6.033: Intro to Computer Networks
Layering & Routing

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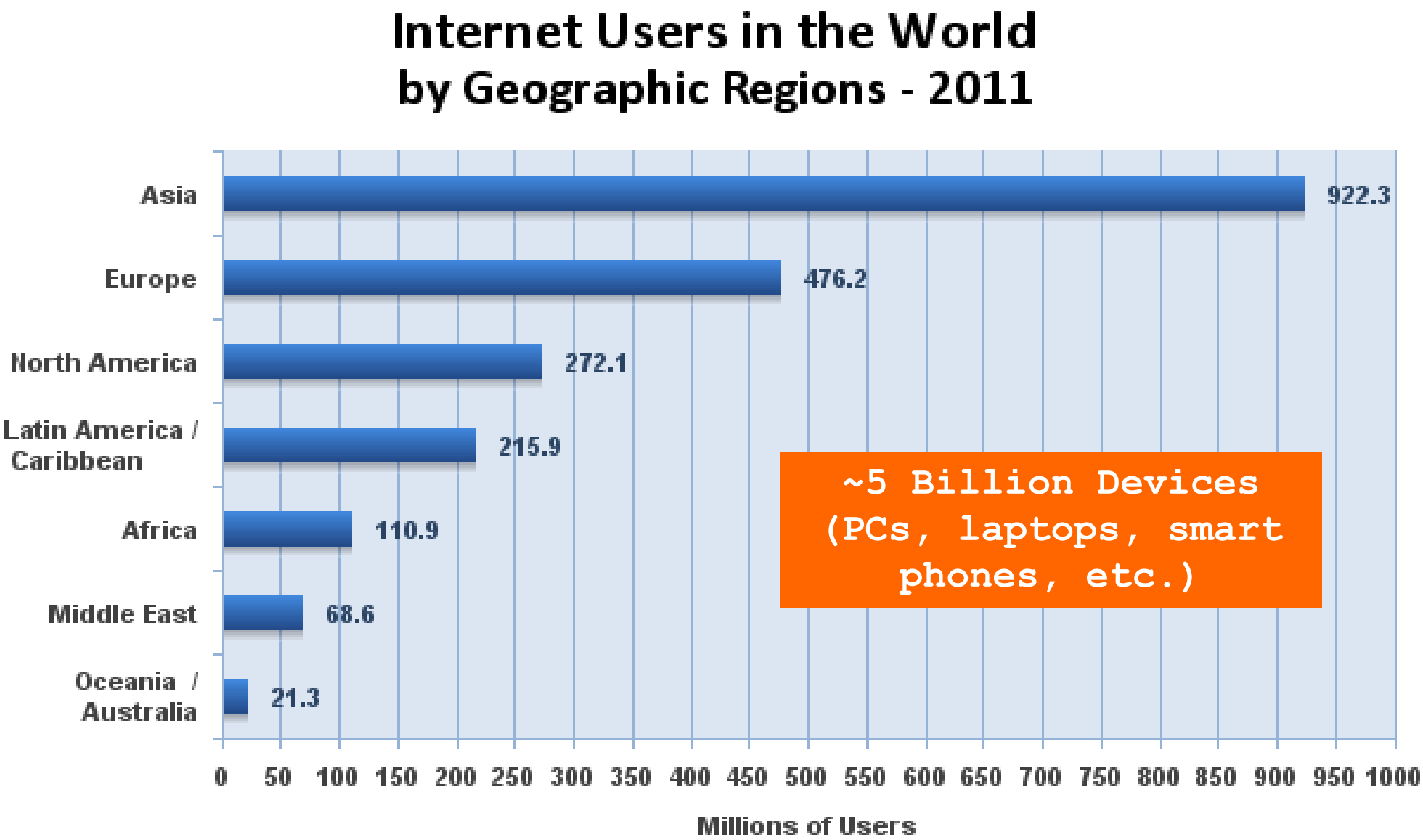
Some slides are contributed by N. McKewon, J. Rexford, I. Stoica

The Internet is an Exciting Place

Two Billion Internet Users



Source: Internet World Stats - www.internetworldstats.com/stats.htm
Estimated Internet users are 2,095,006,005 on March 31, 2011

The Internet is a Tense Place

Information Age
News, analysis & insight for IT & business leaders

Egypt blocks Internet access amid protests

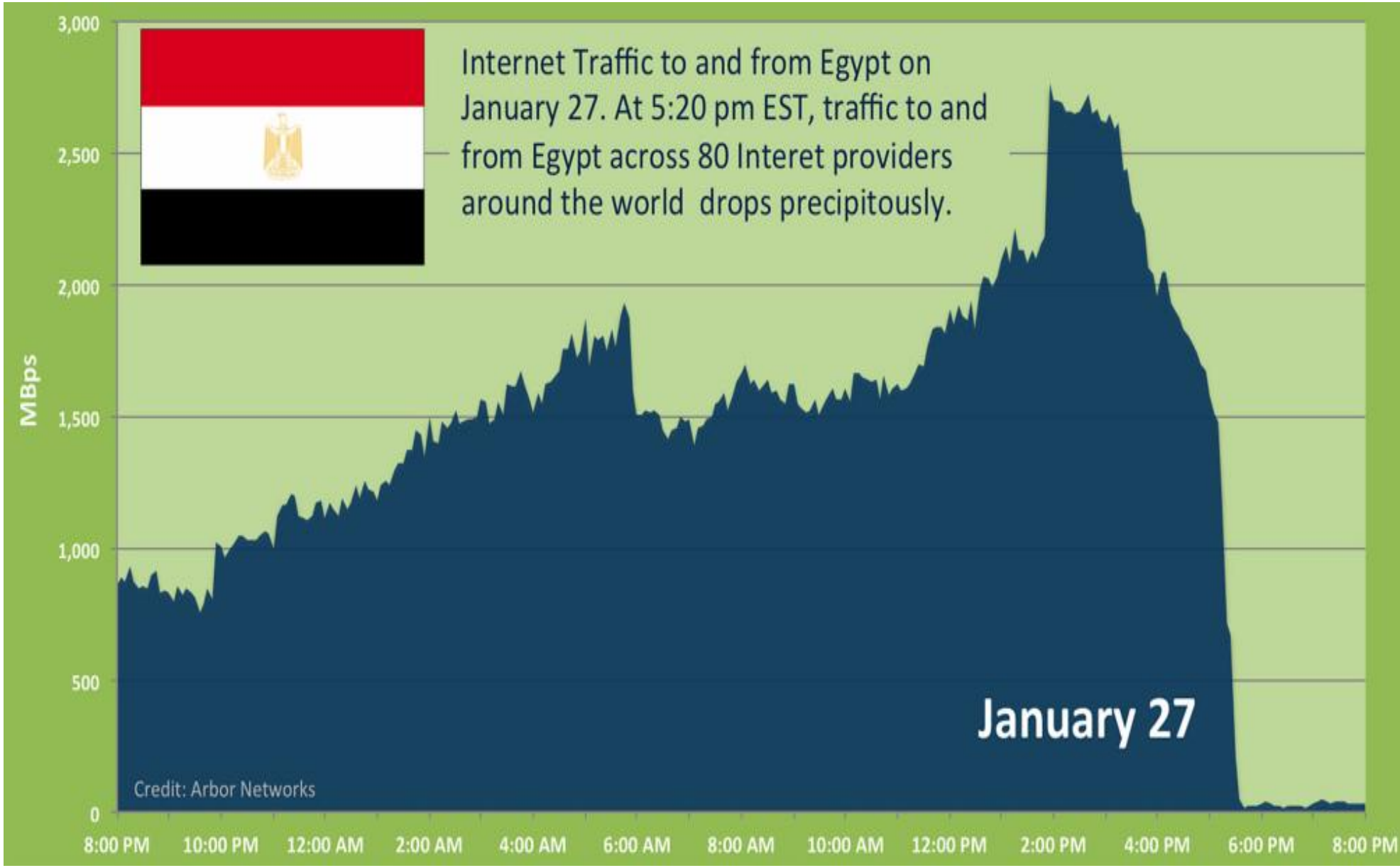
28 JANUARY 2011 **Daniel Shane**

Government orders telcos to block web access as protestors take to the streets

The Egyptian government has called on telecommunications providers in the country to block access to the Internet in response to widespread civil unrest.

Vodafone Egypt, one of the largest operators in the country not controlled by the state, today said it has disabled access following pressure from authorities.

Internet Traffic to/from Egypt

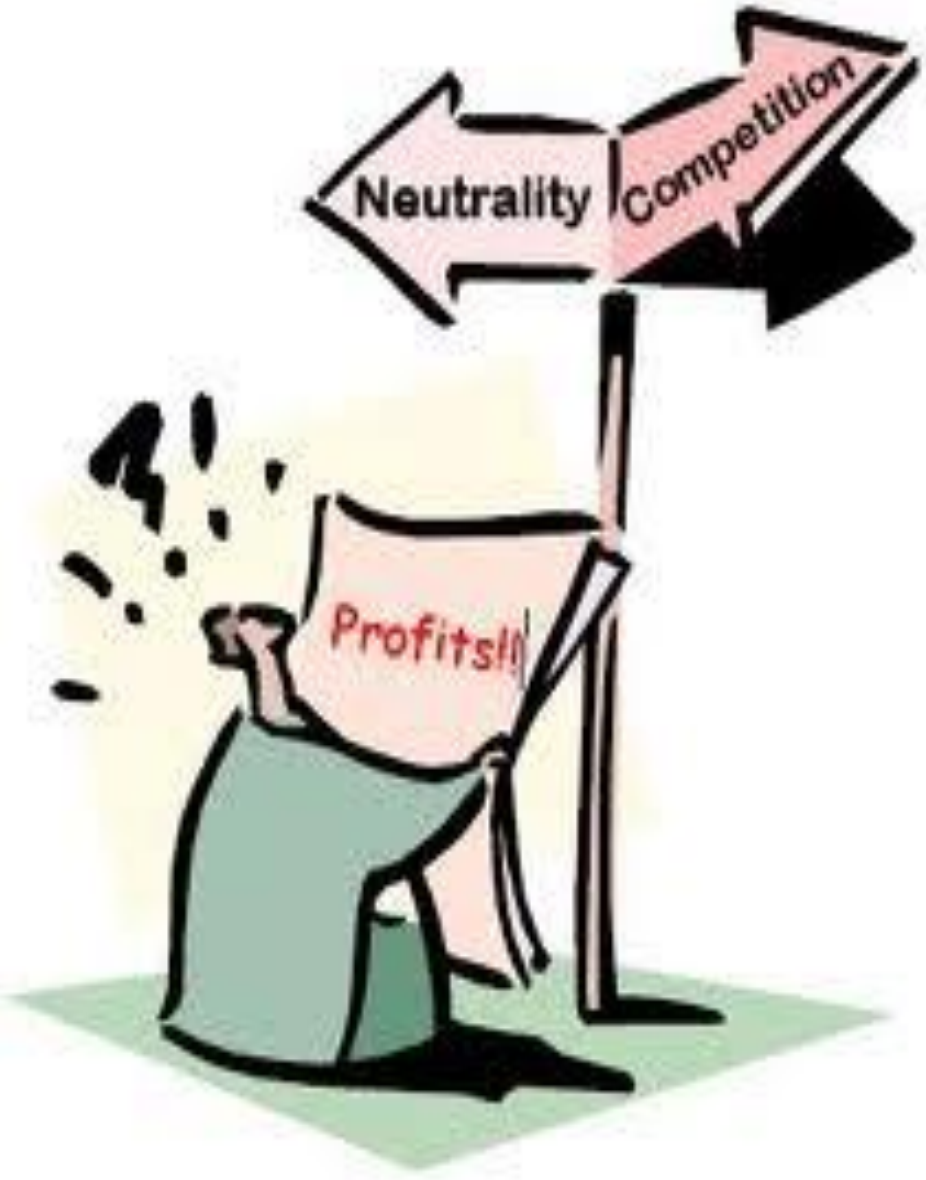


Stop Online Piracy Act (SOPA)

Network Neutrality

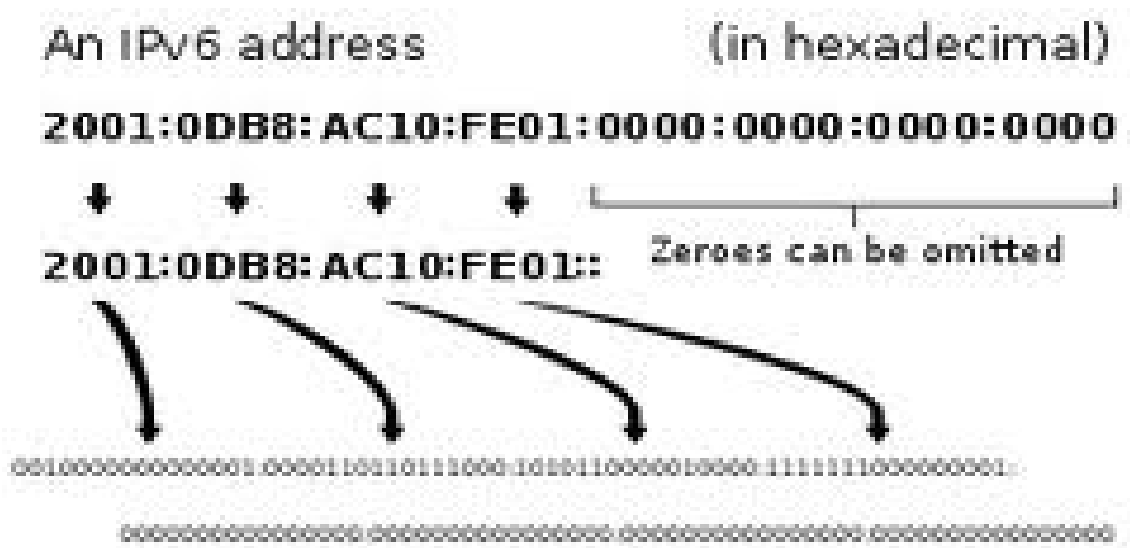
FCC Rules Against Comcast P2P Throttling

The U.S. Federal Communications Commission has ordered Comcast to stop interfering with peer-to-peer traffic on its broadband network…

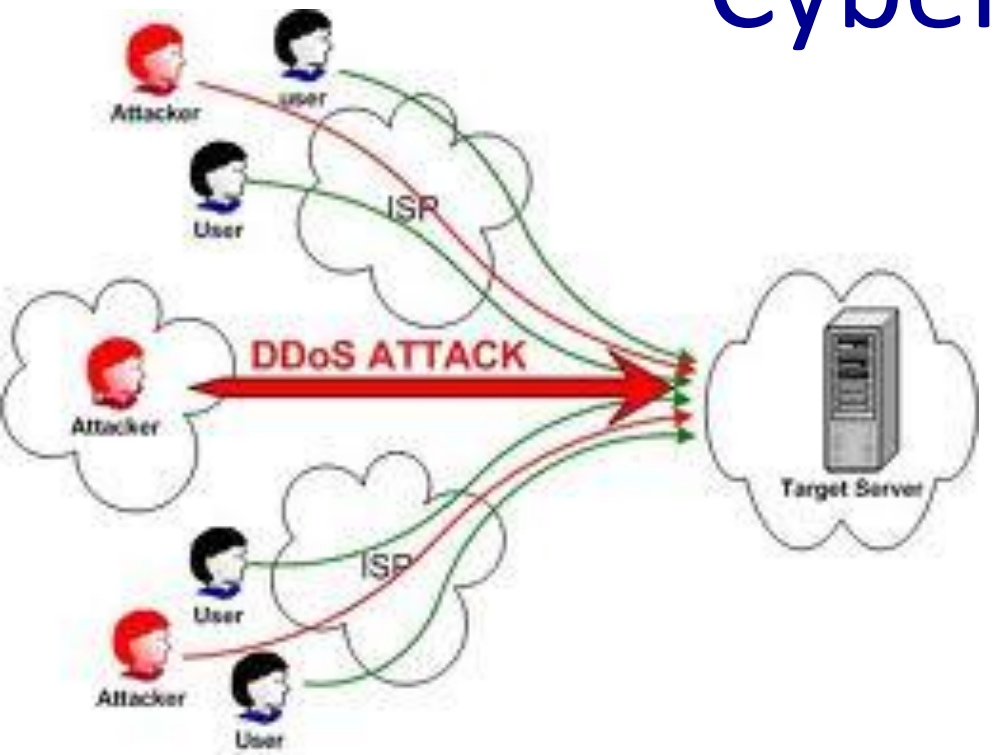


IP Address Space Exhaustion

"Currently, the Internet is built using IPv4, but on February 3, 2011, the global supply of unassigned IPv4 Internet addresses was exhausted. On that date, the Internet Assigned Numbers Authority has distributed the final five blocks of approximately 16 million IPv4 addresses among the five Regional Internet Registries."



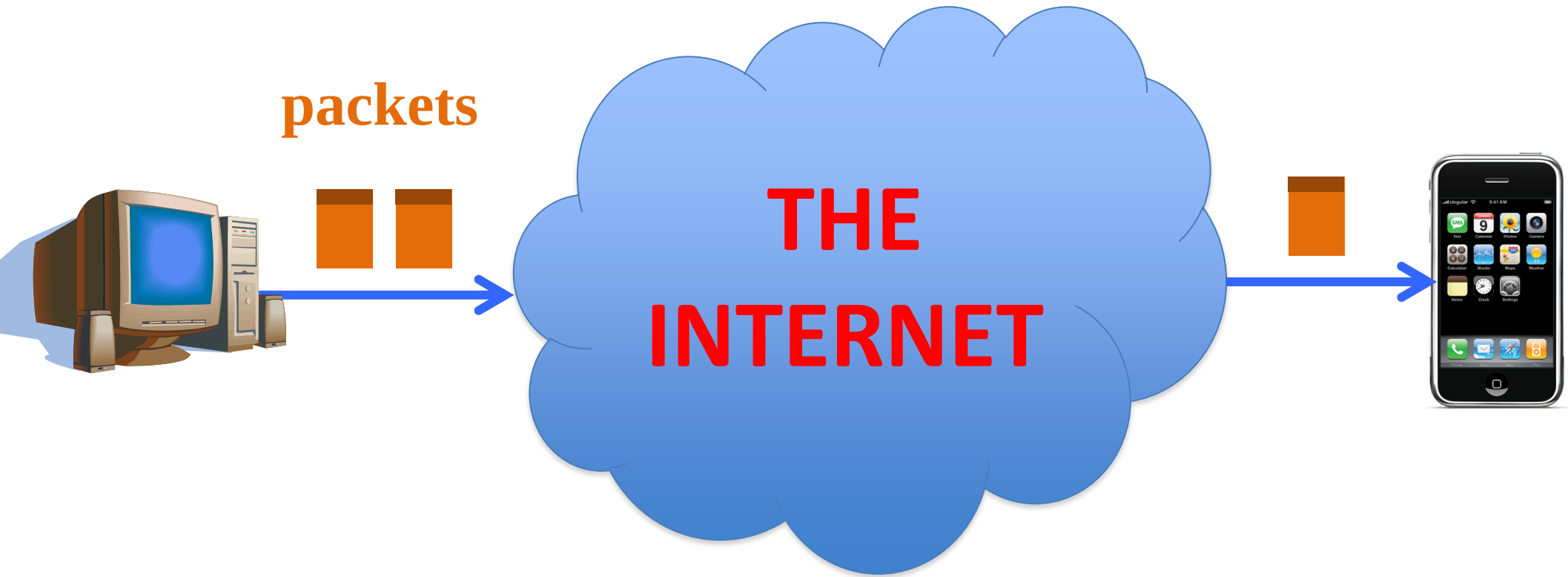
Cyber Attacks



What *is* the Internet?

3 guiding principles!

“Best-Effort Packet Delivery Service”



“Power at the Edge”

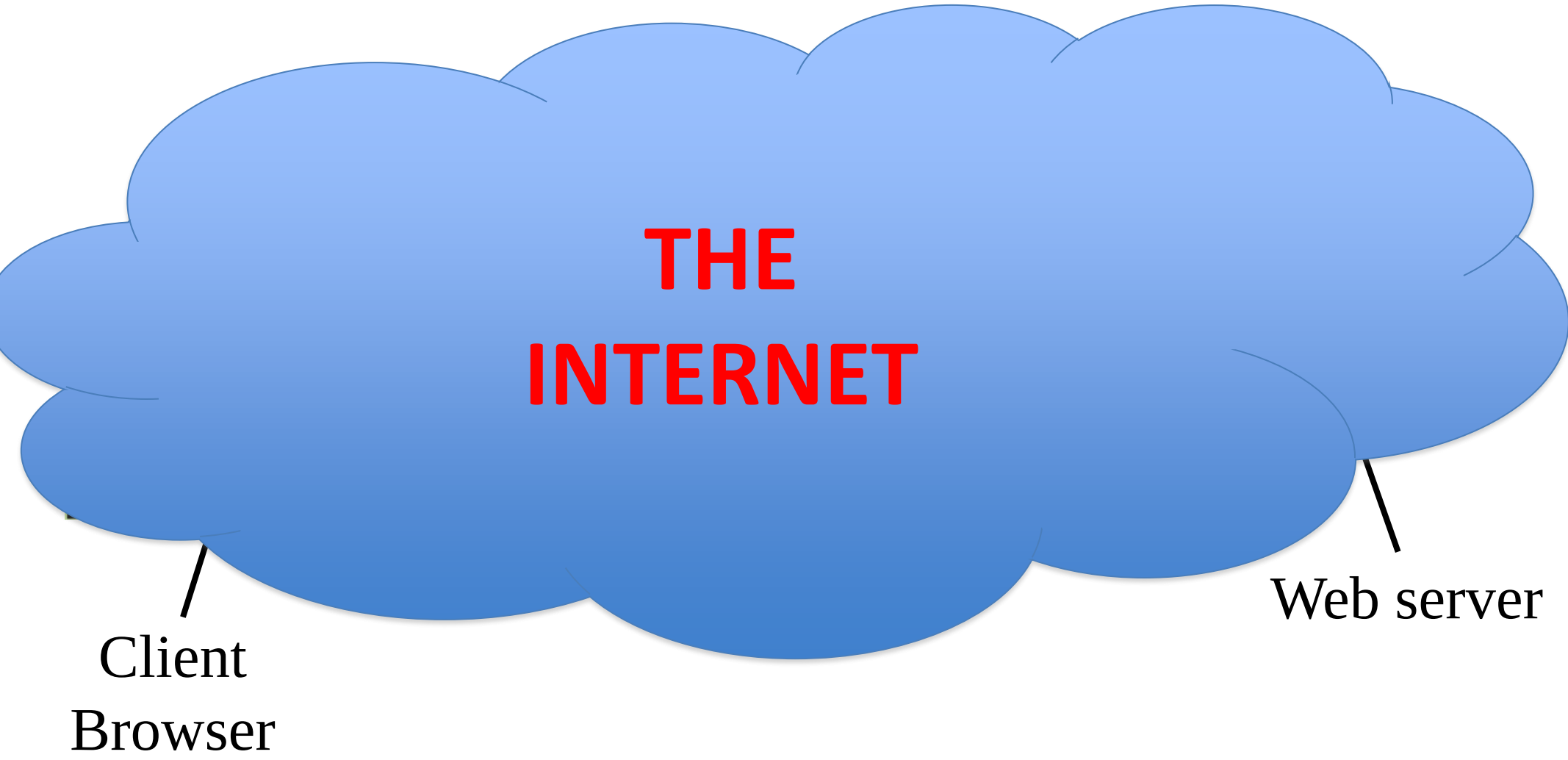
End-to-End Principle

Whenever possible, communications protocol operations should be defined to occur at the end-points of a communications system.

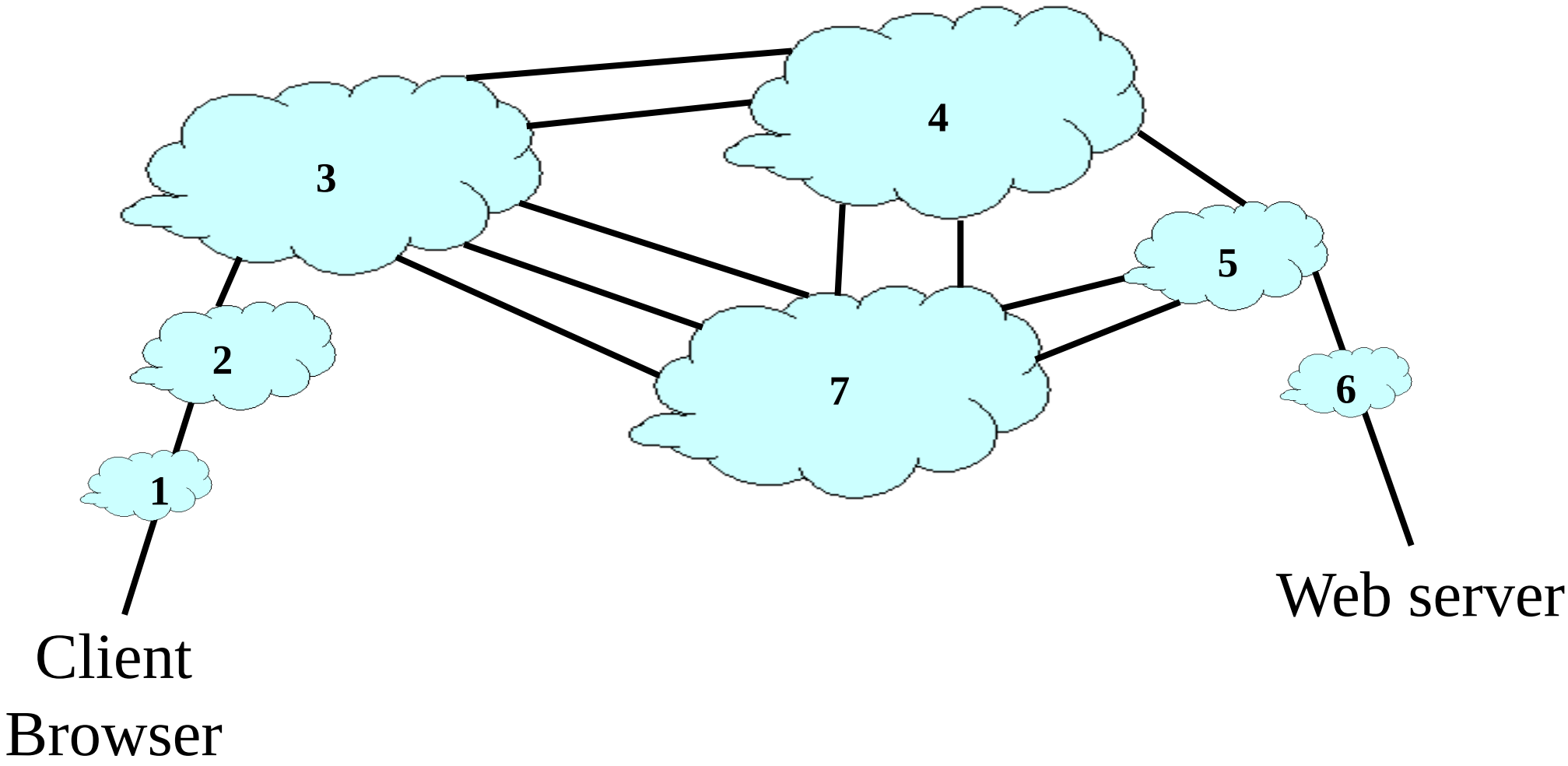
Keeps the network simple and scalable

Allows for easy introduction of new services at the edges

“A Network of Networks”



“A Network of Networks”

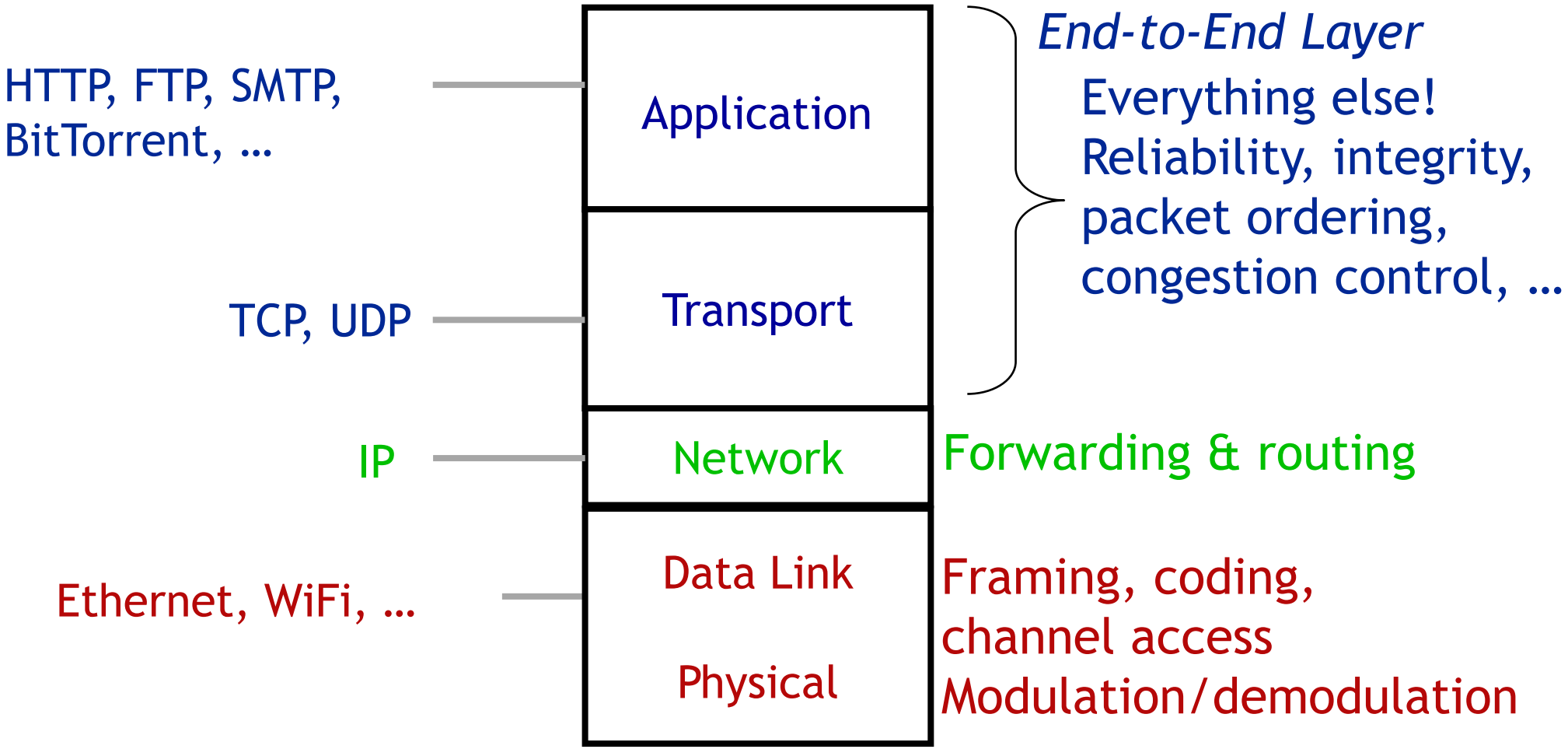


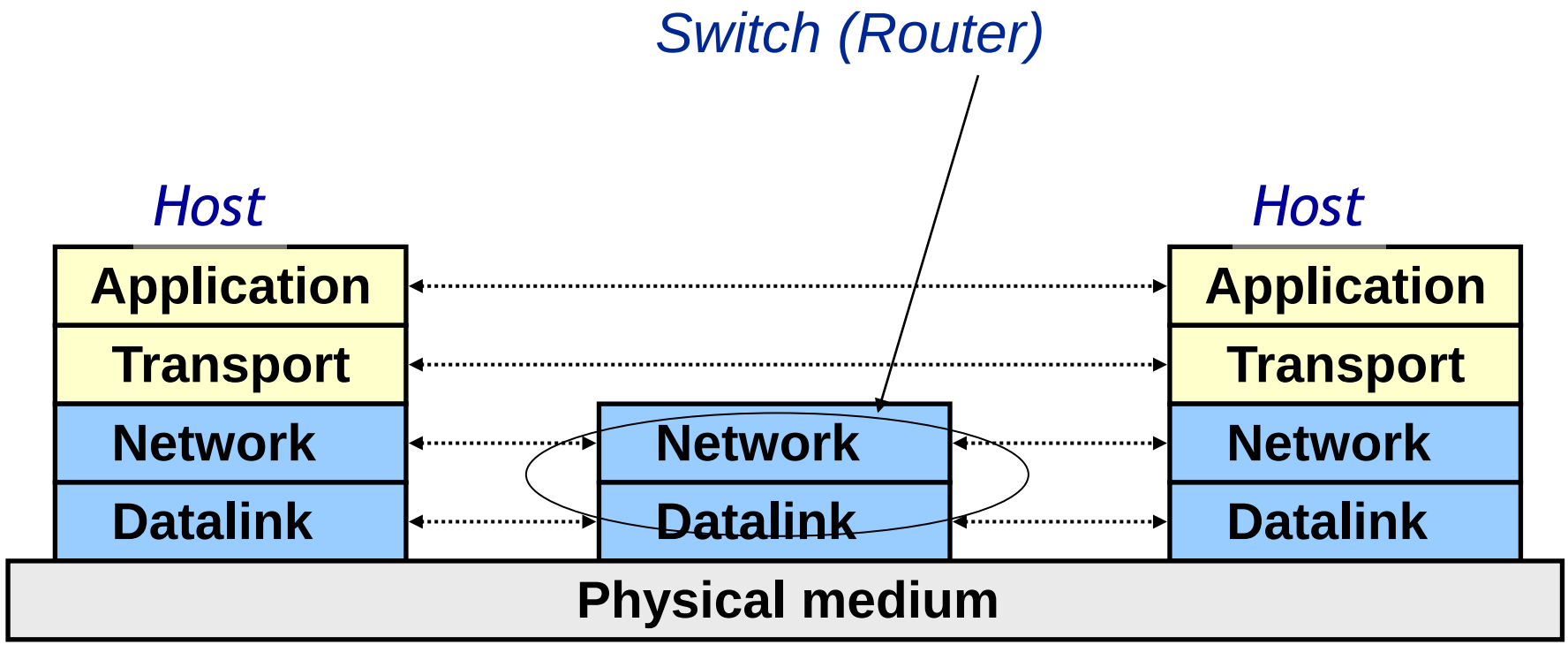
How the Internet is Organizing?
Layering

Layering

- Layering is a particular form of abstraction
- The system is broken into a **vertical stack** of **functions/protocols**
- The service provided by one layer is based solely on the service provided by layer below
  - This is the “up/down” interface

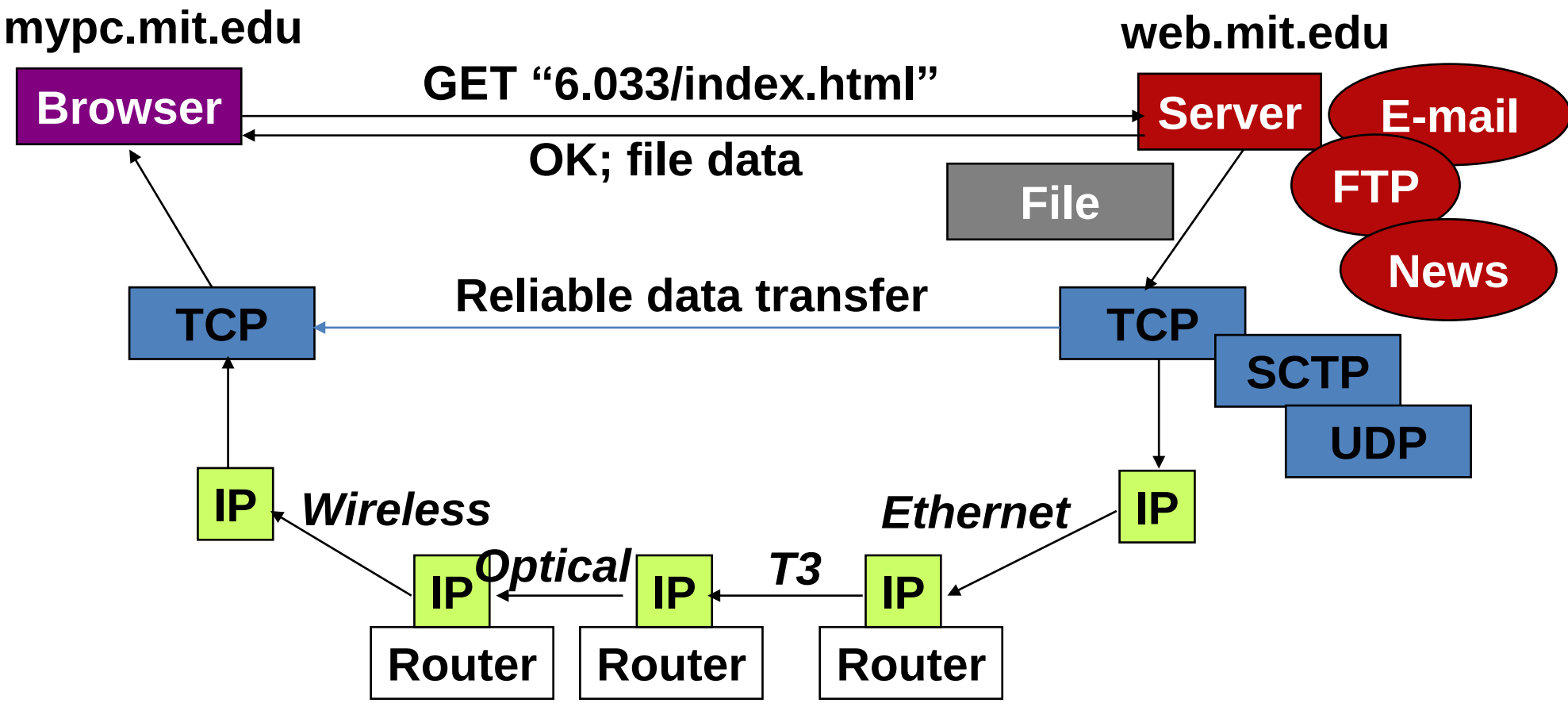
Layering in the Internet



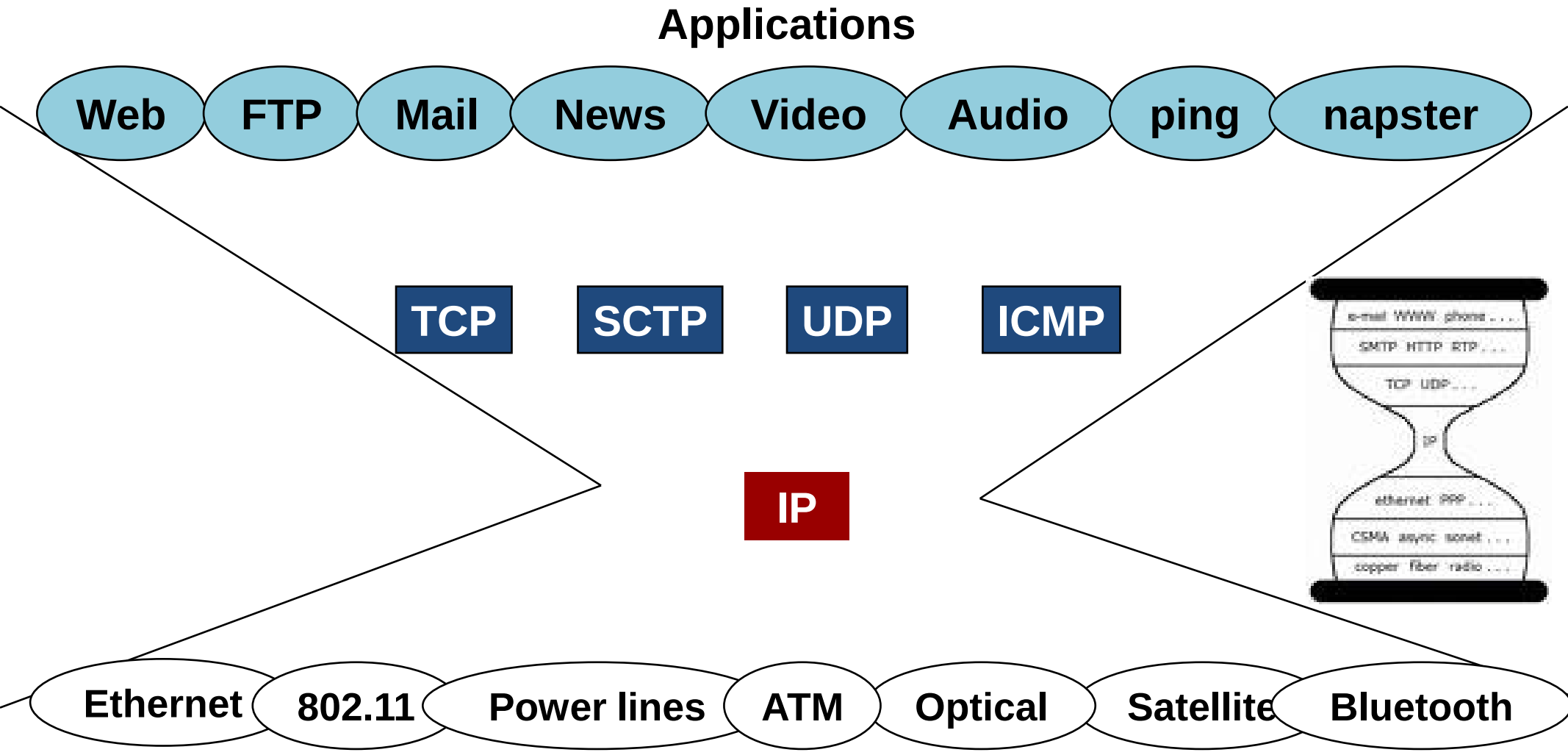


- Link and network layers are implemented everywhere
- The end-to-end layer (i.e., transport and application) is implemented only at hosts

An Example


mypc.mit.edu
web.mit.edu
Browser
GET “6.033/index.html”
Server
E-mail
OK; file data
FTP
File
News
TCP
Reliable data transfer
TCP
SCTP
UDP
IP
Wireless
Ethernet
IP
Optical
T3
IP
IP
IP
Router
Router
Router

The Internet "Hourglass"



- Many applications, transports, and link protocols
- All use IP at the network layer: universal network layer

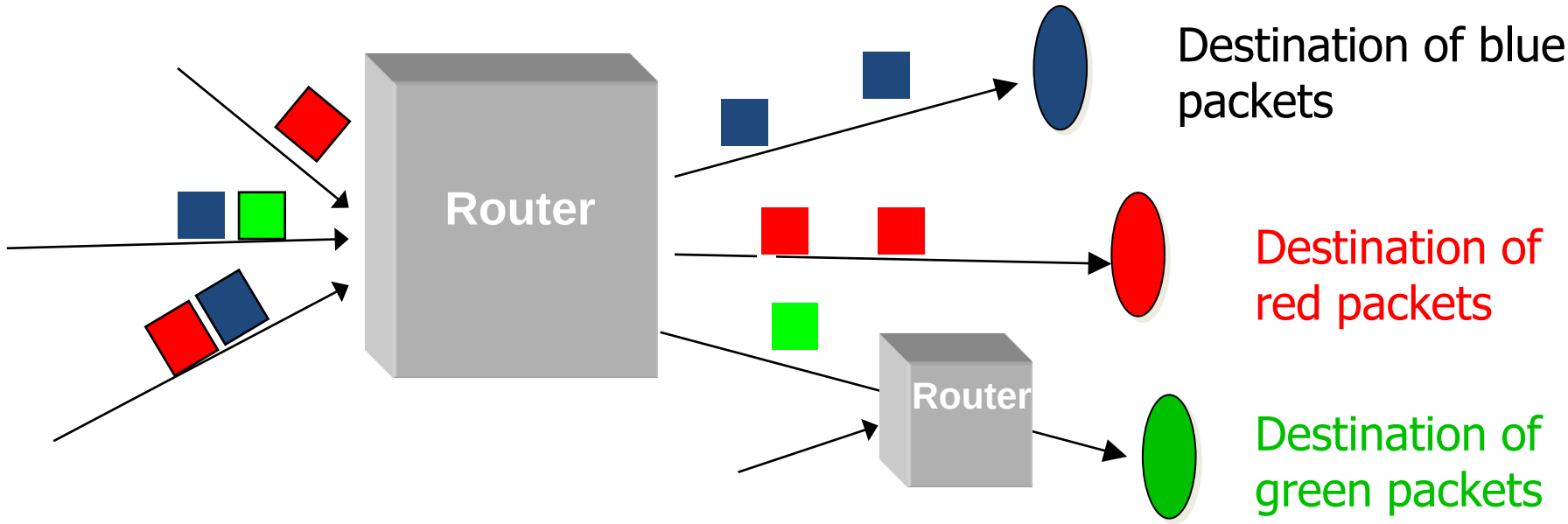
Network Layer

Routing (figuring out the routes)

&

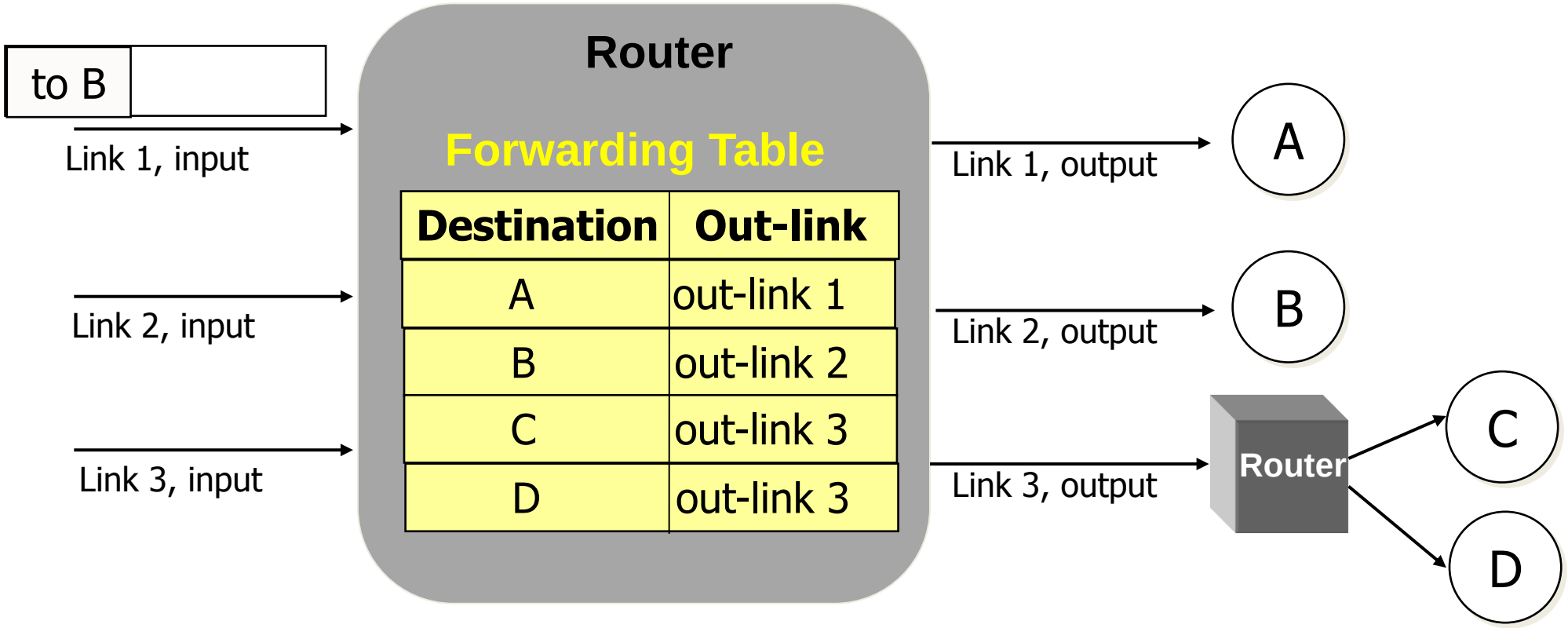
Forwarding (sending the packets)

How Does a Router Forwards the Packets?



- A router has input links and output links
- A router sends an input packet on the output link leading toward the packet's destination node
- A router does not care of who generated the packet

How does the router know which output link leads to a packet destination?



- Packet header has the destination
- Router looks up the destination in its table to find output link
- Table is built using a routing protocol

Basic Requirements of a Routing Protocol

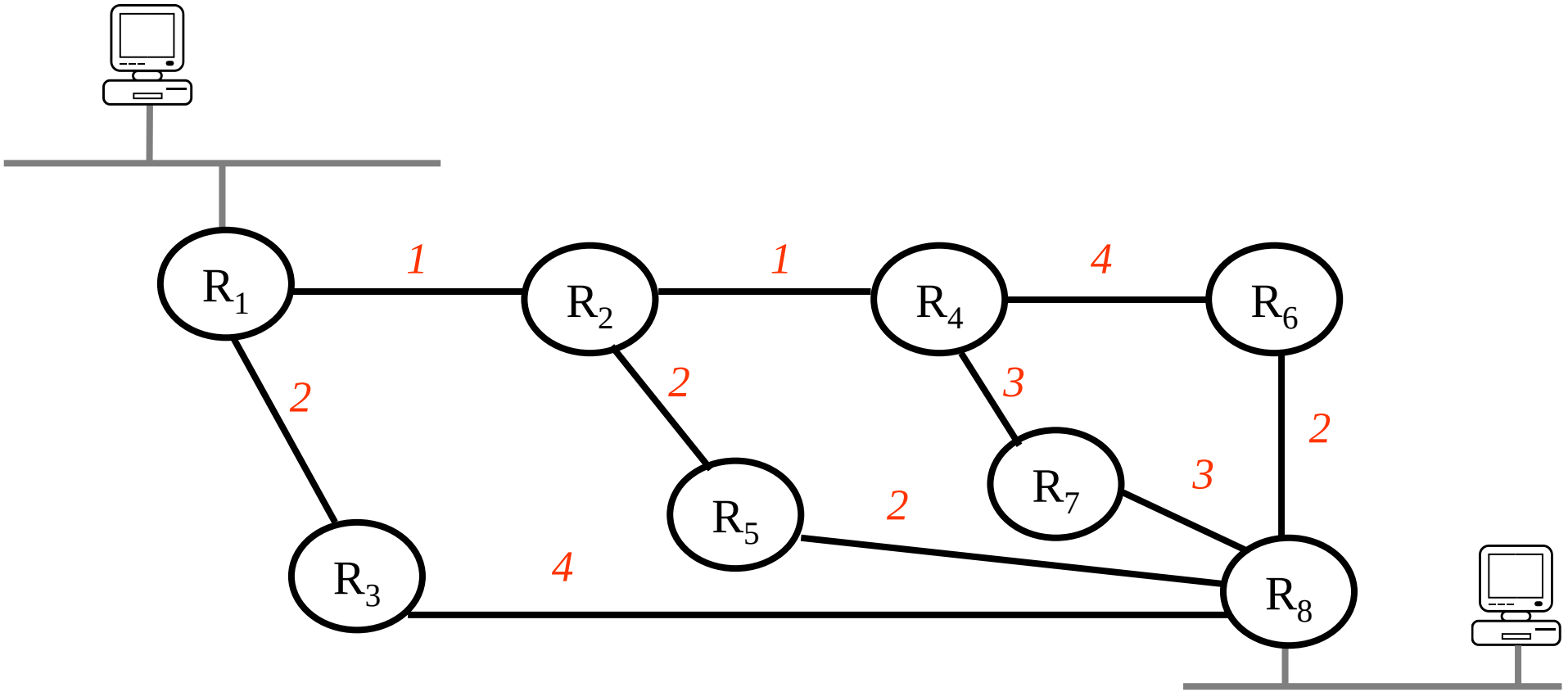
- Finds a path from source to destination
- Optimizes some metric (delay, cost, etc.)
- Has no (permanent) loops

Distance Vector Routing

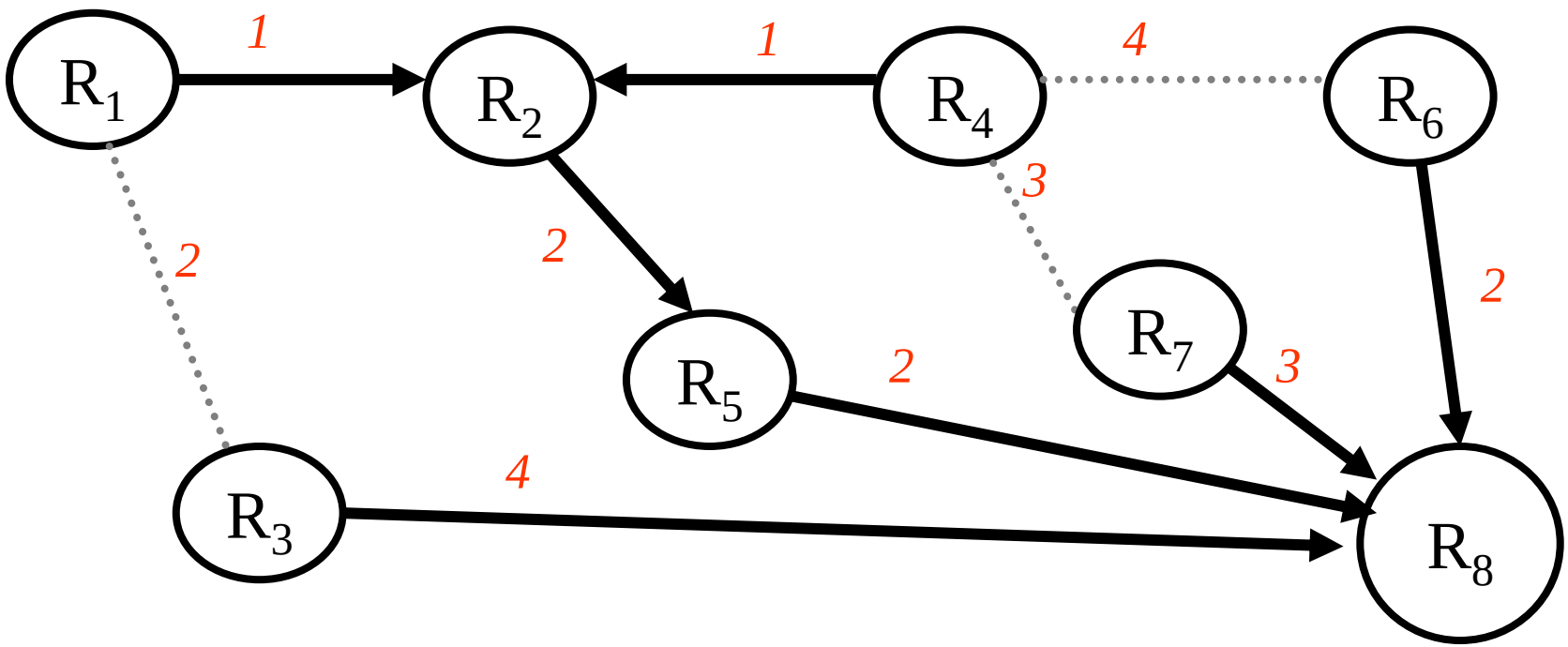
- Initialize
  - Distance to self is zero and next hop is self
  - Distance to anyone else is infinity
- Announce: Every T seconds
  - Tell neighbors distances to all destinations
- Update route to dst. upon message from j
  - Distance via j = j's distance + weight of link to j
  - If distance via j is shorter than current distance, update routing table to go via j

Example

Objective: Determine the route from (R_1, …, R_7) to R_8 that minimizes the distance



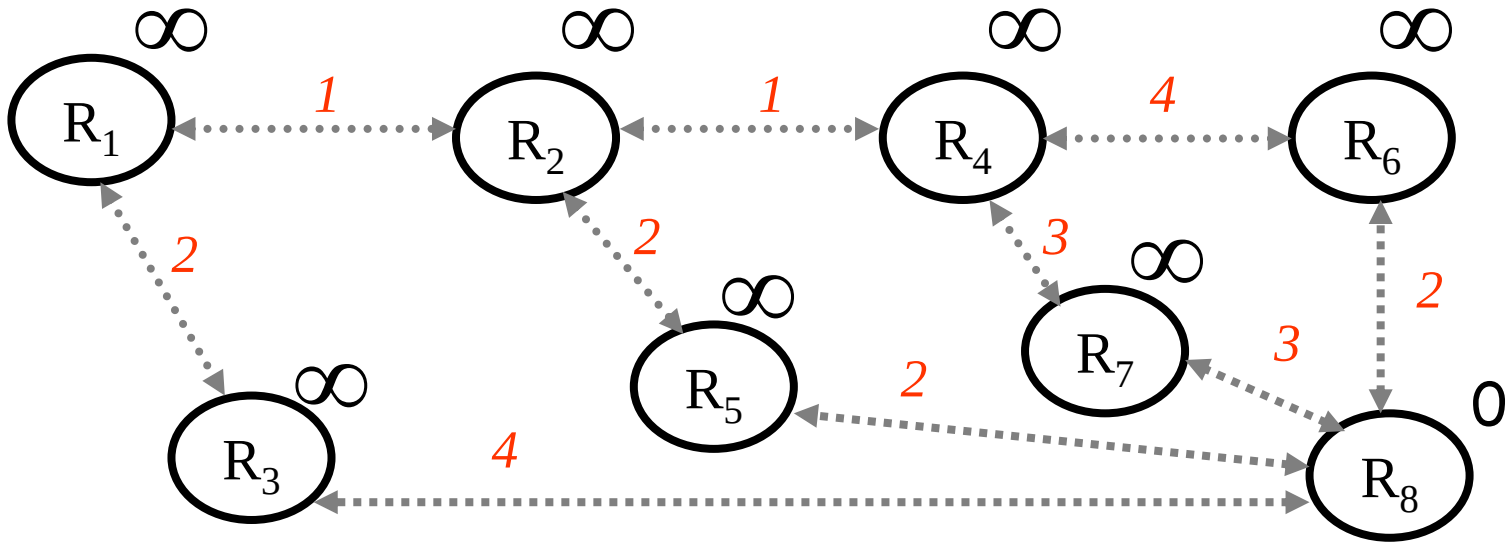
Solution is simple by inspection... (in this case)



The shortest paths from all sources to a destination (e.g., R_8) is the spanning tree routed at that destination.

Distance Vector Routing

Example

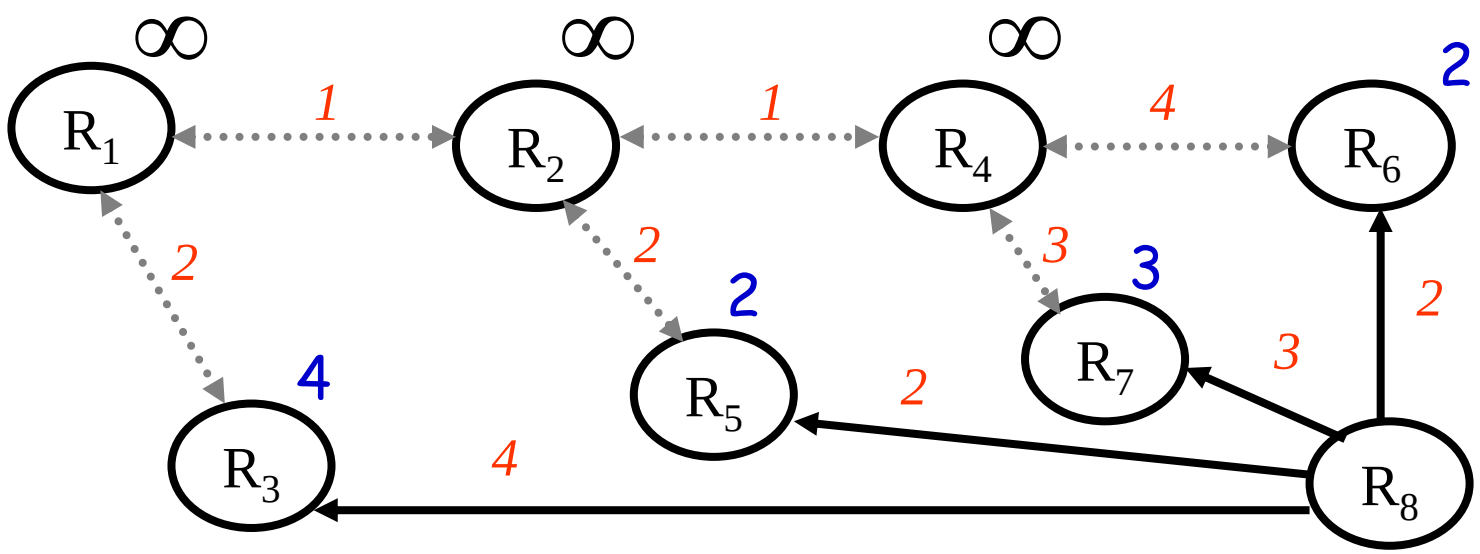


Initial State: All routers except R8 set their route length to ∞. R8 sets its route length to 0.

Distance Vector Routing

Example

R_1	Inf
R_2	Inf
R_3	4, R_8
R_4	Inf
R_5	2, R_8
R_6	2, R_8
R_7	3, R_8



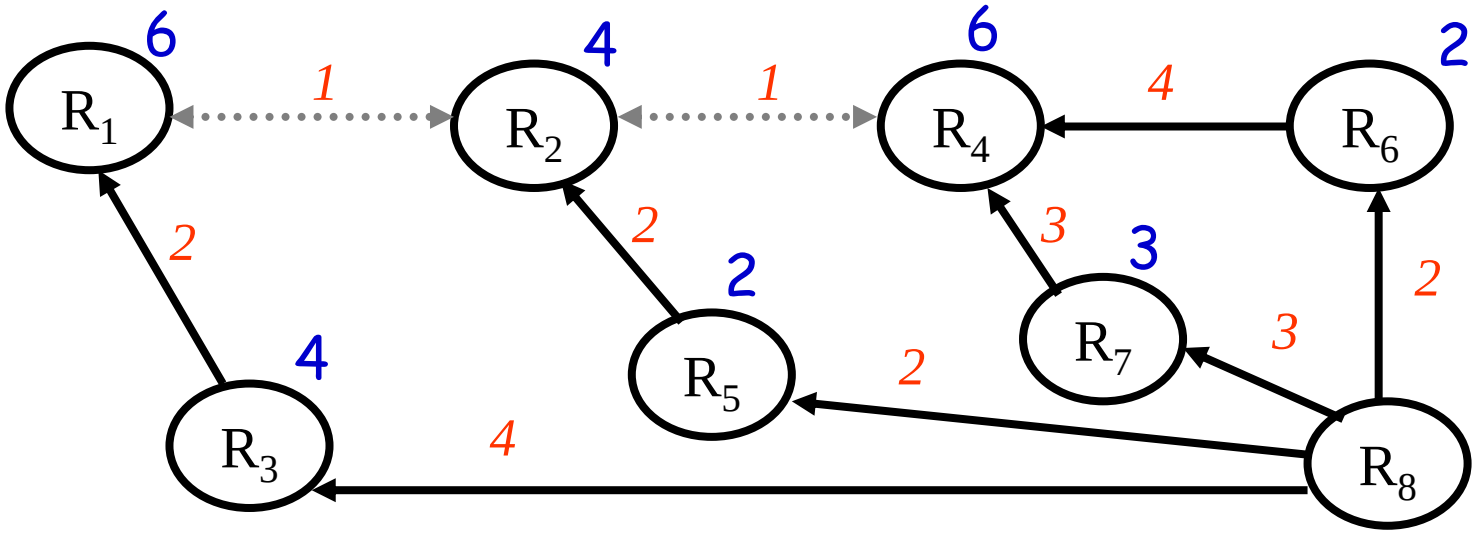
- Every T seconds, Router *i* tells its neighbors about its current lowest-cost path to R8
- Each router updates its distance as *min(current distance, received distance + link weight)*

Note, routing tables have both the next-hop and the distance

Distance Vector Routing

Example

R_1	6, R3
R_2	4, R5
R_3	4, R_8
R_4	6, R7
R_5	2, R_8
R_6	2, R_8
R_7	3, R_8

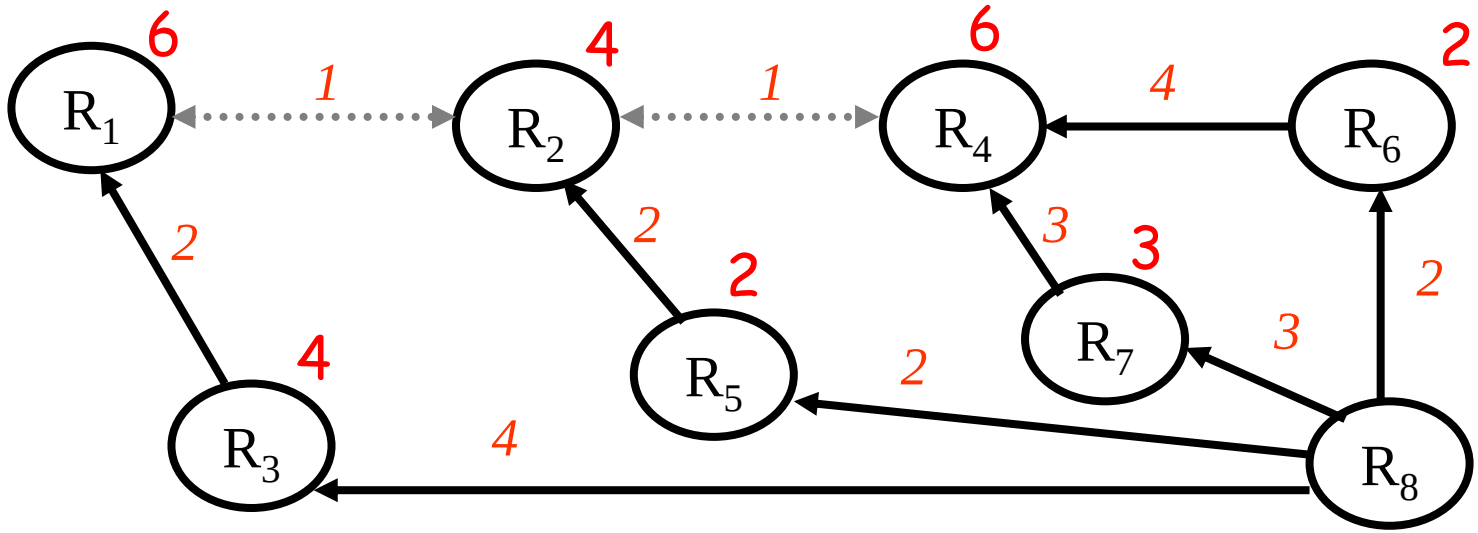


Repeat until no distance change

Distance Vector Routing

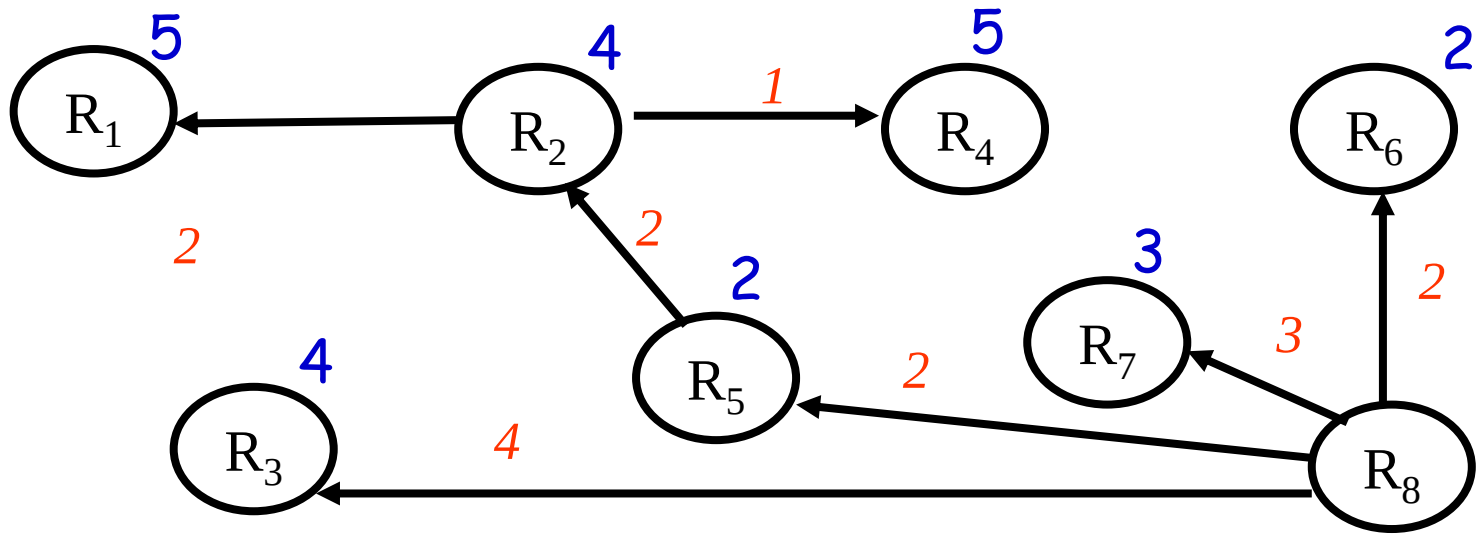
Example

R_1	6, R3
R_2	4, R5
R_3	4, R_8
R_4	6, R7
R_5	2, R_8
R_6	2, R_8
R_7	3, R_8



Final Iteration

R_1	5, R2
R_2	4, R5
R_3	4, R_8
R_4	5, R2
R_5	2, R_8
R_6	2, R_8
R_7	3, R_8



Summary

- Internet architecture is based on layering

  E2E Layer

  Network Layer

  Link Layer

- Job of Network Layer is Routing & Forwarding
  - Routers build routing tables using routing protocol
  - Routers forward packets based on the packet's header and the routing table