This time

Starting with

Networking Basics

- A whirlwind tour of networking
- What is a protocol?
- What are the abstractions / mental models?
- Network stack

(1) Protocols

Agreement on how to communicate

- Syntax:
  - How the communication is specified and structured
  - Format, order of messages

- Semantics:
  - What the communication means
  - Actions that should be taken when transmitting, receiving, or when a timer expires.

(1) Protocols

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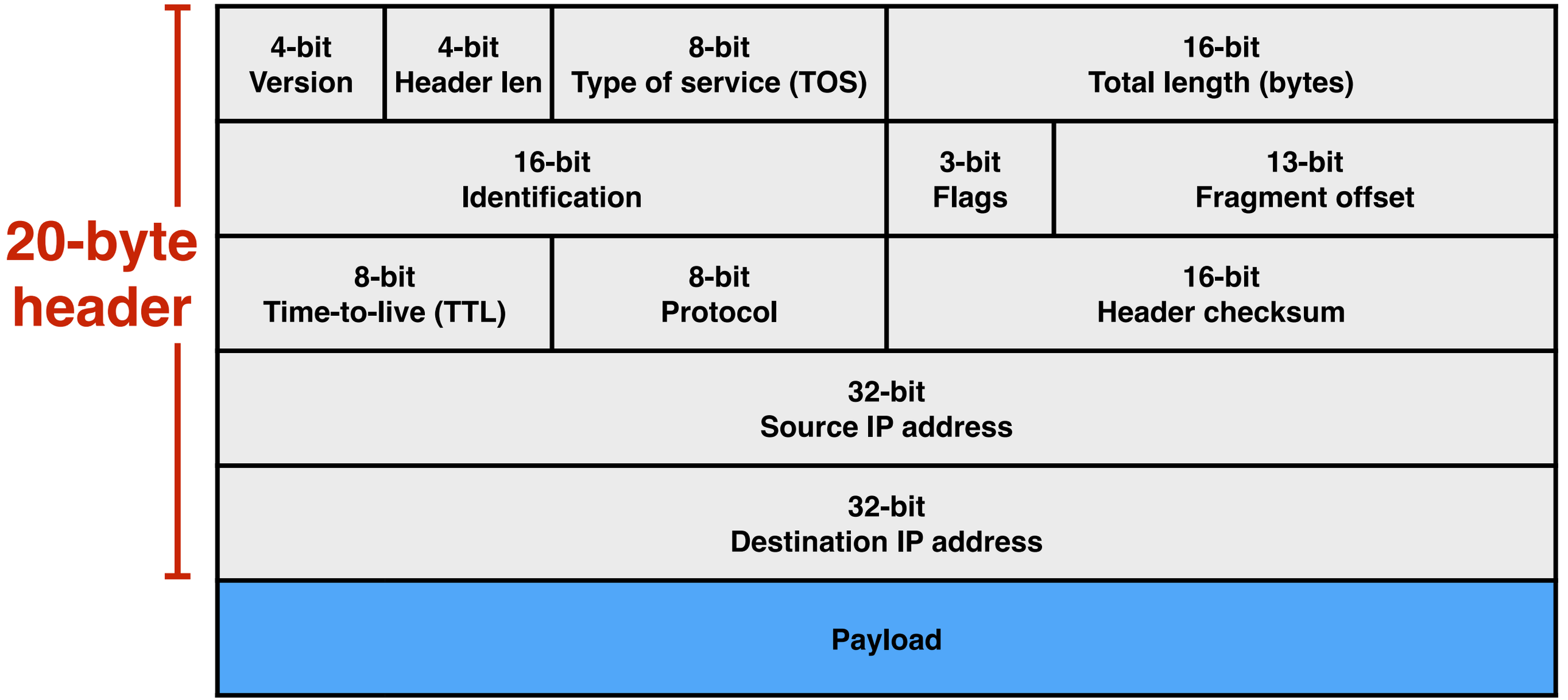
An algorithm for communicating.
***And* a "language" to speak.**

IP packet “header”



The payload is the “data” that IP is delivering:

May contain another protocol’s header & payload, and so on

(2) The network is “dumb”

- End-hosts are on the periphery of the network
  - They can *connect* to one another, even though they are *not physically connected* to one another

- Routers are the interior nodes that
  - “Route”: *determine how* to get to B
  - “Forward”: actually forward traffic from A to B

- Principle: the routers have no knowledge of ongoing connections through them
  - They do “destination-based” routing and forwarding
    - Given the destination in the packet, send it to the “next hop” that is best suited to help ultimately get the packet there

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Mental model: The postal system

Postal system analogy

- Messages are self-contained
  - Post: a message in an envelope
  - Internet: data in a packet

- Interior routers forward based on destination address
  - Post: zip code, then street, then building, then apartment number (then the right individual)
  - Internet: progressively smaller blocks of IP addresses, then your computer (then the right application)

- Simple, robust.
  - More sophisticated things go at the *ends of the network*

(3) Layers

- The design of the Internet is strongly partitioned into layers
  - Each layer relies on the services provided by the layer immediately below it…
  - … and provides service to the layer immediately above it

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Code you write

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Analogy:

Code you write

Run-time library

System calls

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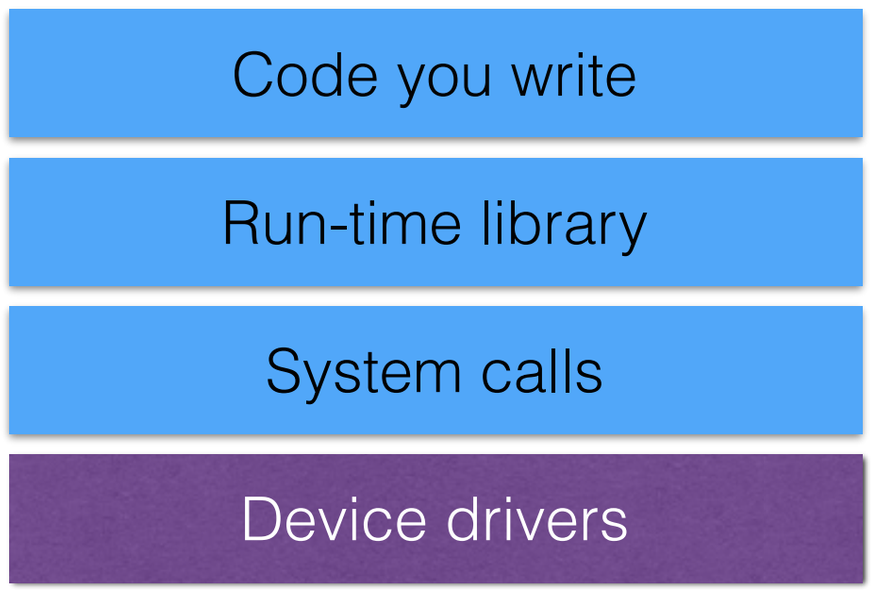

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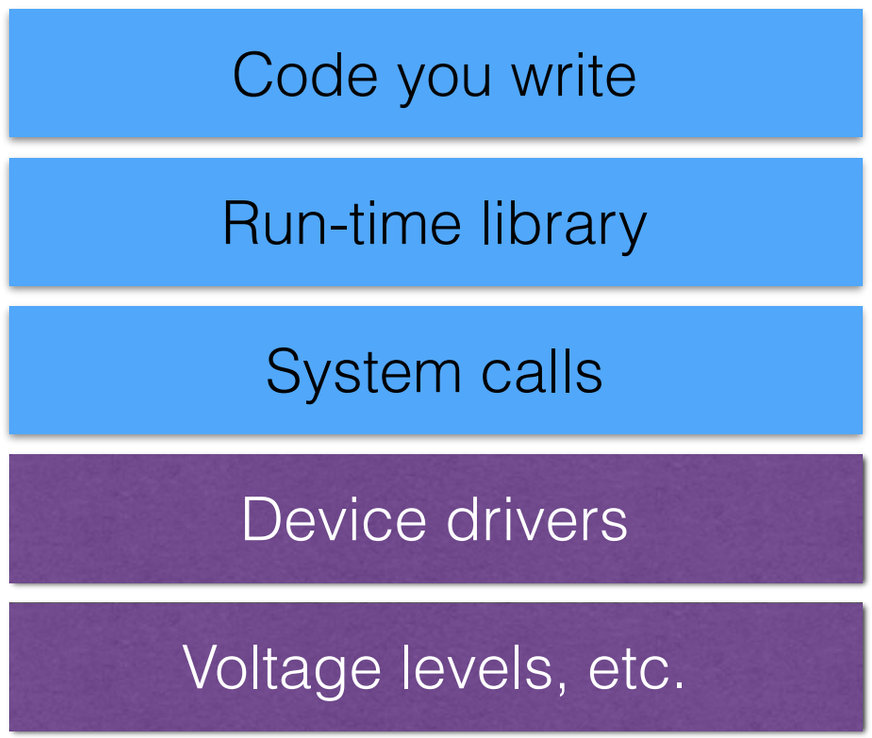

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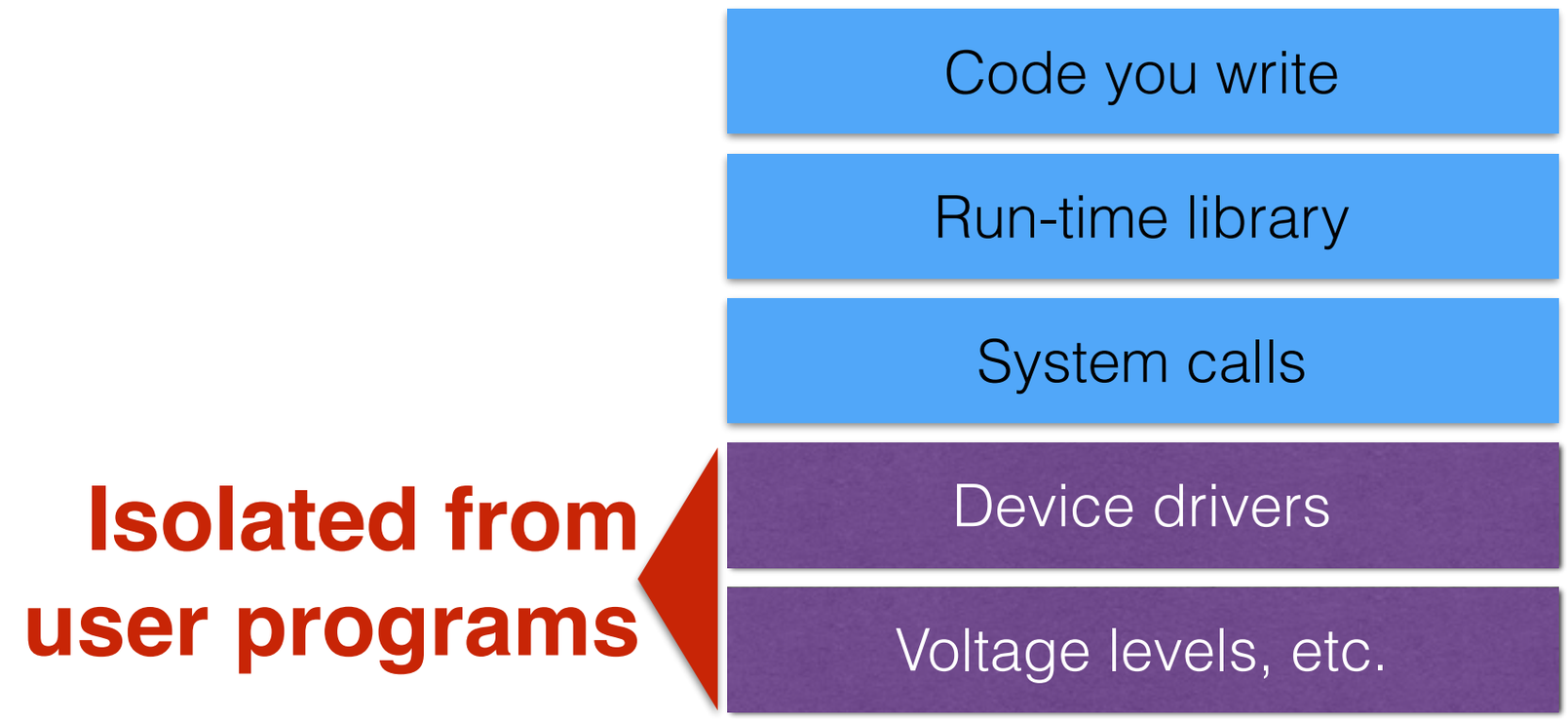

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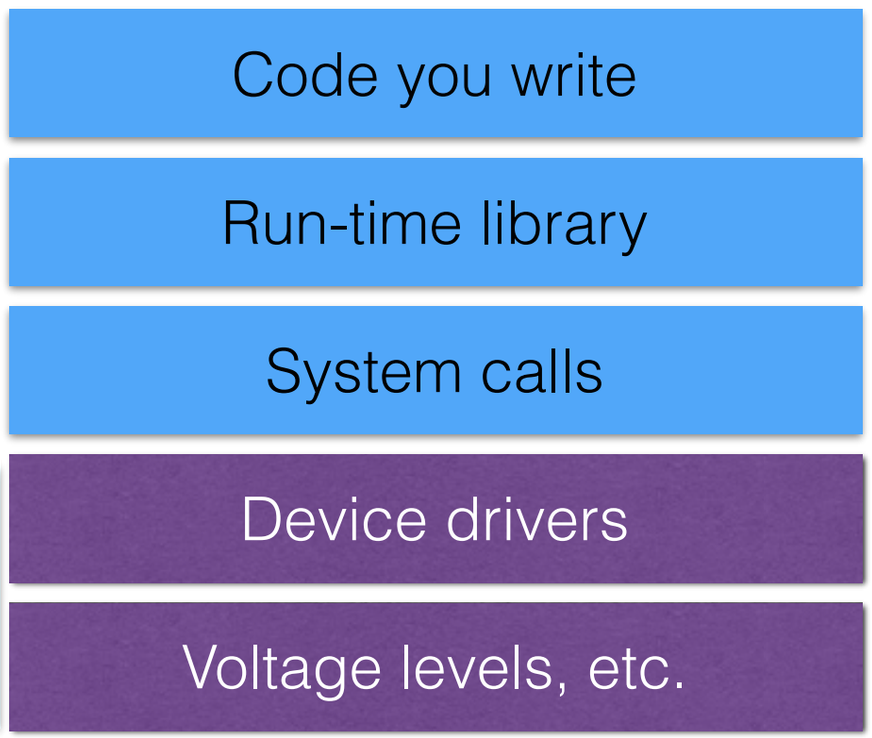

Isolated from user programs

Each layer has a well-defined *role* that builds off of the layer below it

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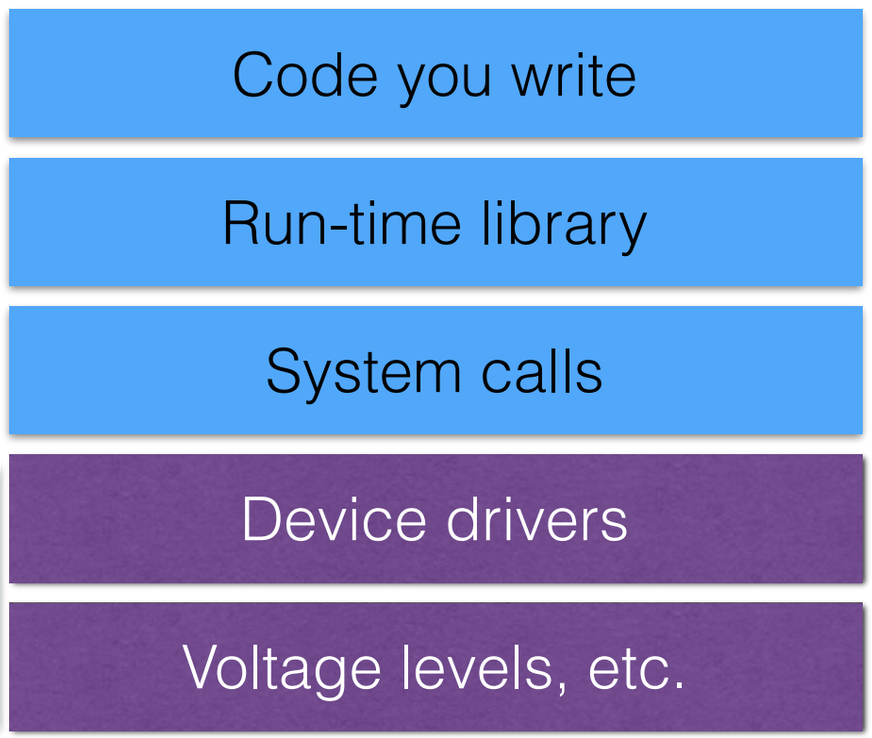
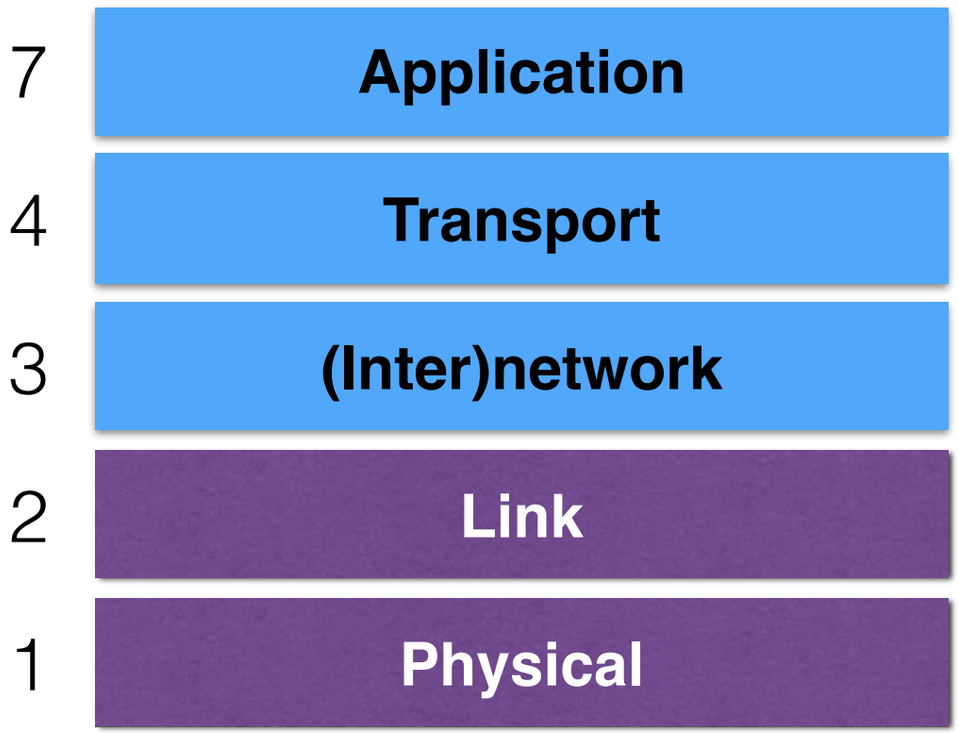


Isolated from user programs

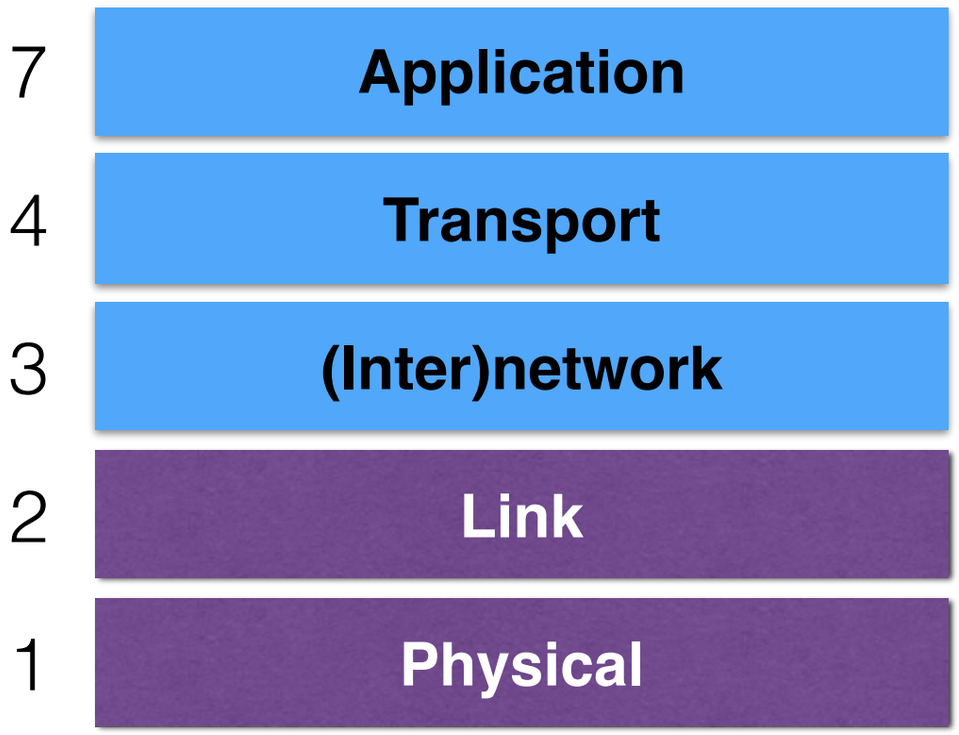
Each layer has a well-defined *role* that builds off of the layer below it

Between each layer is a well-defined *interface*

Internet layering = “Protocol stack”



Layer 1: Physical layer

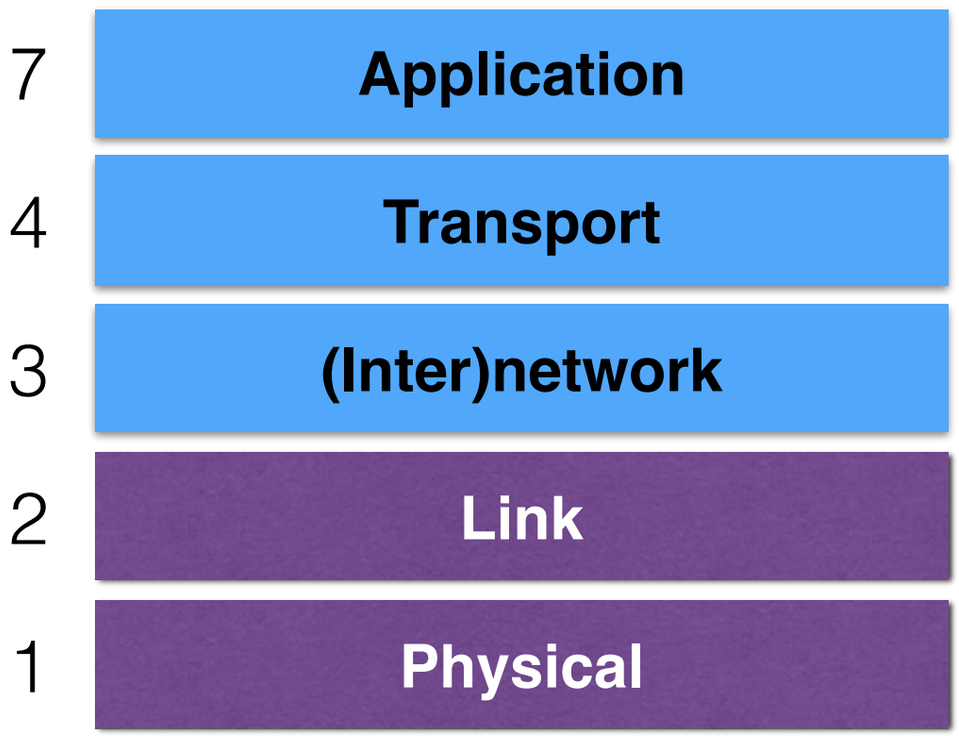


- Encoding of bits to send over a ***single*** physical link
- Examples:
  - Voltage levels
  - RF modulation
  - Photon intensities

<u>Physical layer:</u>
transmitting a single bit
over a physical link
(though not necessarily *wired* link)

End-host C

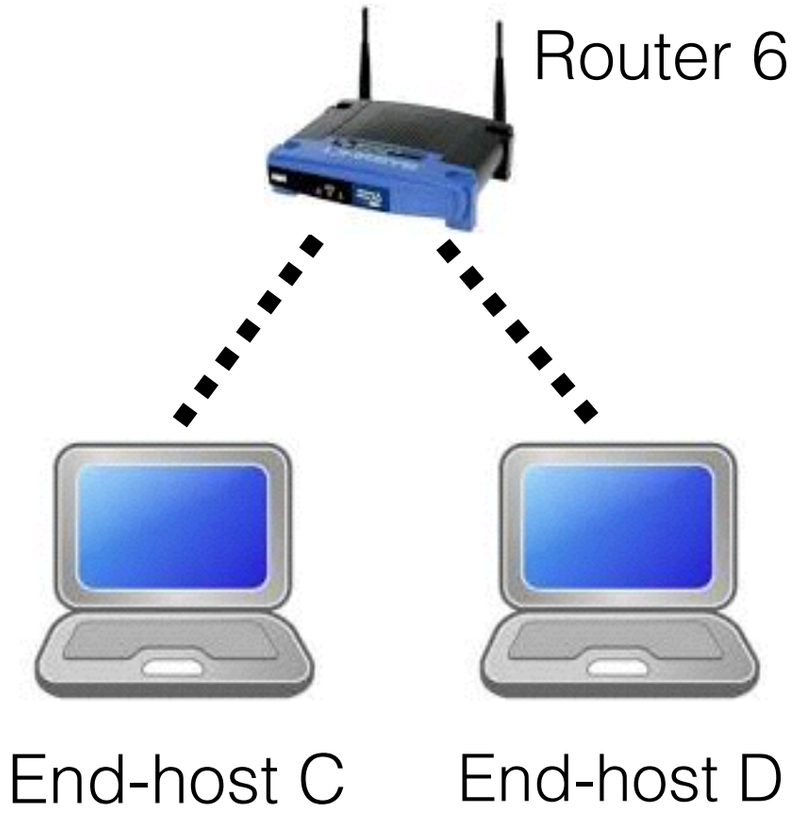
Layer 2: Link layer



- Framing and transmission of a collection of bits into individual **messages** sent across a single subnetwork (one physical topology)
- Provides **local** addressing (MAC)
- May involve multiple *physical links*
- Often the technology supports **broadcast**: every "node" connected to the subnet receives
- Examples:
  - Modern Ethernet
  - WiFi (802.11a/b/g/n/etc)

<u>Link layer</u>

- transmitting messages
- over a *subnet*
- src/dst identified by globally unique **MAC addrs**



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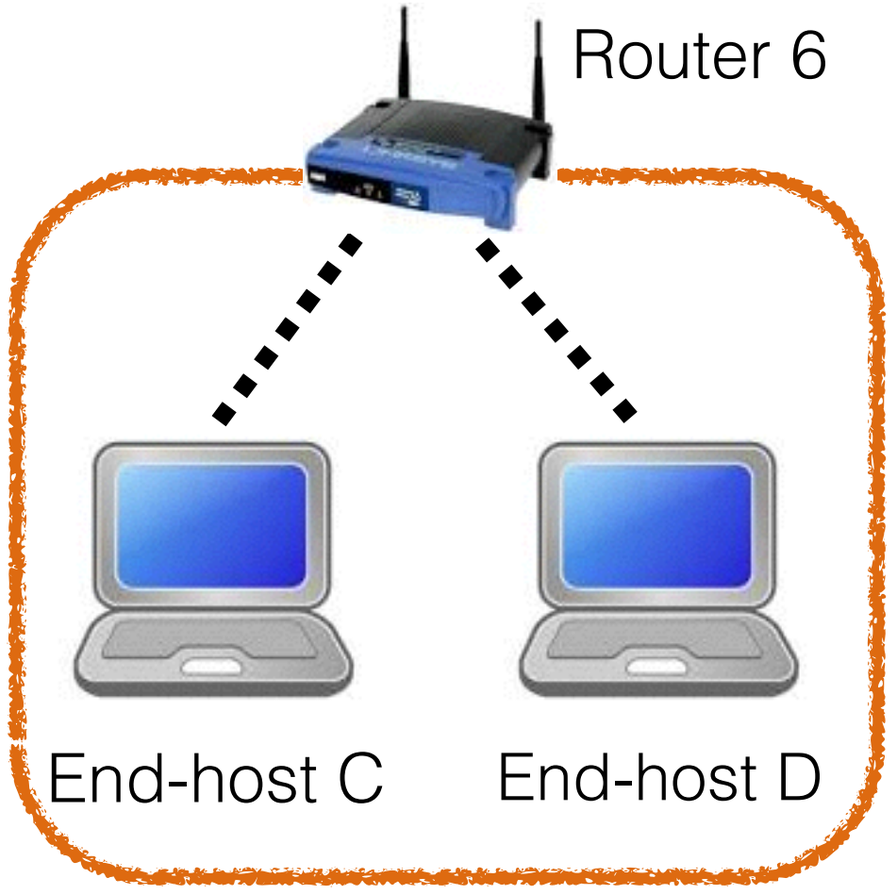

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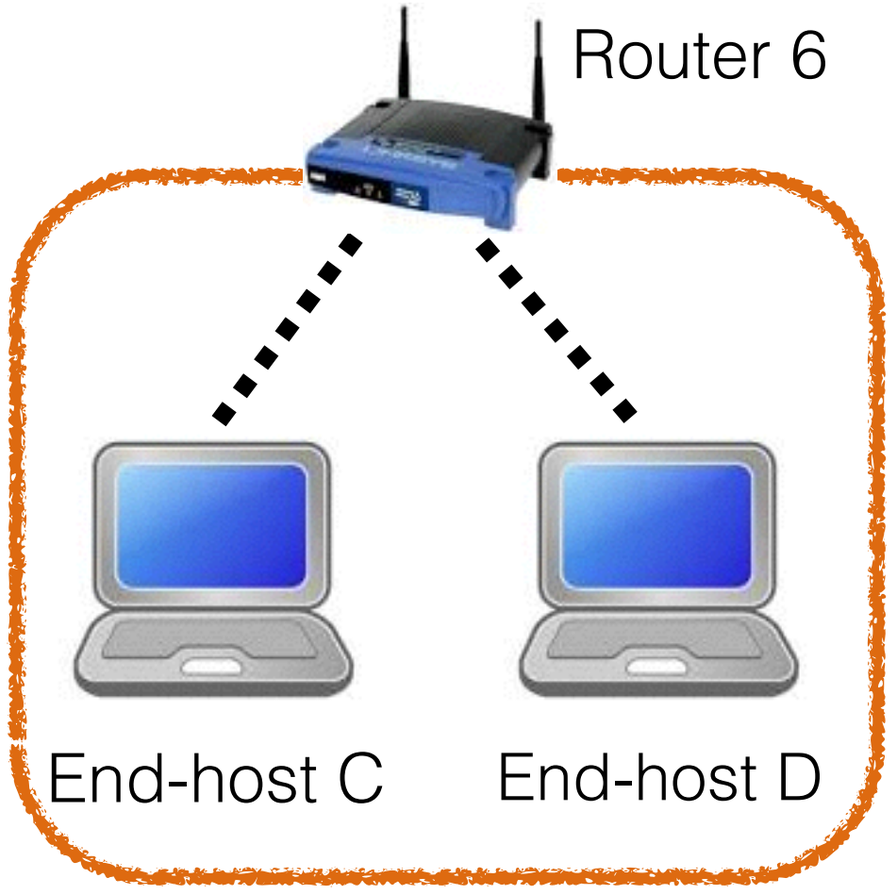
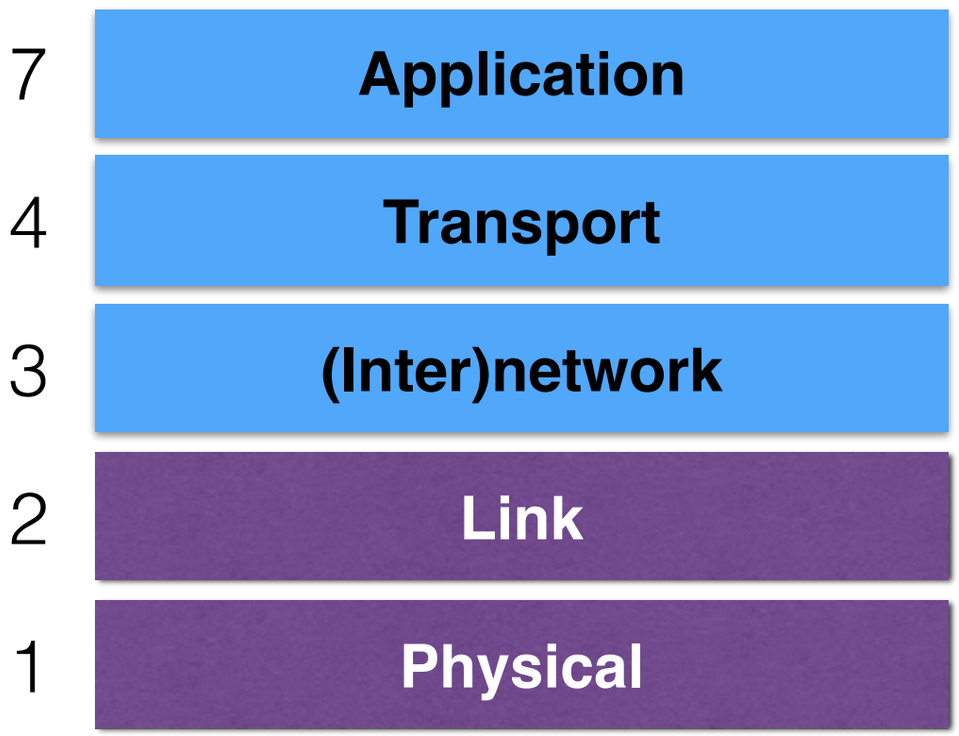


Because you need to be able to join any subnet and be uniquely distinguishable

Layer 3: (Inter)network layer



- Bridges multiple “subnets” to provide *end-to-end* internet connectivity between nodes
- Provides **global** addressing (IP addresses)
- Only provides **best-effort** delivery of data (i.e., no retransmissions, etc.)
- Works across different link technologies

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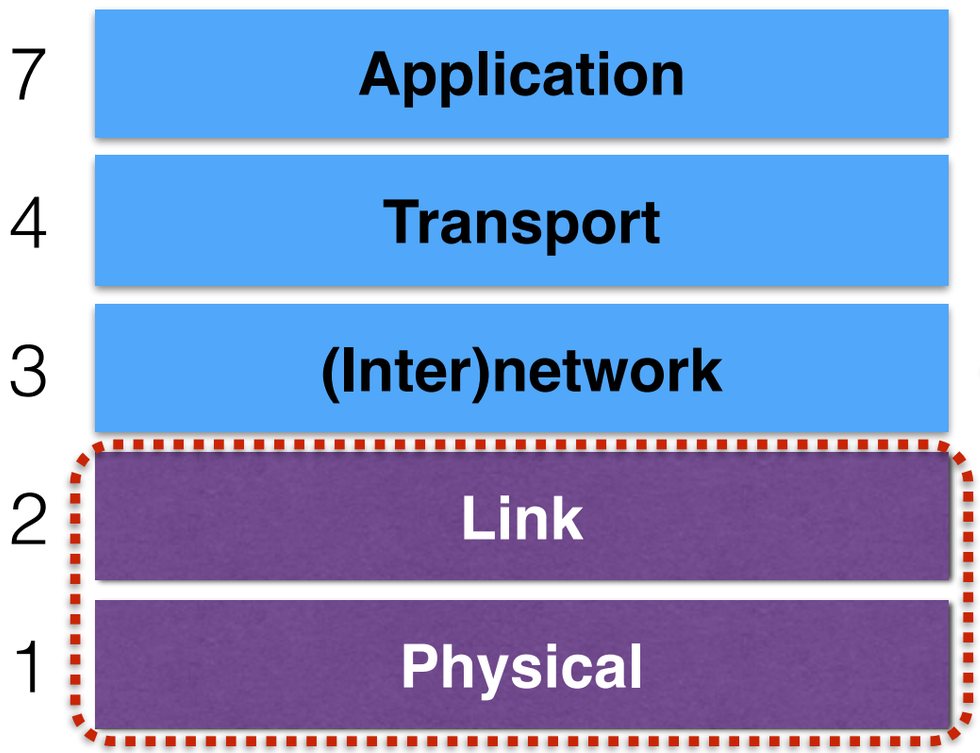

Different for each Internet "hop"

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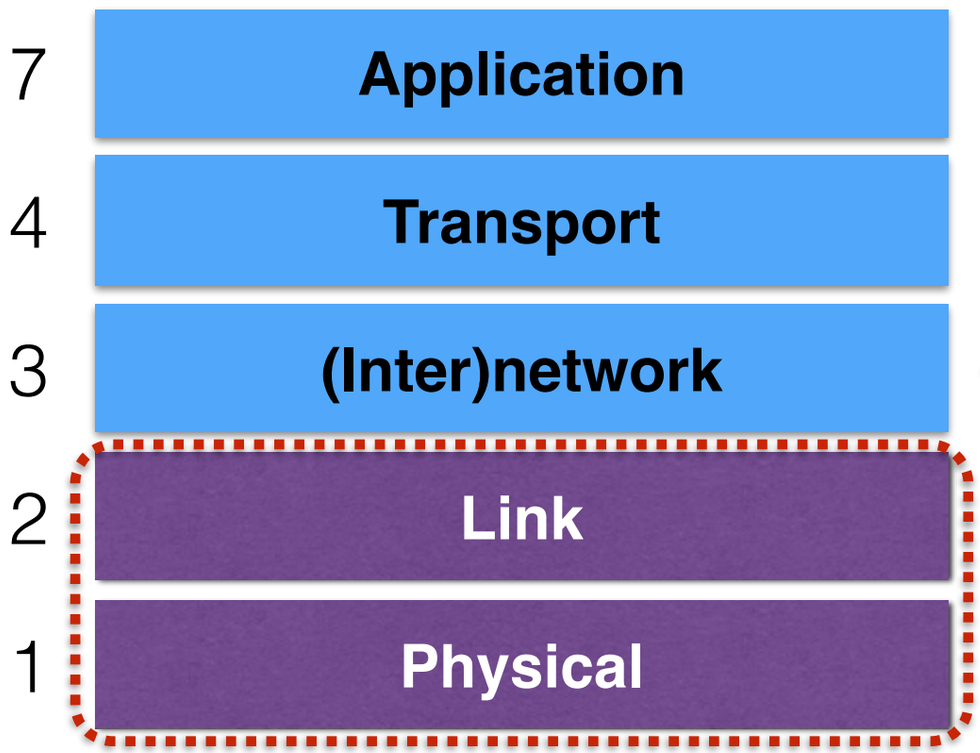

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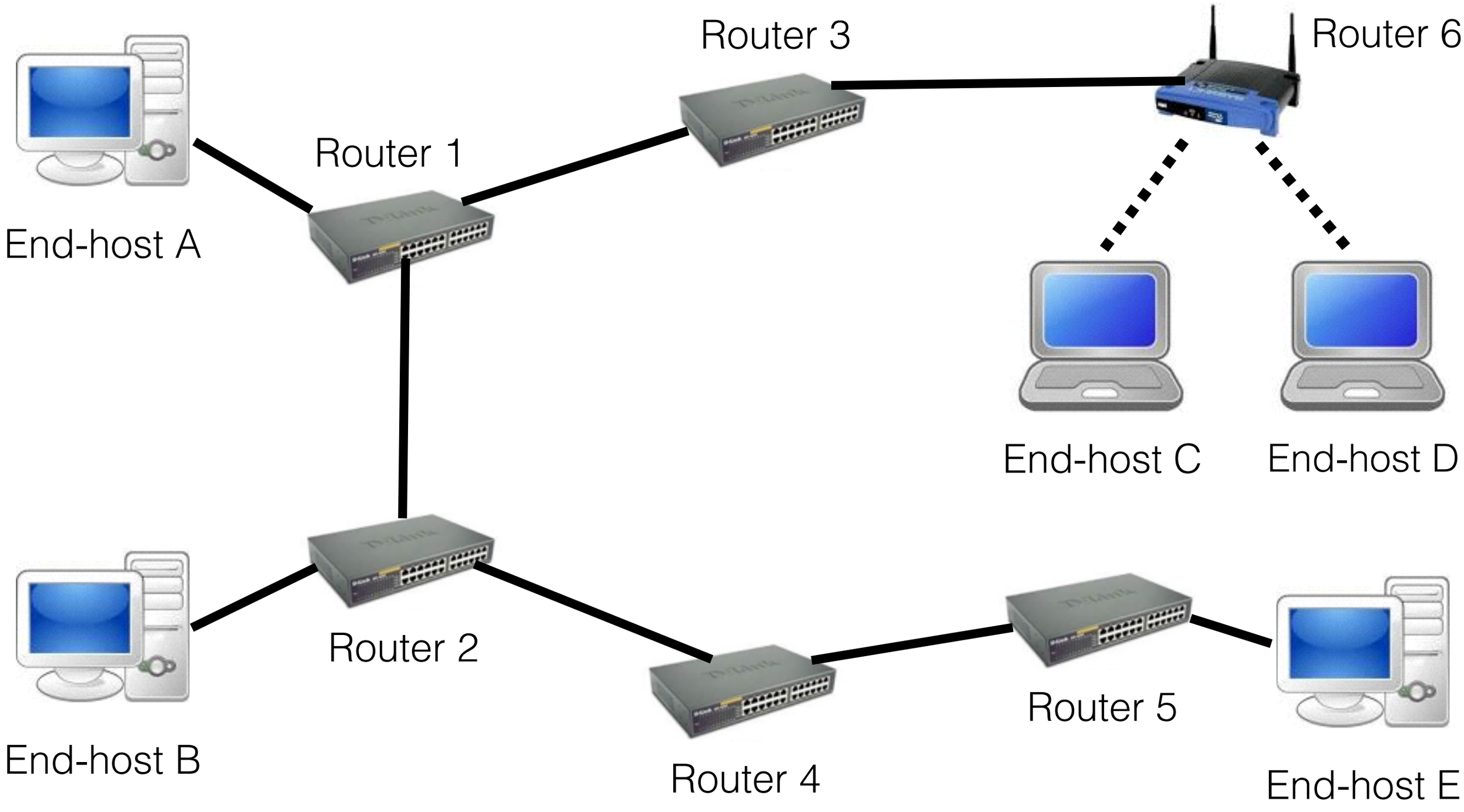
Lowercase-i "internet" = network of networks.
Uppercase-i Internet = "*the* Internet"

Network layer

- transmitting packets
- within or across subnets
- src/dst identified by locally unique **IP addrs**



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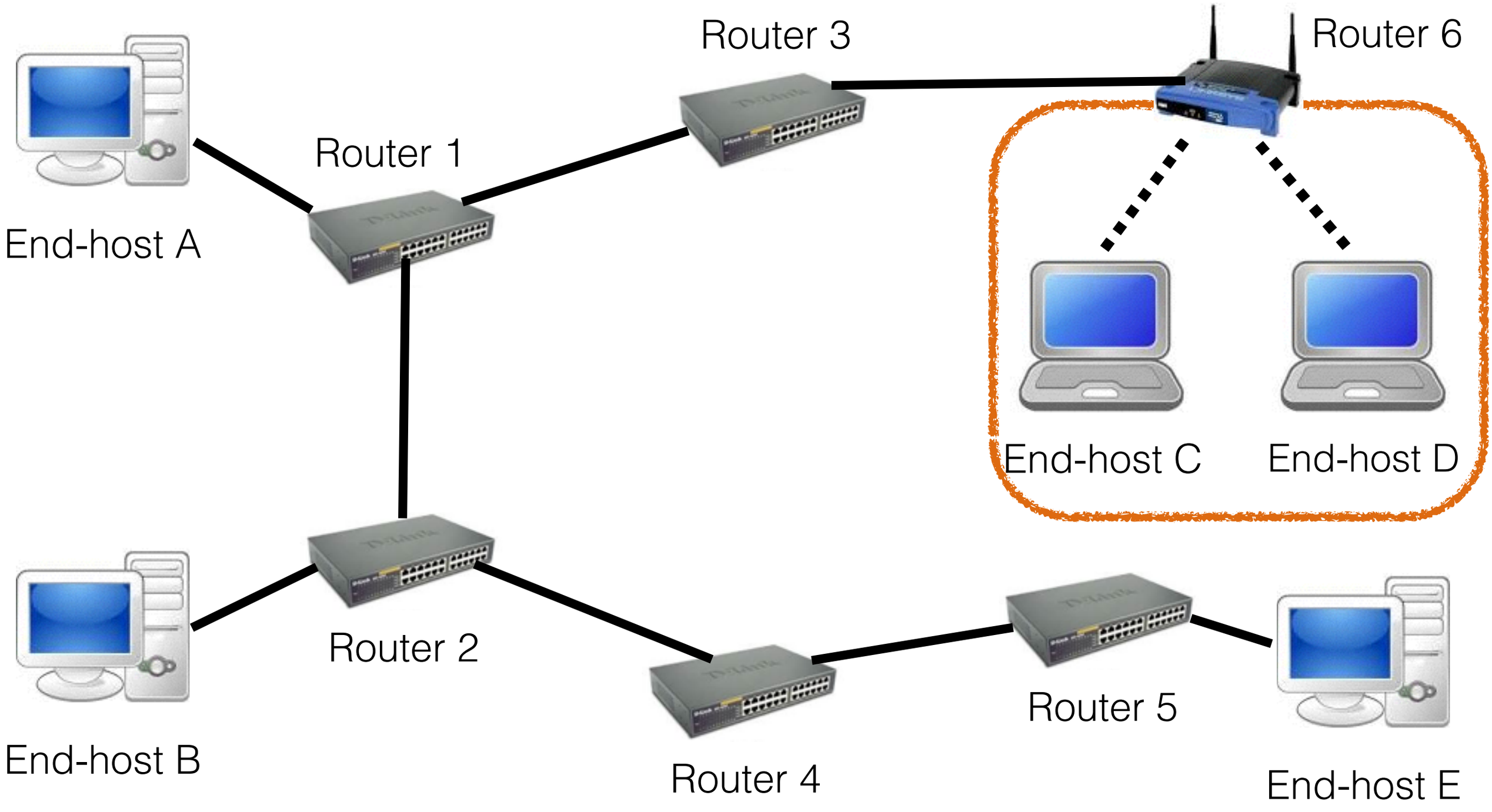

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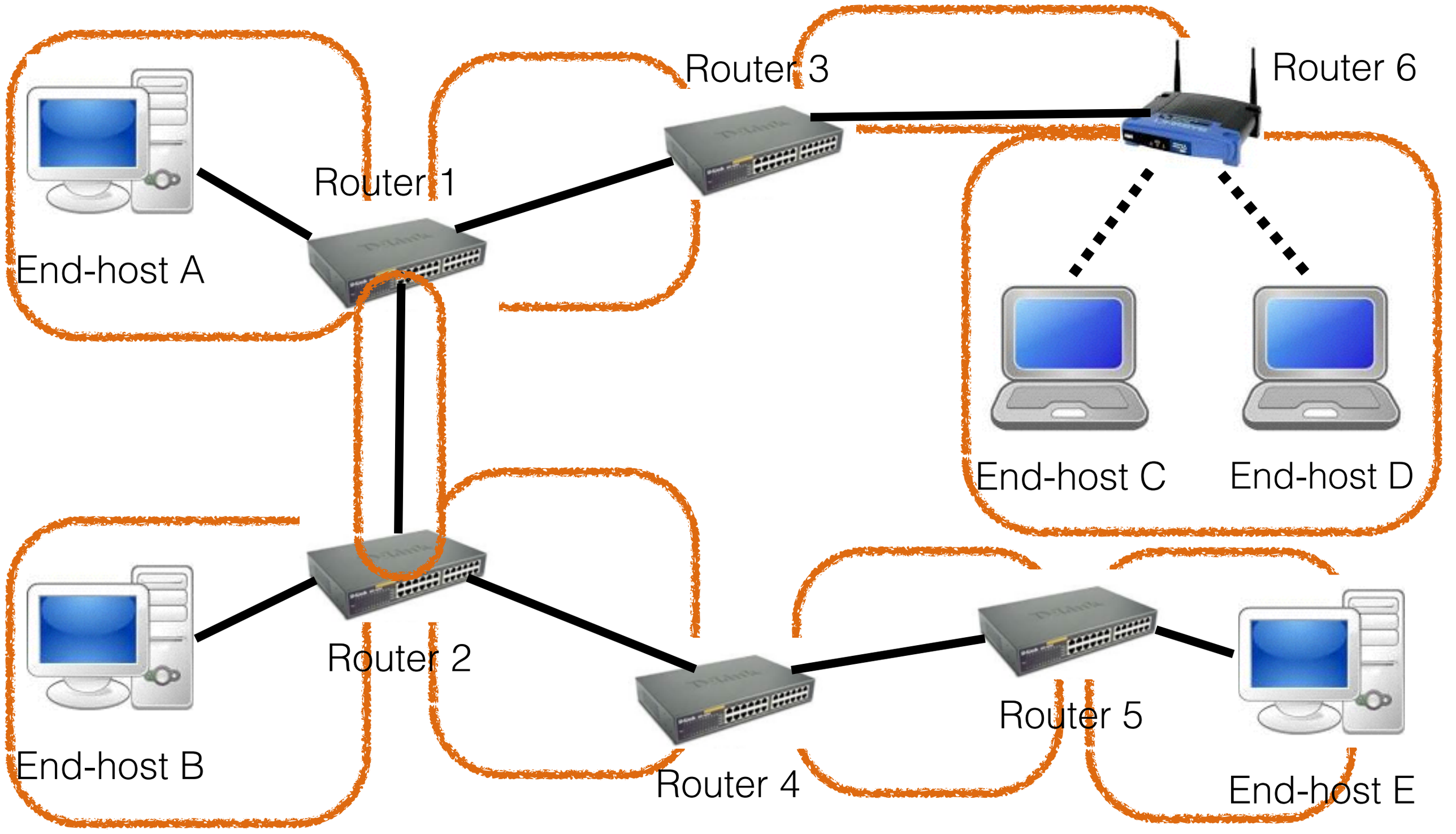

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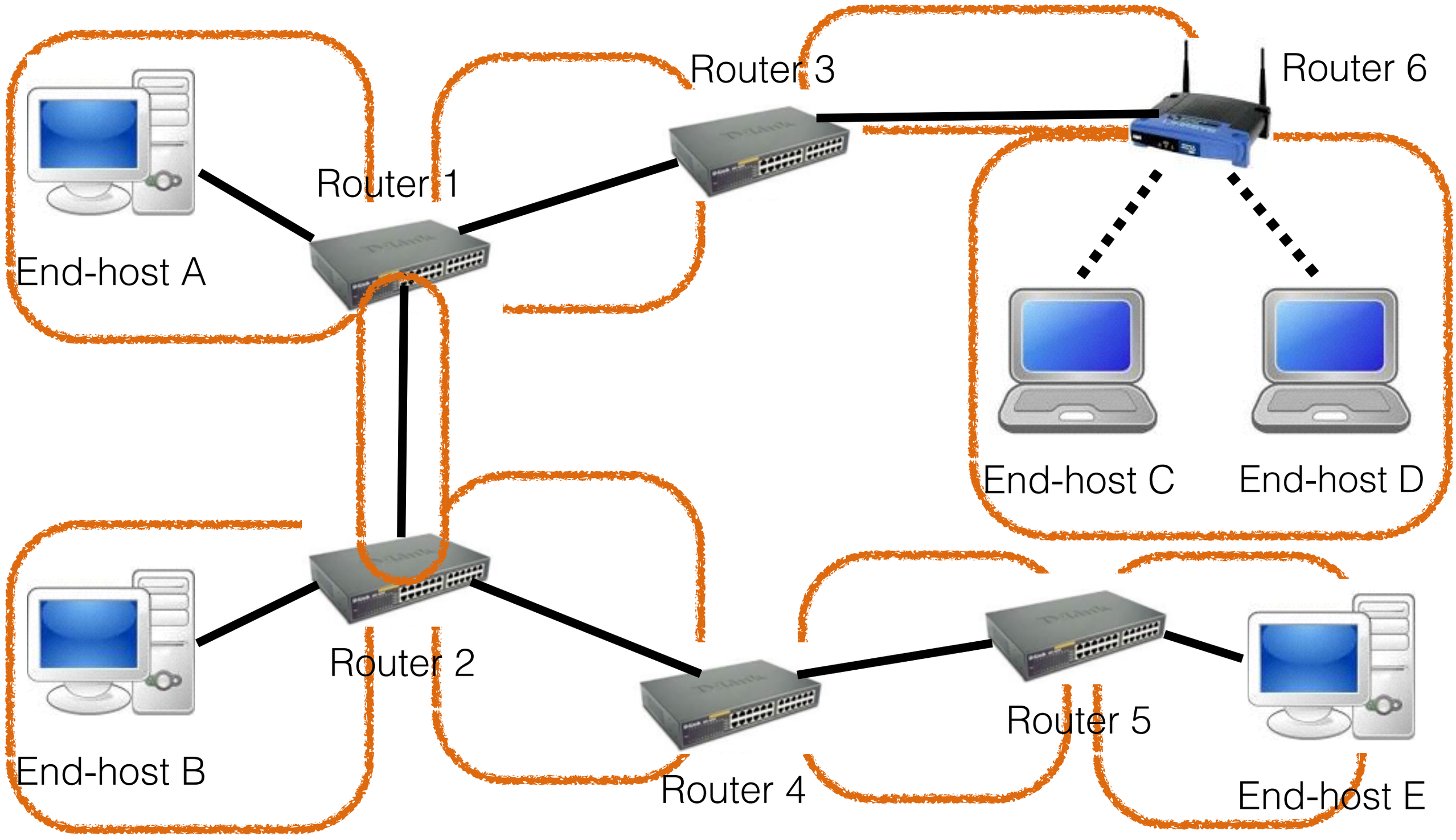

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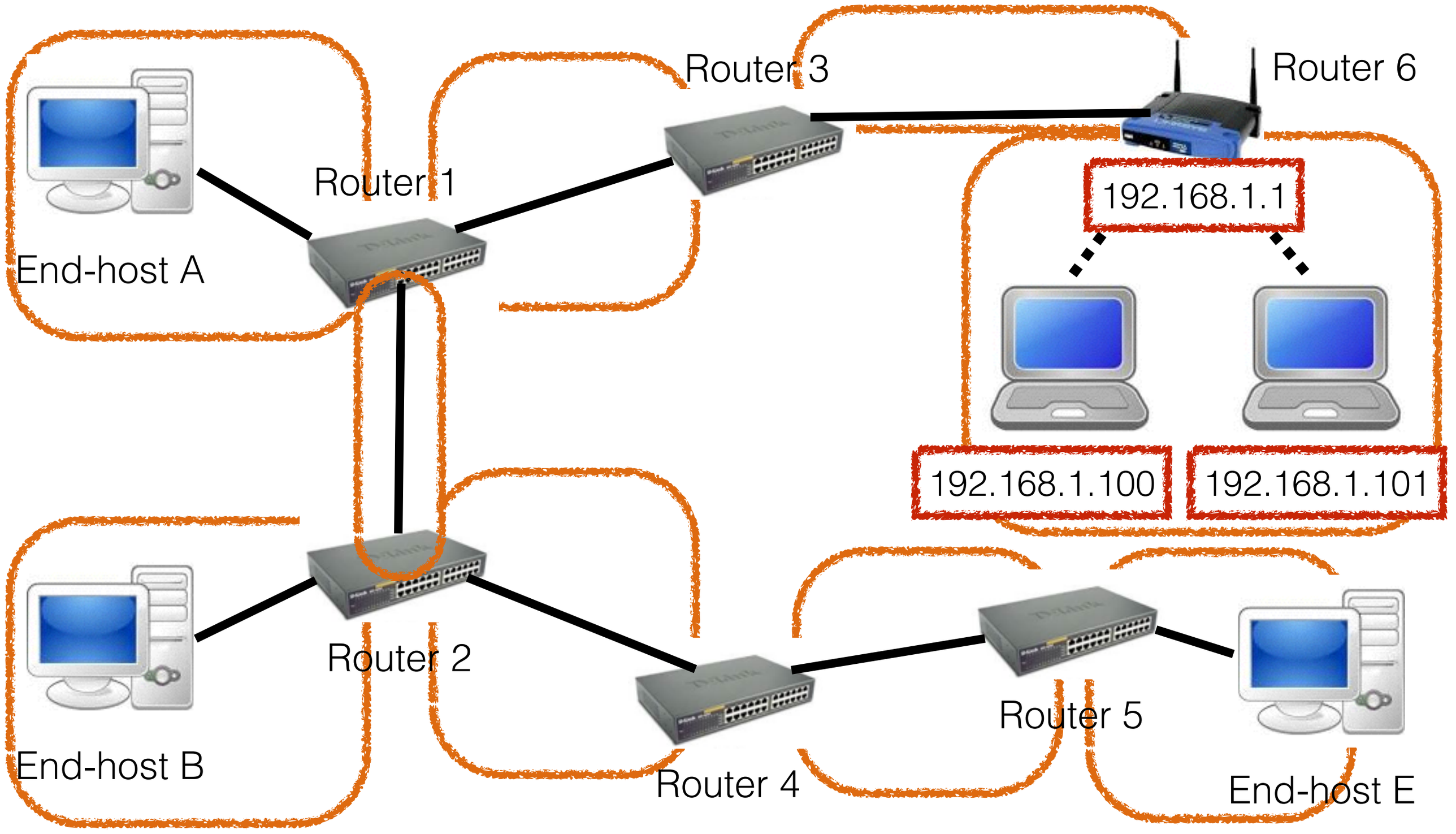

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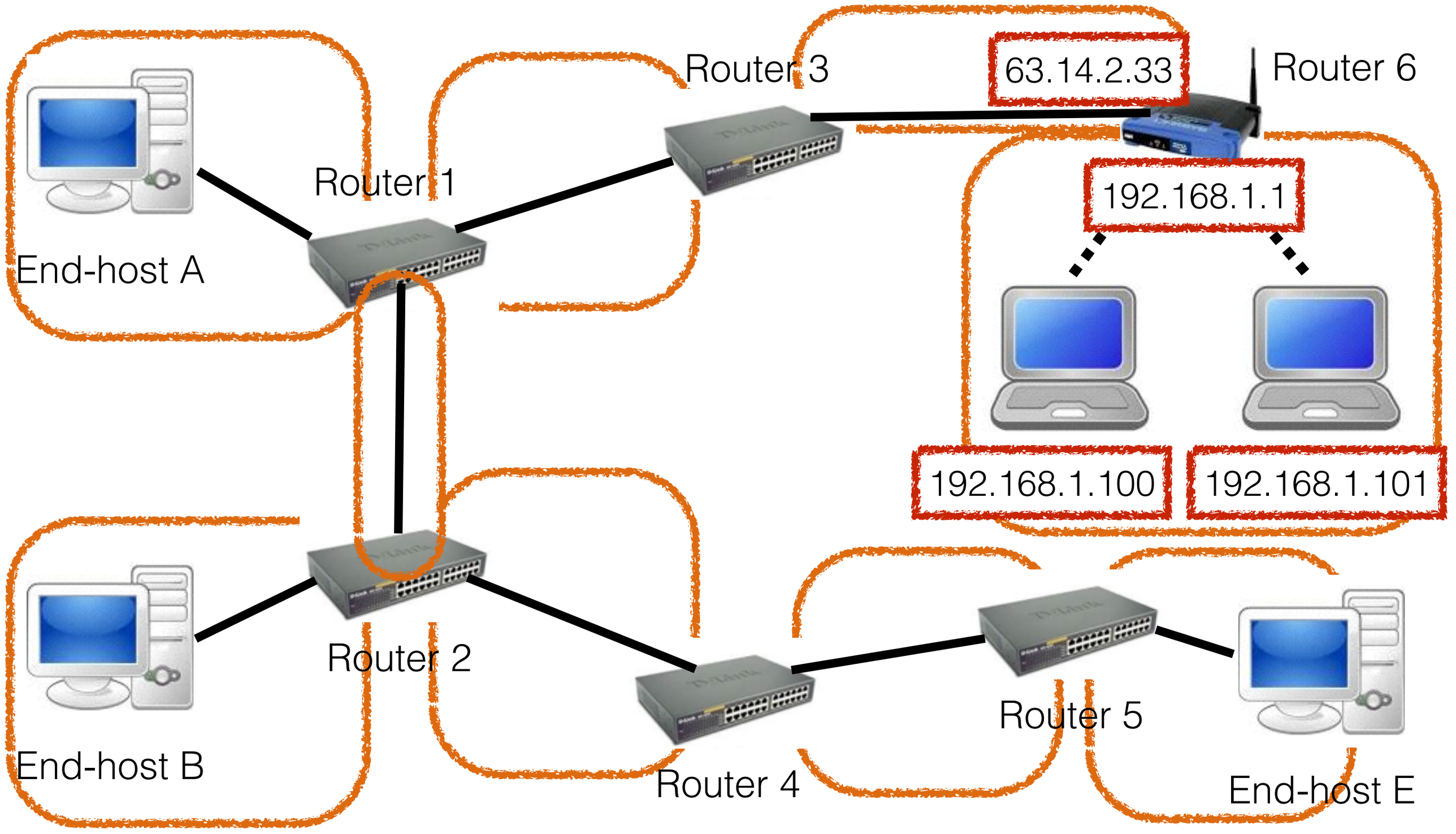
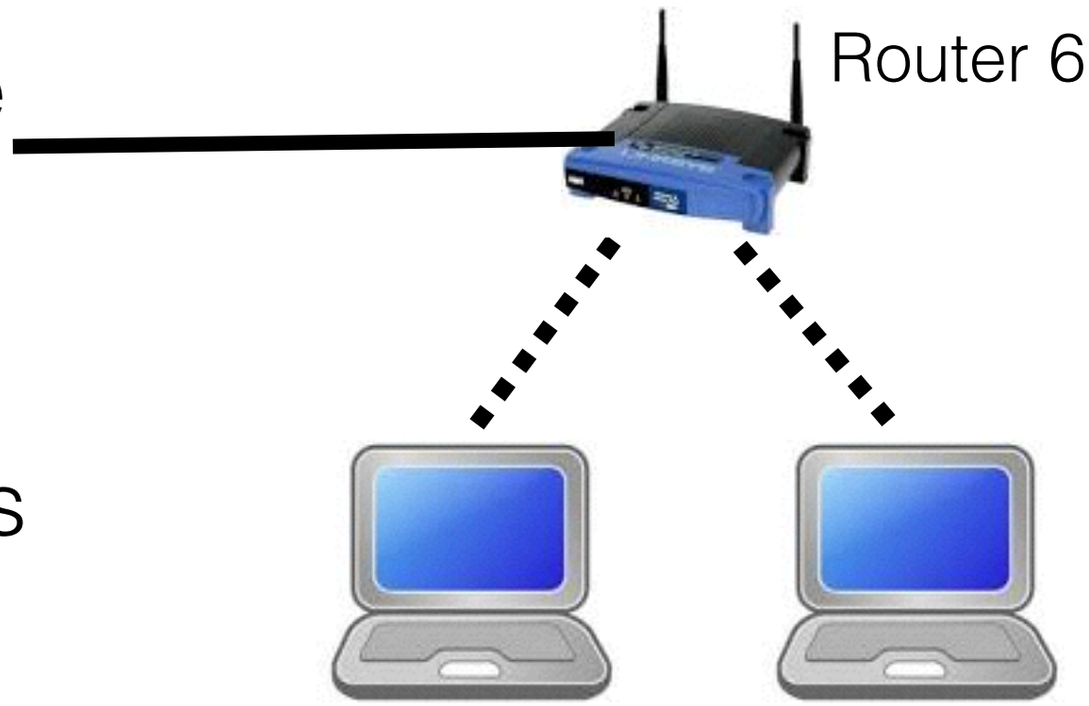


Local uniqueness is often enough

There are only 2^32 IP addrs

Many machines don’t need to be publicly reachable

Some addresses are “private” addresses



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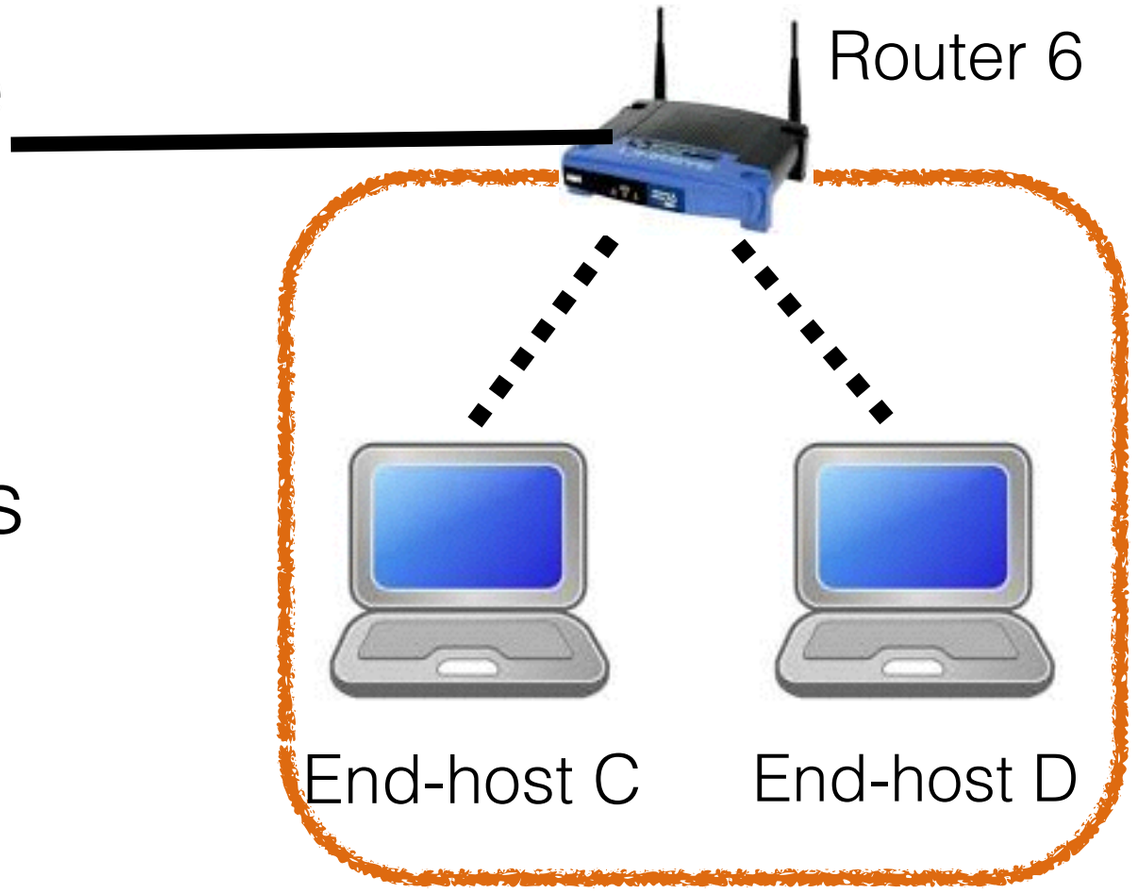

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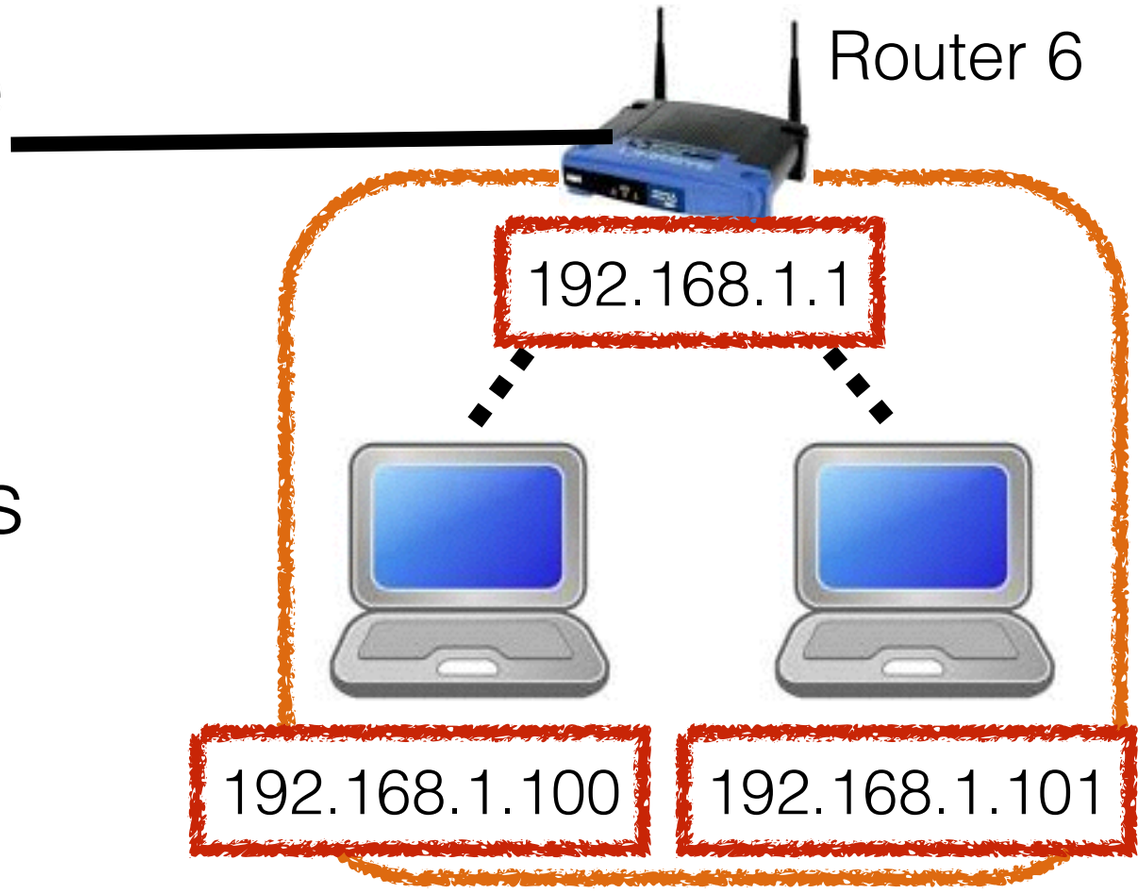

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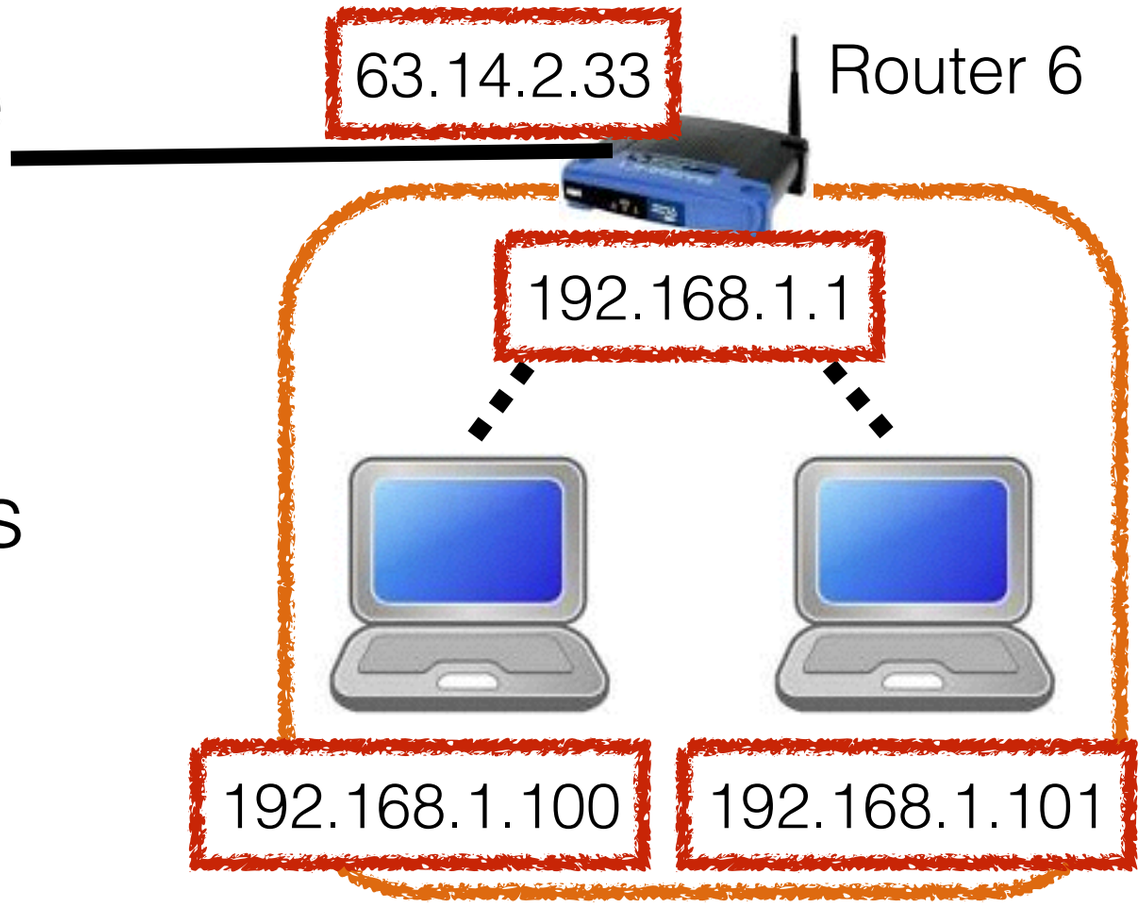

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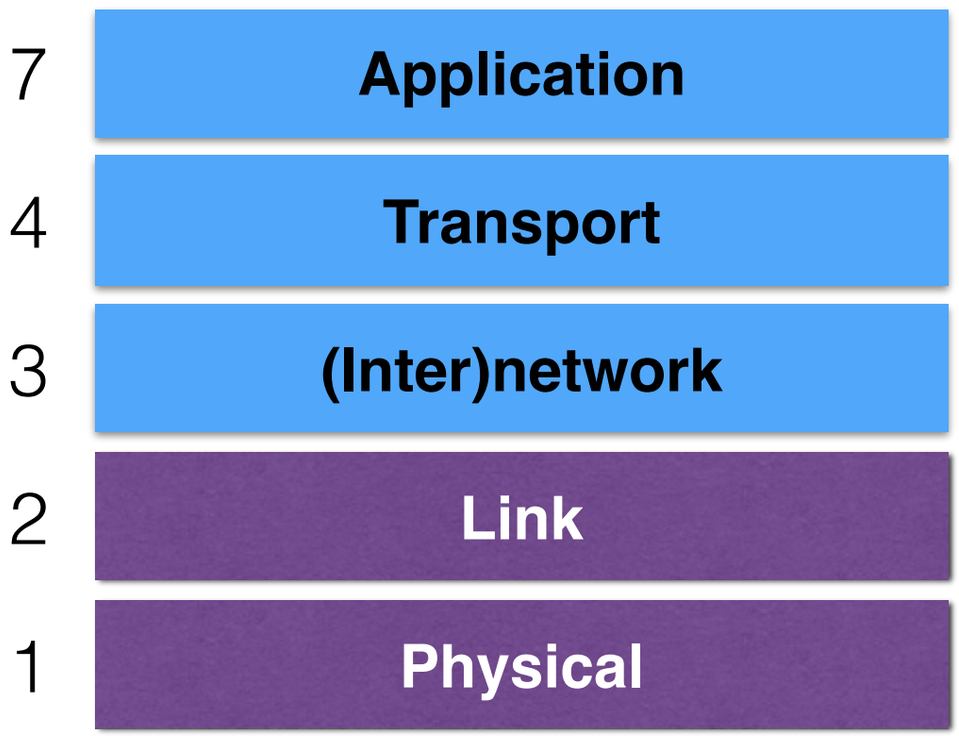
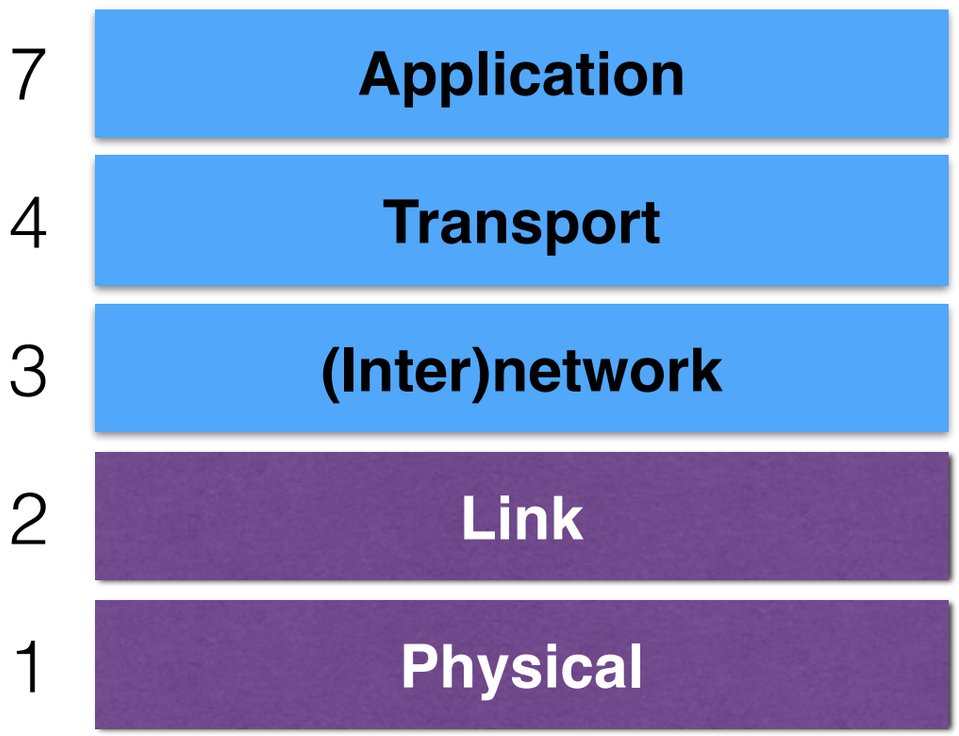
Layer 4: Transport layer



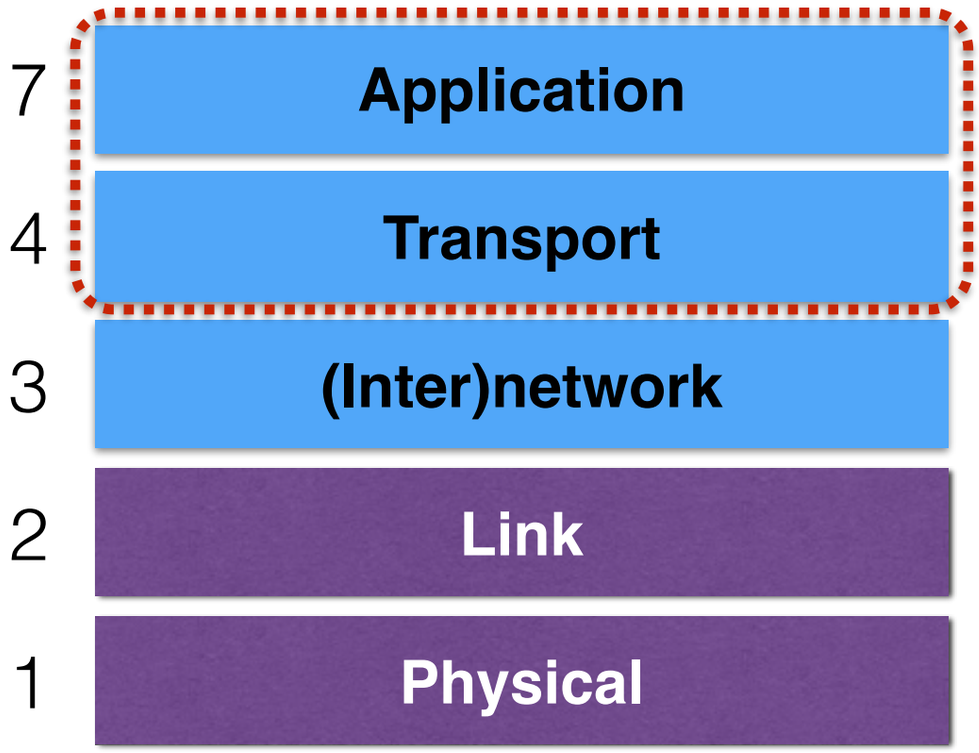
- End-to-end communication between **processes**
- Different types of services provided:
  - UDP: unreliable *datagrams*
  - TCP: *reliable* byte stream
- "Reliable" = keeps track of what data were received properly and retransmits as necessary

Layer 7: Application layer



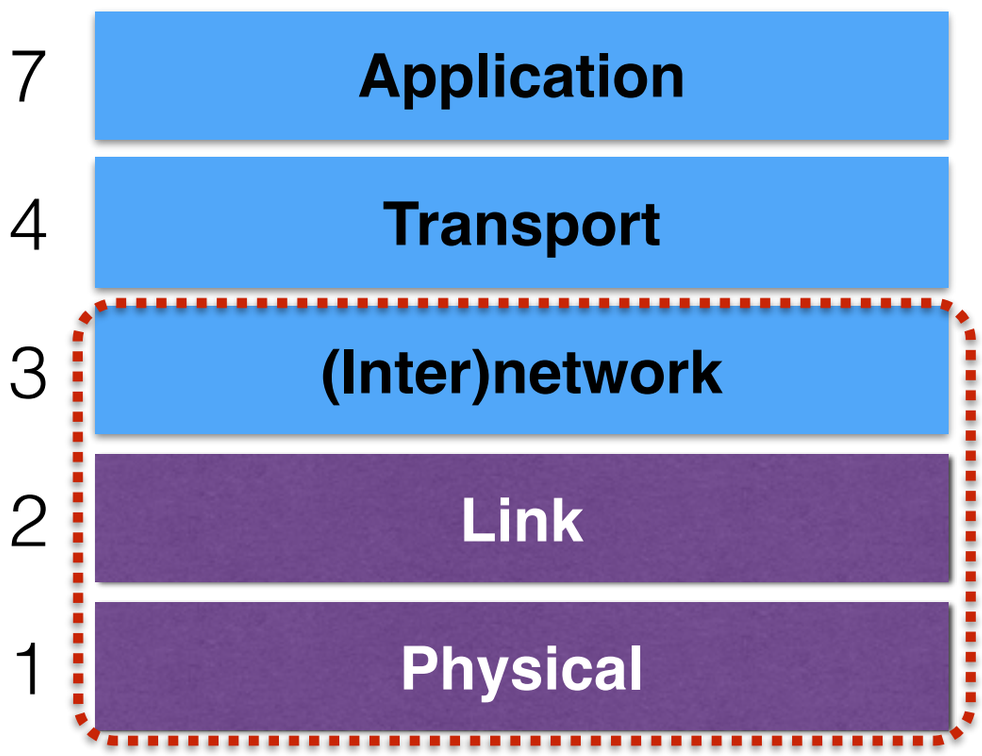
- Communication of whatever you want
- Can use whatever transport(s) is(are) convenient/appropriate
- Freely structured
- Examples:
  - Skype (UDP)
  - SMTP = email (TCP)
  - HTTP = web (TCP)
  - Online games (TCP and/or UDP)

Internet layering = “Protocol stack”



Implemented only at end hosts, not at interior routers (this is our “dumb network”)

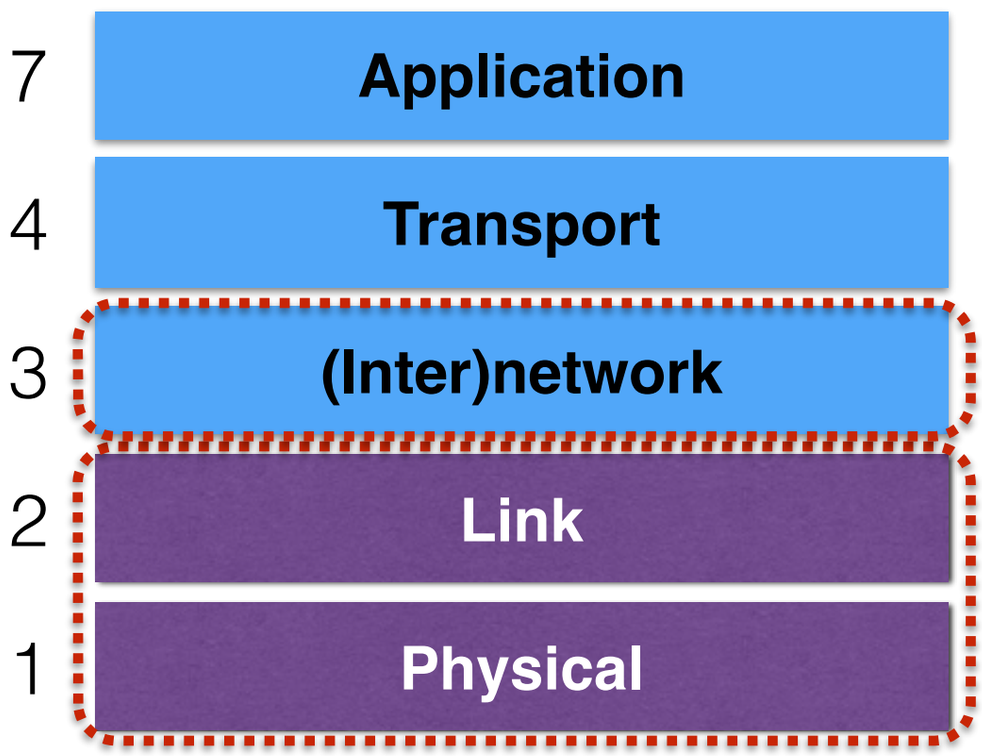
Internet layering = “Protocol stack”



Implemented *everywhere*

The network is “dumb” but it needs to know precisely this much to do its job.

Internet layering = “Protocol stack”

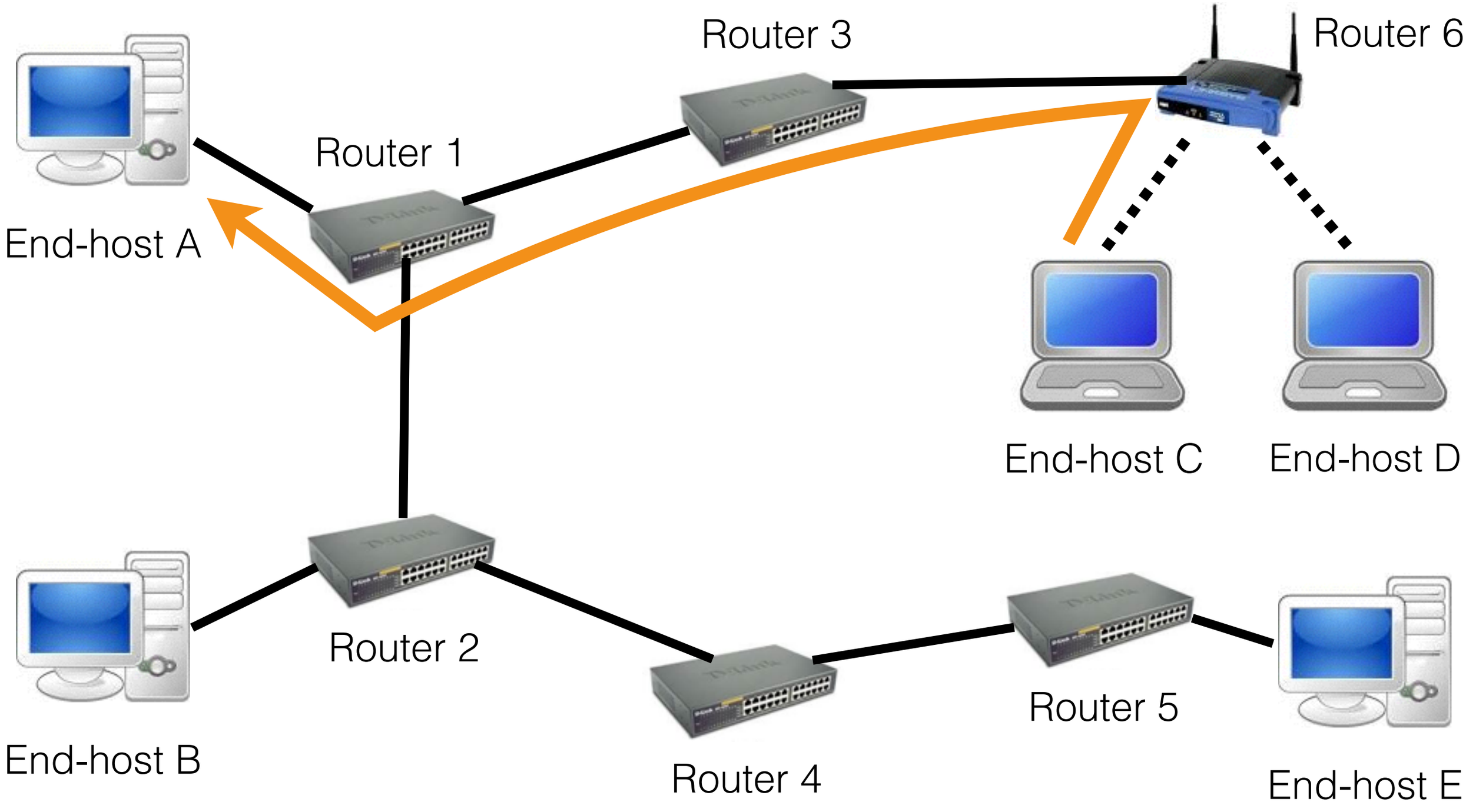


~Same for each Internet “hop”

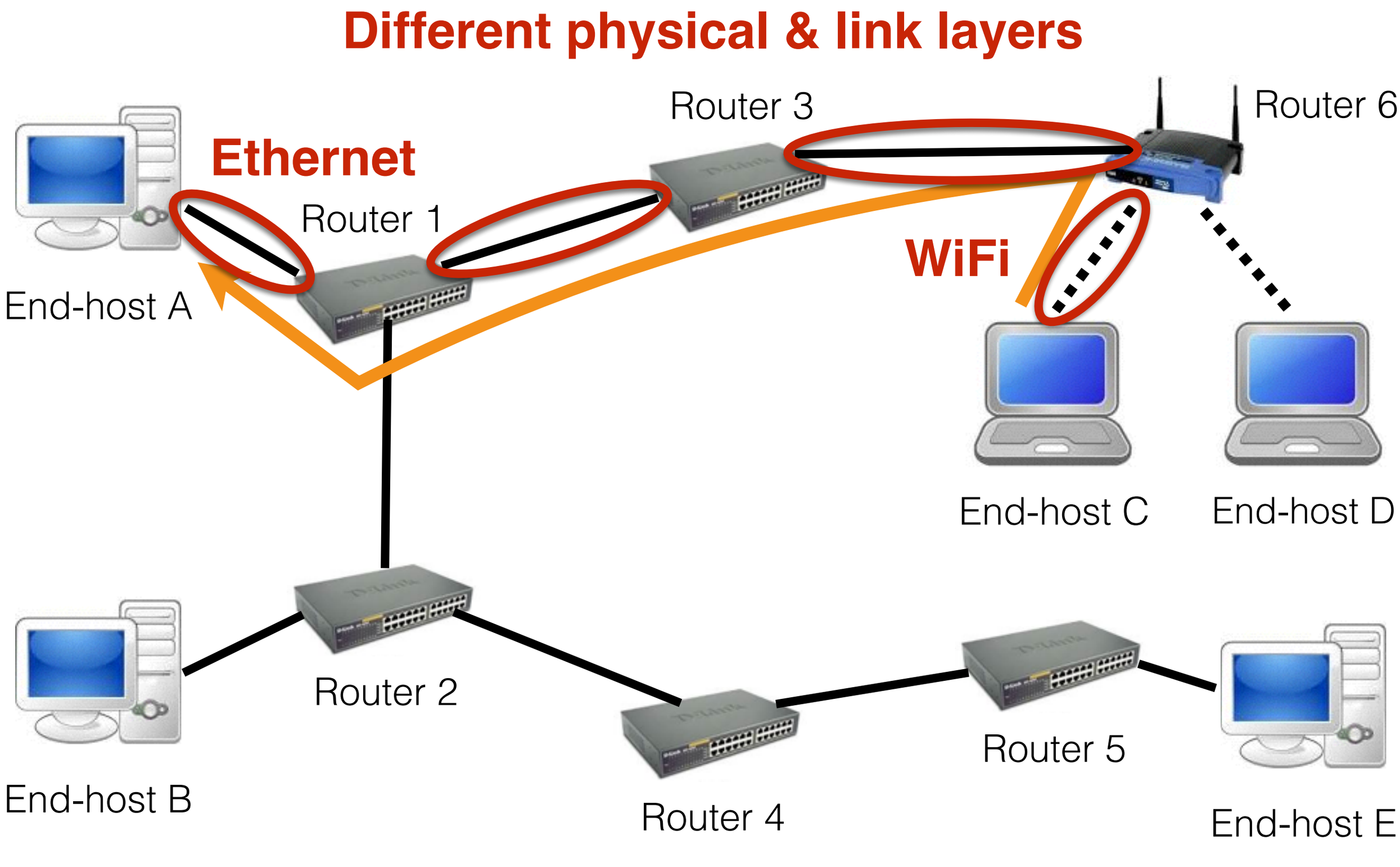
Can be different for each Internet “hop”

Hop-by-hop vs. end-to-end layers

Host C communicates with host A



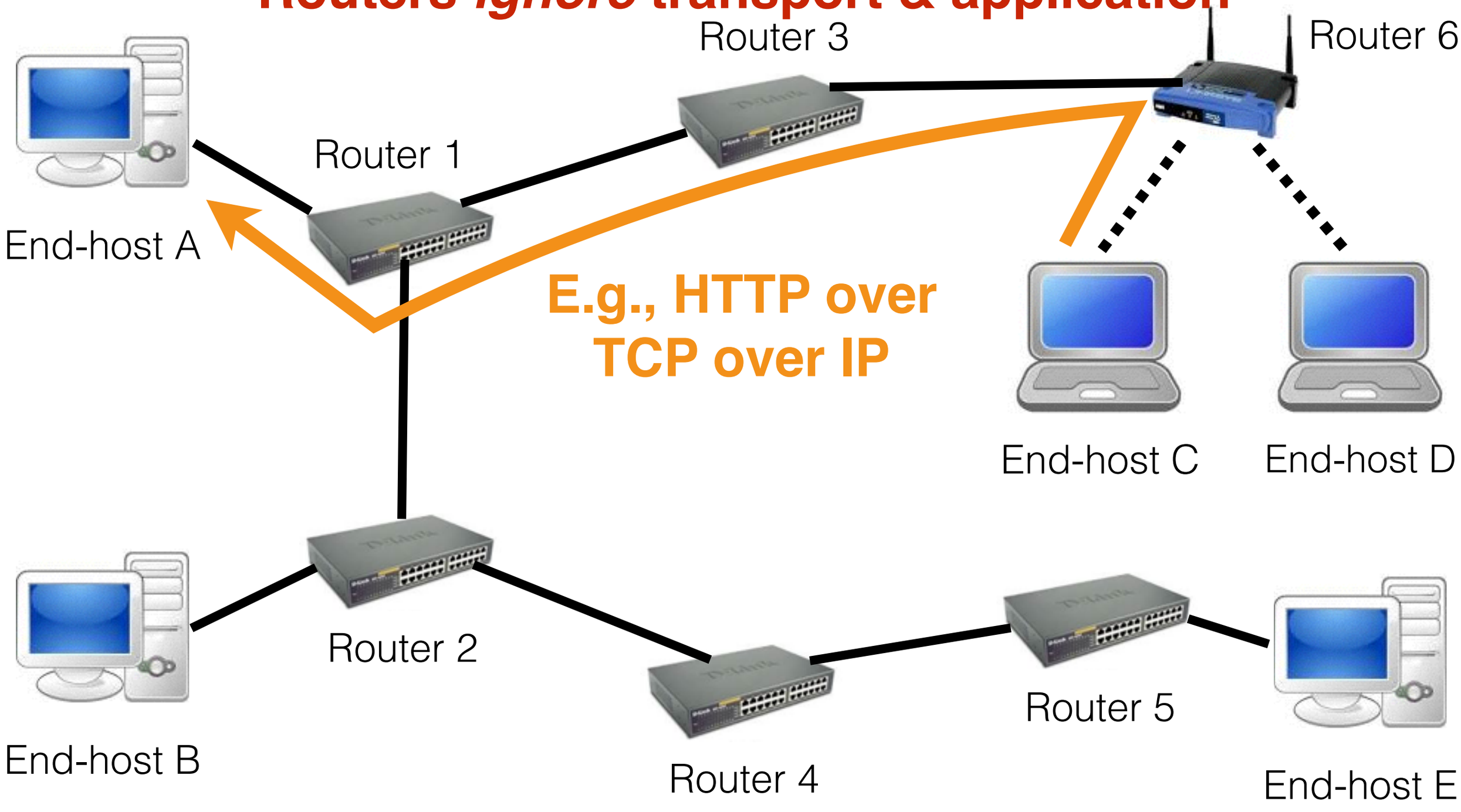
Hop-by-hop vs. end-to-end layers



Hop-by-hop vs. end-to-end layers

Same network, transport, and application layers (3/4/7)

Routers *ignore* transport & application



Next time

- You now know the overall design:
  - What each layer is responsible for
  - What the predominant protocols are at each layer

- The overall design principles have been absolutely critical to making an Internet that can evolve with changing needs… for the most part

- But the devil's in the details

- We will dig into specific protocols to understand the kinds of attacks that can happen at the networking layer and how to protect against them