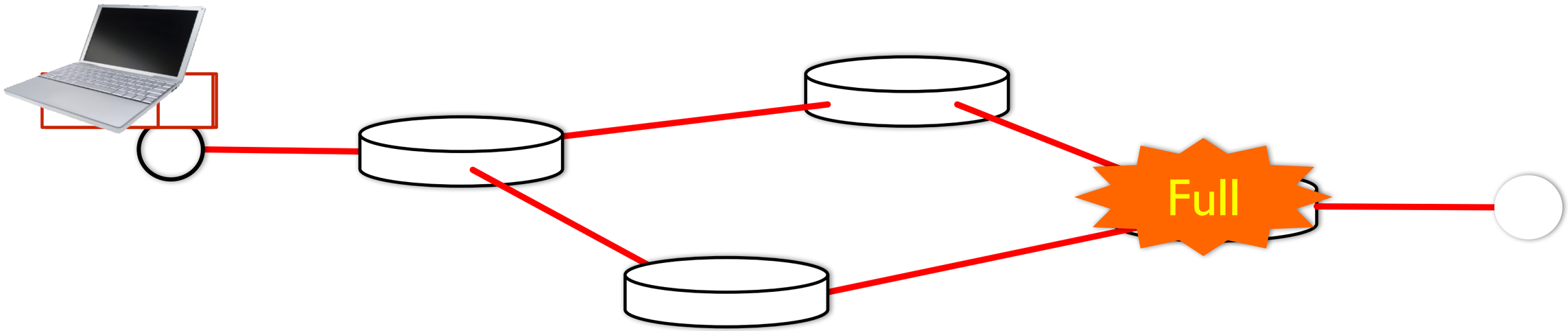
Packets may arrive out of order



Packets may be duplicated



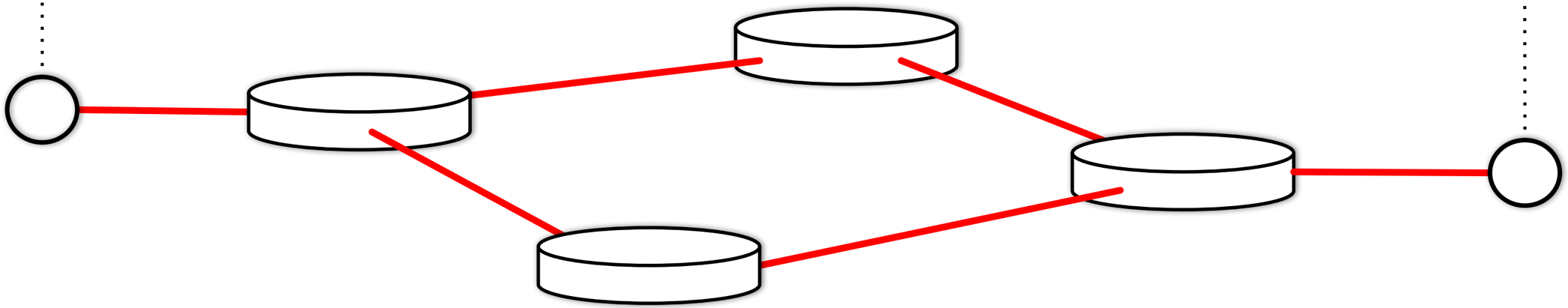
They may not arrive at all!



Summary so far

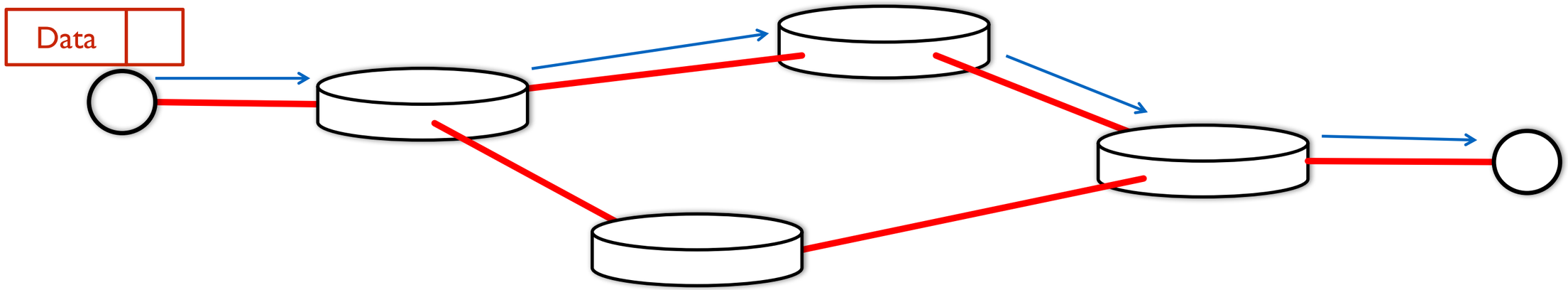
Applications send and receive data in packets….

…over an Internet that is unreliable.



What do Internet packets look like?

Internet addresses



Internet Addresses ("IP address")

All Internet packets carry a destination IP address.

We usually write the IP address like this:

171.64.74.58

Internet “IP” Addresses

The IP address tells each router where to send the packet next.

A network in the CS Department at Stanford University

171.64.74.58

The computer yuba.stanford.edu

Can we see the path our packets take?

Yes!

On your computer, try: “ping yuba.stanford.edu”

and “traceroute yuba.stanford.edu”

(Windows: “tracert yuba.stanford.edu”)

ping yuba.stanford.edu

From Turkey, it takes about 180ms to reach yuba and back again
("round-trip-time")


Map
About 180ms “round-trip”
Greenland
Iceland
Finland
Russia
Norway
United Kingdom
Canada
Germany
France
Spain
Italy
Turkey
Kazakhstan
Mongolia
China
Afghanistan
Iran
Iraq
Pakistan
India
Thailand
Saudi Arabia
Egypt
Libya
Algeria
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
Kenya
DR Congo
Tanzania
Angola
Namibia
Botswana
South Africa
Madagascar
United States
Mexico
Venezuela
Colombia
Peru
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Chile
Japan
South Korea
Papua New Guinea
Australia
North Pacific Ocean
North Atlantic Ocean
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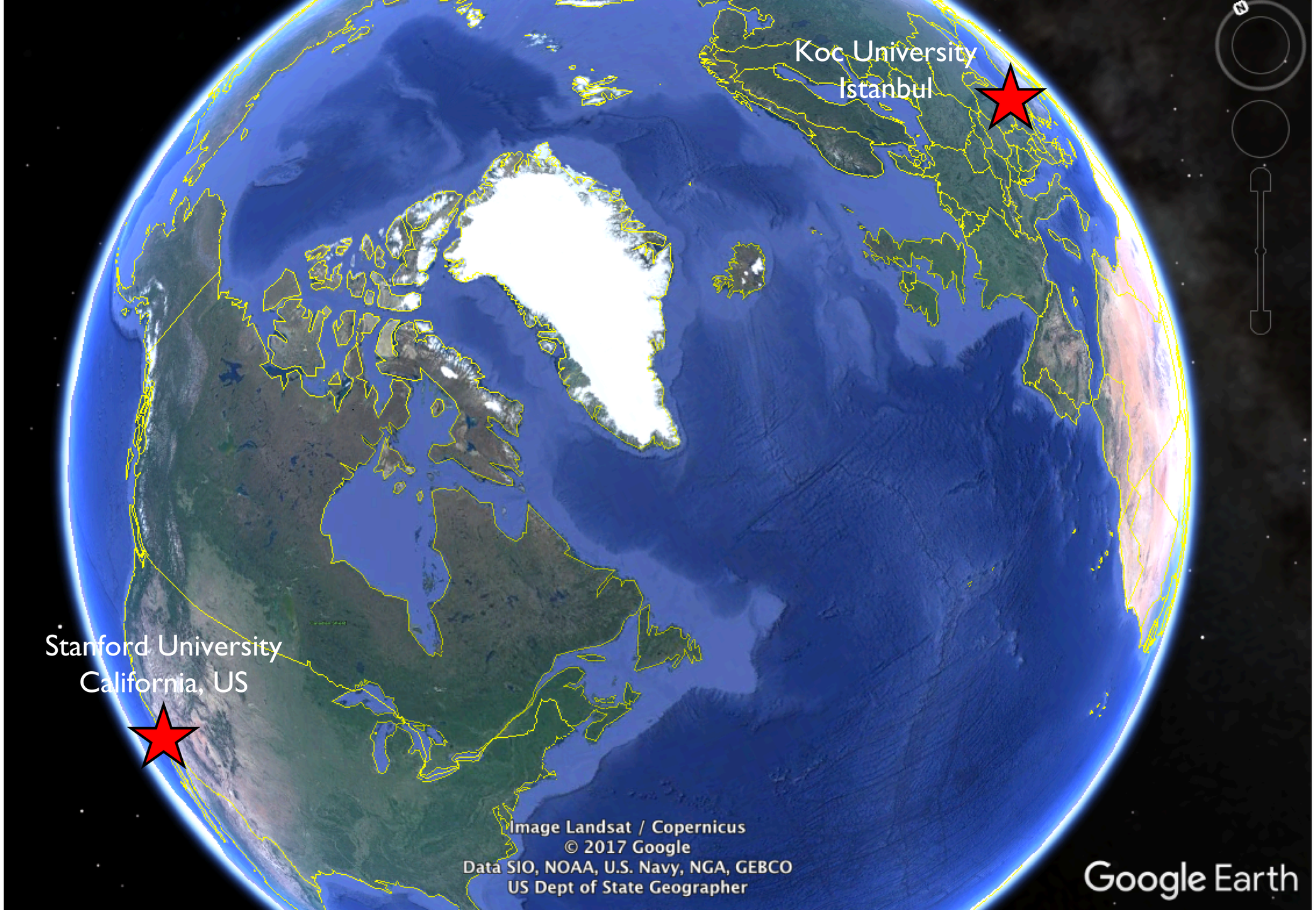
Indian Ocean


Koc University
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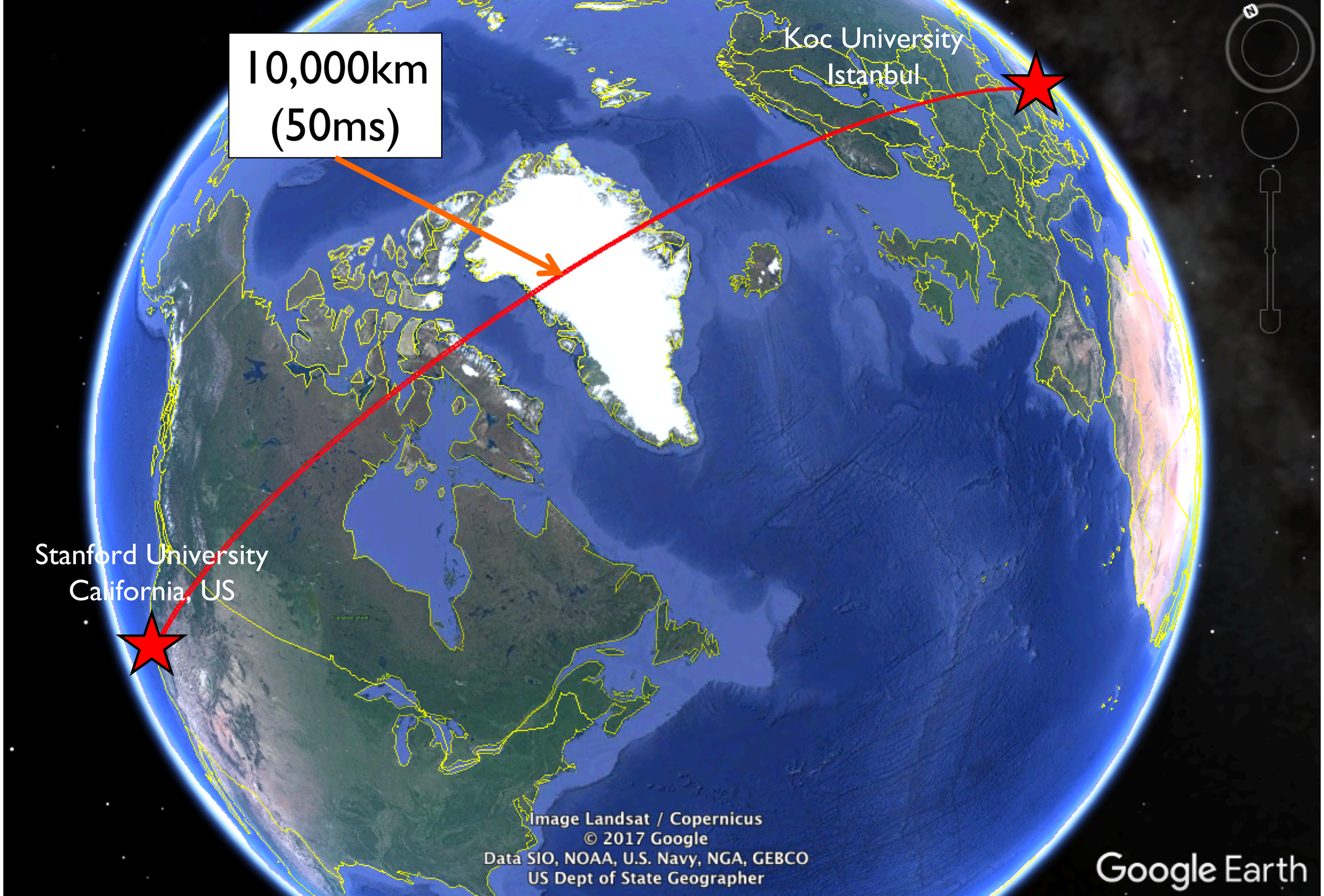
Stanford University
California, US
Image Landsat / Copernicus
© 2017 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
Google Earth

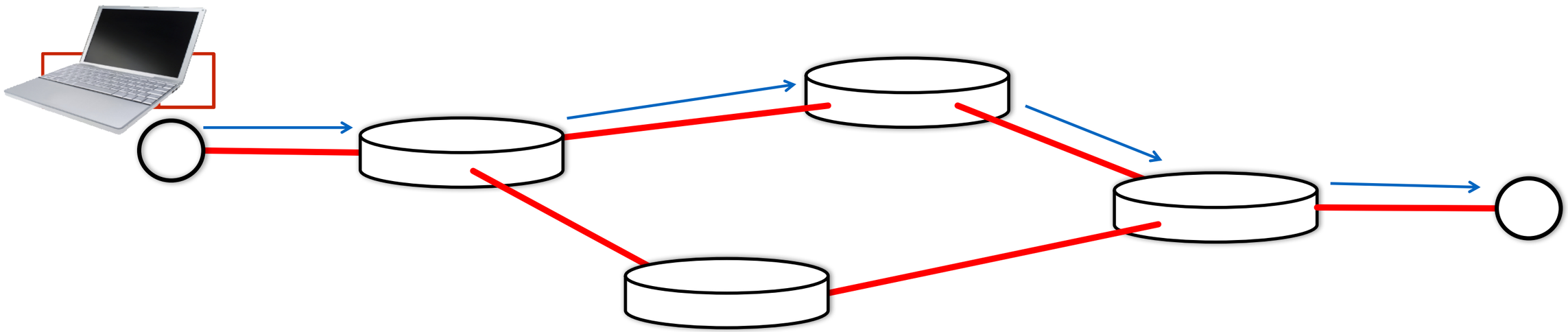

10,000km
(50ms)
Koc University
Istanbul
Stanford University
California, US
Image Landsat / Copernicus
© 2017 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
Google Earth


Koc University
Istanbul
18,000km
(90ms)
Stanford University
California, US
The real path
our packets take
2 x 90ms = 180ms
Image Landsat / Copernicus
© 2017 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer
Google Earth

How packets find their way across the Internet

Routers forward packets **one at a time**.

Routers look at IP addresses, then send packets to a router closer to the destination.



IP Addresses

The IP address tells a router where to send the packet next.

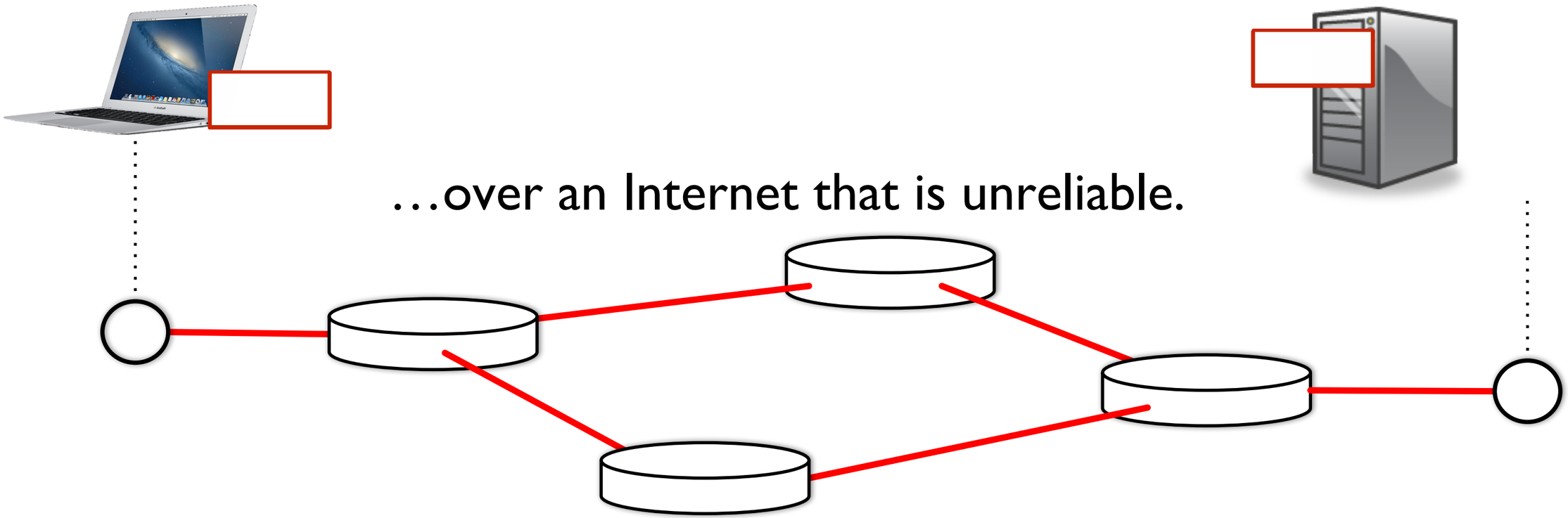
IP addresses have *structure (yapı)*

A network interface at Stanford University

An address managed by ISP (Internet Service Providers)

Summary so far

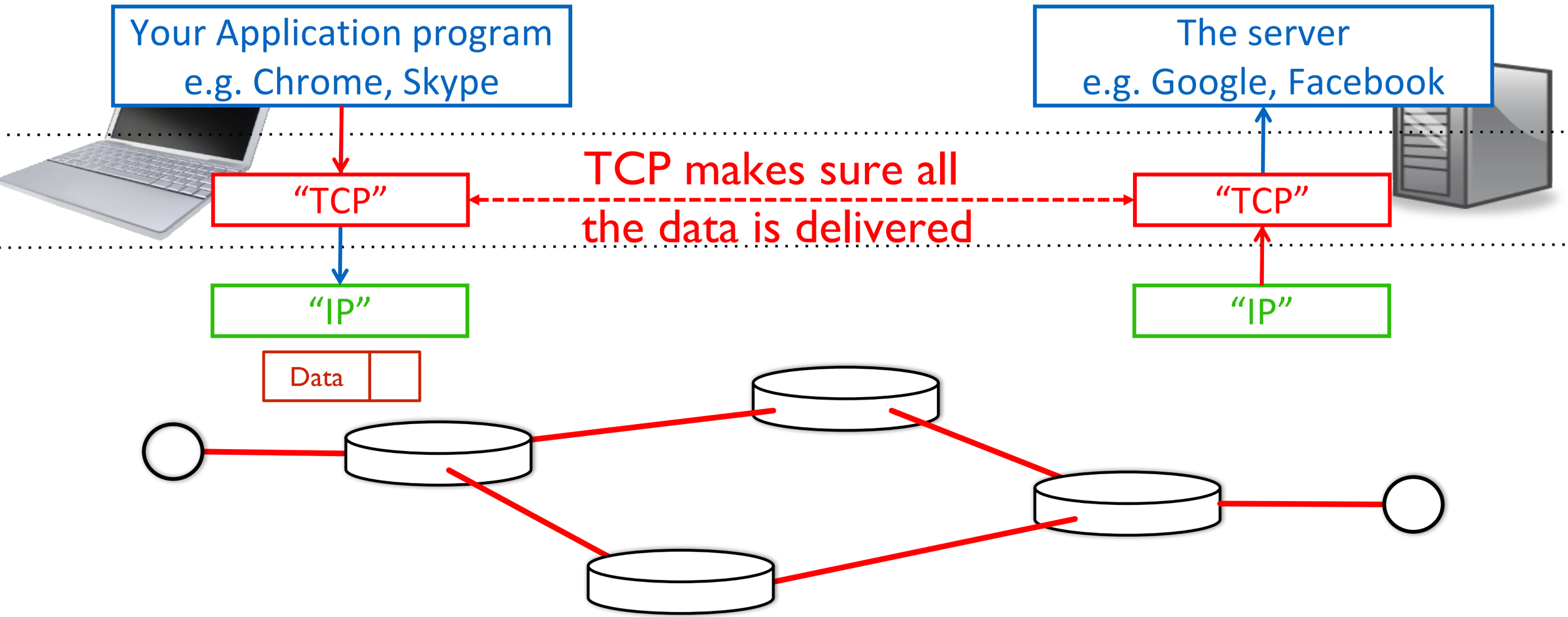
Applications send and receive data in packets….



…over an Internet that is unreliable.

Packets are forwarded hop-by-hop based on the final destination address.

Sending data reliably over an Internet that is unreliable


Your Application program
e.g. Chrome, Skype
The server
e.g. Google, Facebook
"TCP"
TCP makes sure all
the data is delivered
"TCP"
"IP"
"IP"
Data

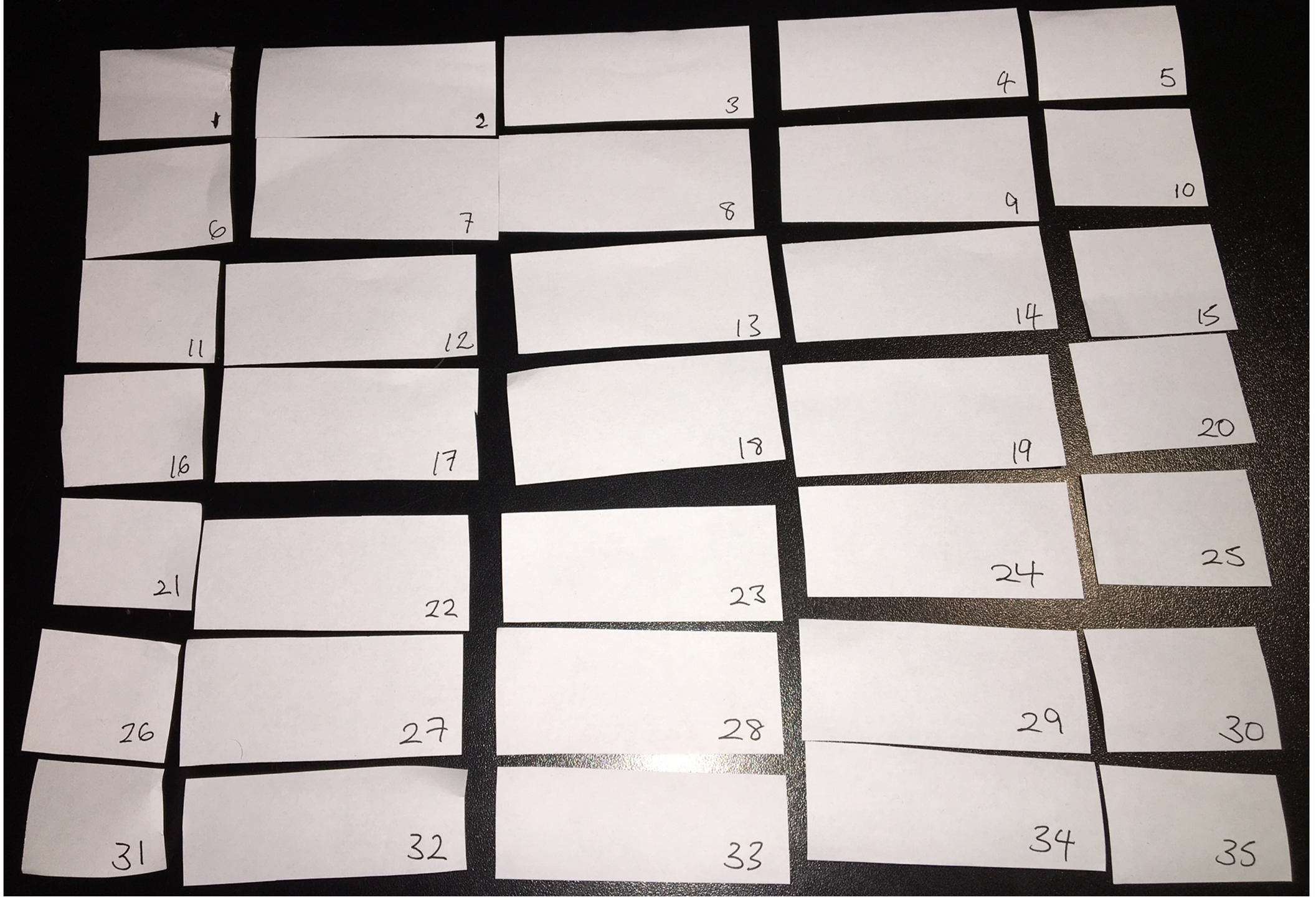
TCP's job

Makes sure all data is delivered correctly.

Delivers data to the application in the right order.

How?

- Add sequence numbers to every packet (so the receiver can check if any are missing, and put them in right order)
- When a packet arrives, send an **acknowledgment of receipt** (*alındığı onay*) or "ACK" back to the sender
- If no acknowledgment is received, resend the data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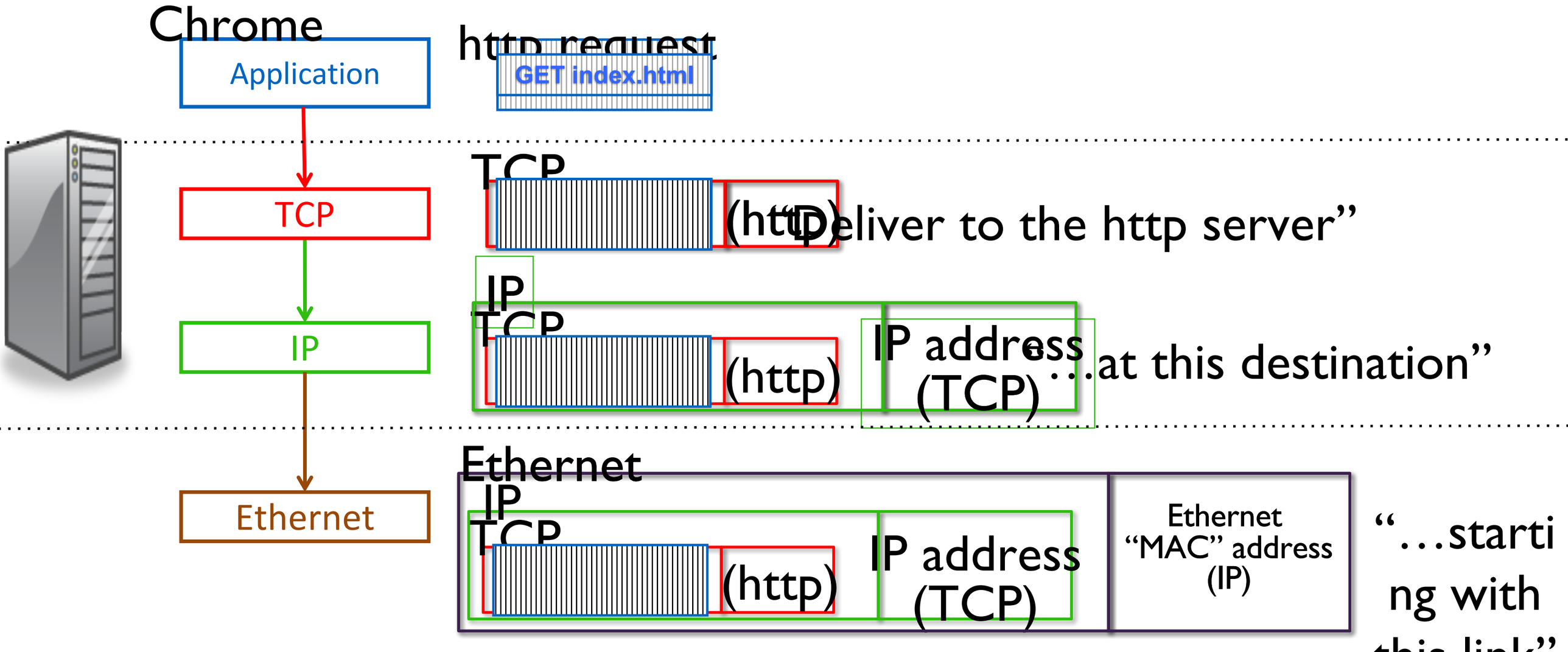
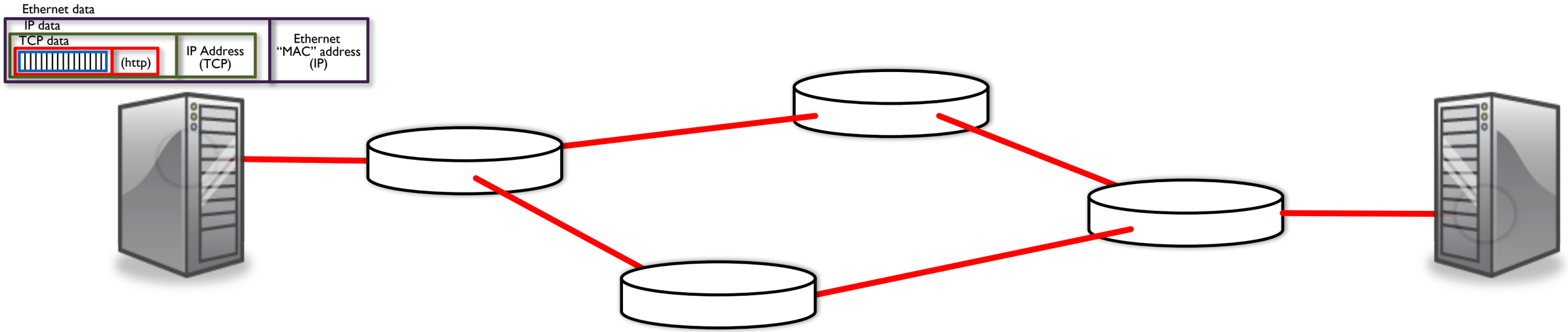
http client (e.g. Chrome)



Here it goes….

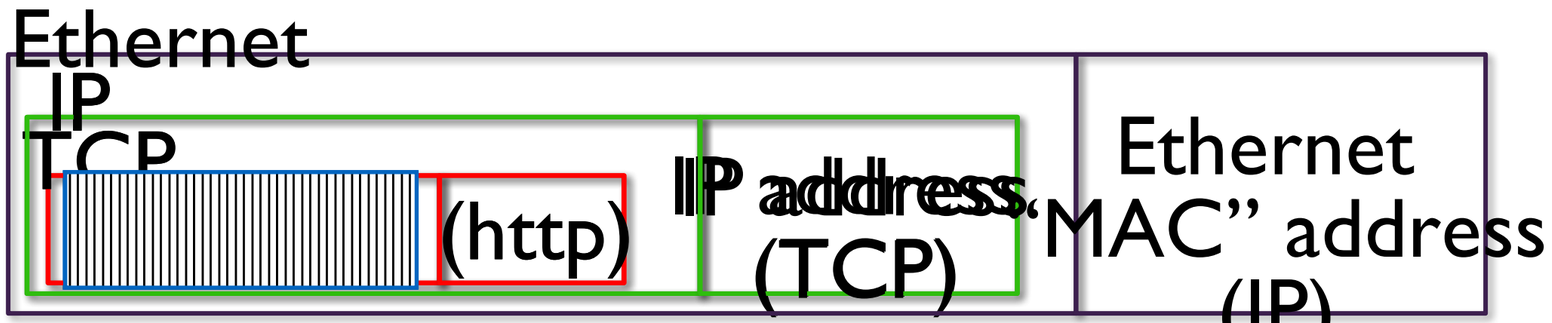

Ethernet data
IP data
TCP data
(http)
IP Address
(TCP)
Ethernet
“MAC” address
(IP)

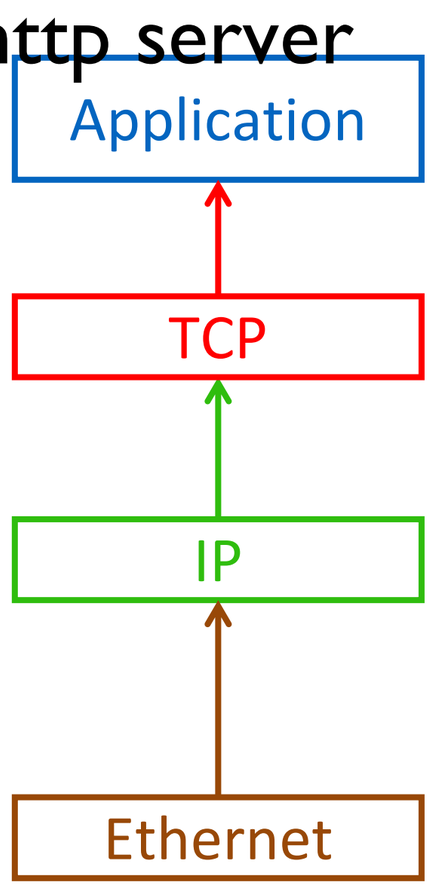
http server (e.g. www.google.com)

http request

"Deliver to the http server"

"Deliver to TCP"



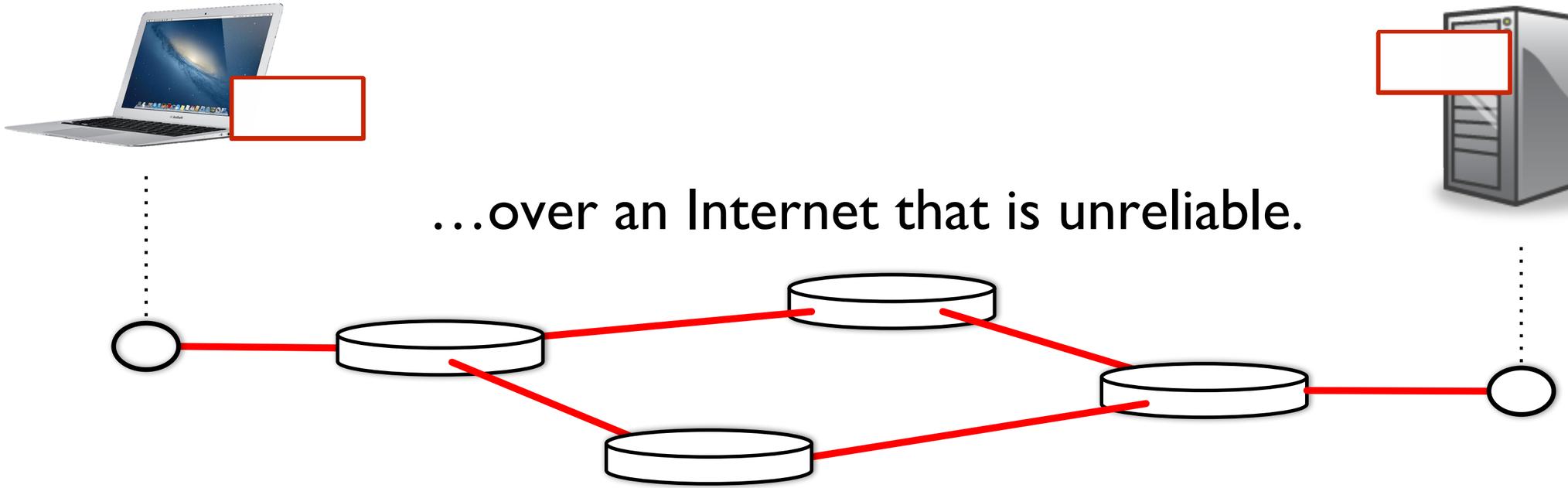


Summary of what we

My Java Program

Someone else's Java Program

Applications send and receive data in packets….



…over an Internet that is unreliable.

Packets are forwarded hop-by-hop using the IP destination address.

Our applications use TCP to make sure they are delivered and put back in the correct order.