Sharing & Evaluating Networks

CPSC 433/533, Spring 2021

Anurag Khandelwal

Administrivia

- I hope by now, you have:
  - **All:** Checked Canvas for all the course policies and administrivia
  - **CPSC 533:** Found resources on how to read/critique papers

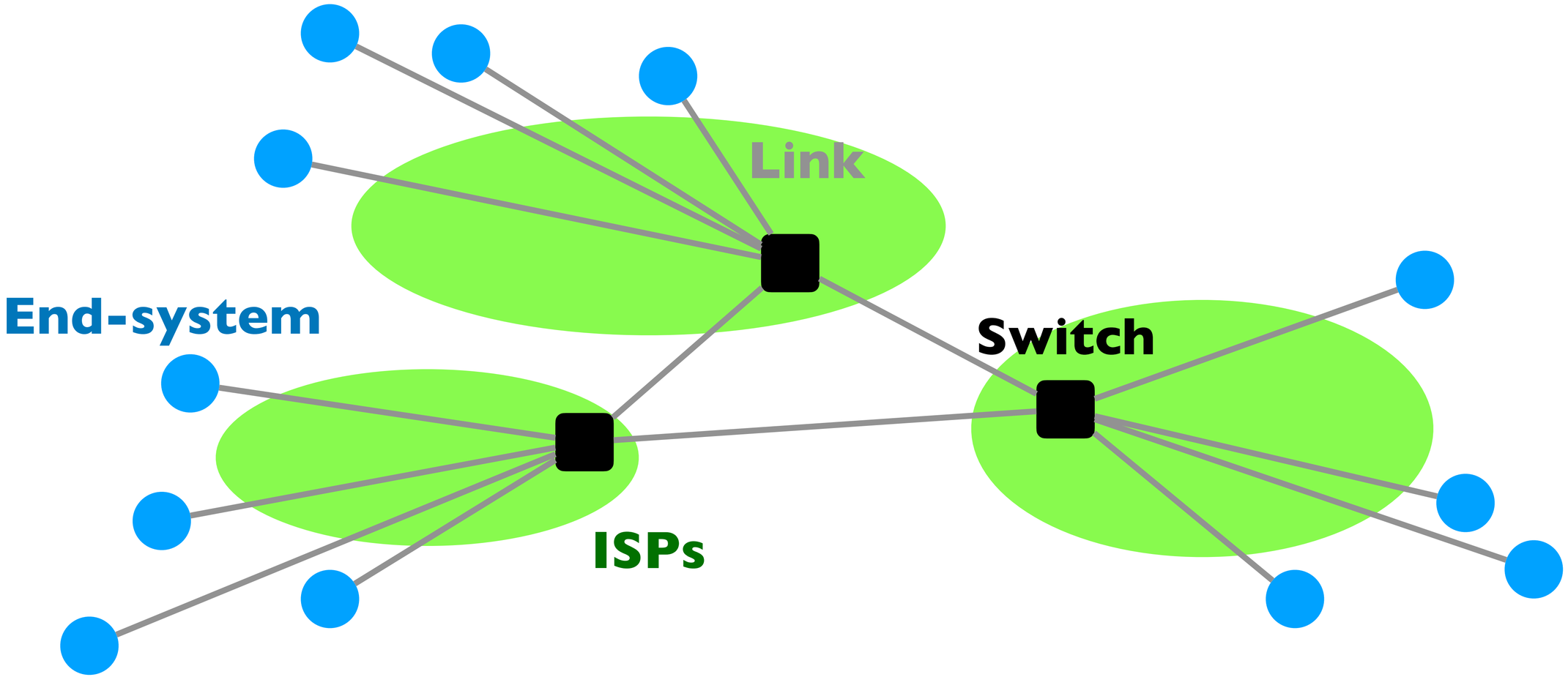
Today's Agenda

- More details on What & How of the Internet
- Sharing a network
- Evaluating a network

Today's Agenda

- More details on What, How and Why of the Internet
- Sharing a network
- Evaluating a network

The What



Digging Deeper into the “What”

The Last Mile

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The Last Mile

Edge Networks: The Last Mile

Telephony Access Technology

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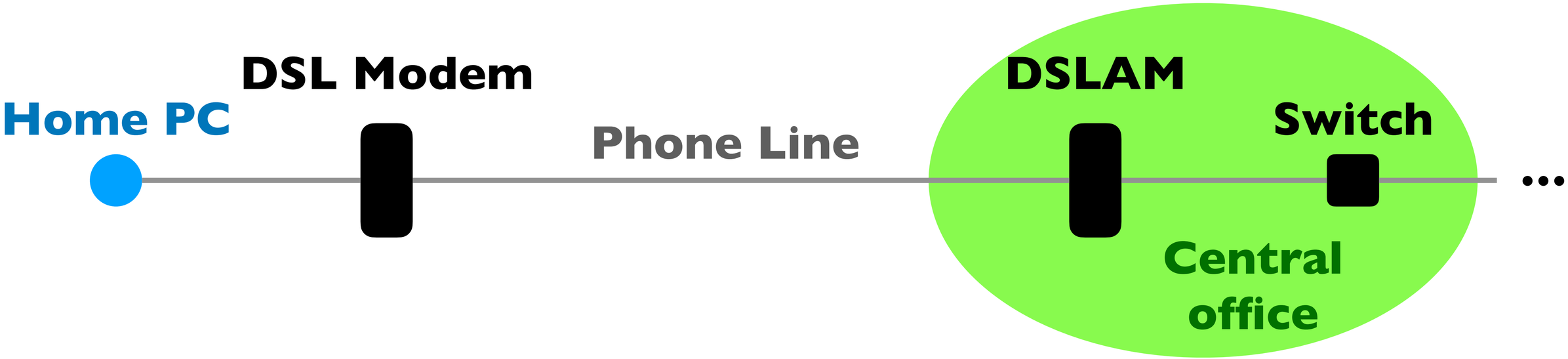

Edge Networks: The Last Mile

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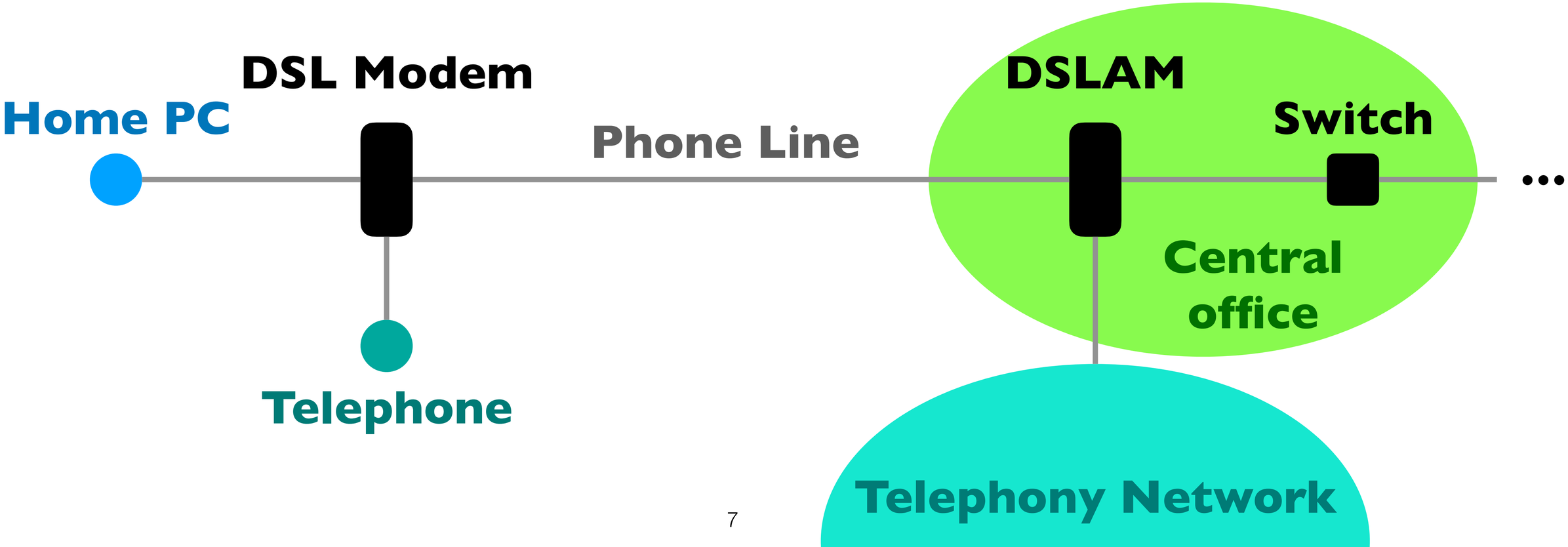
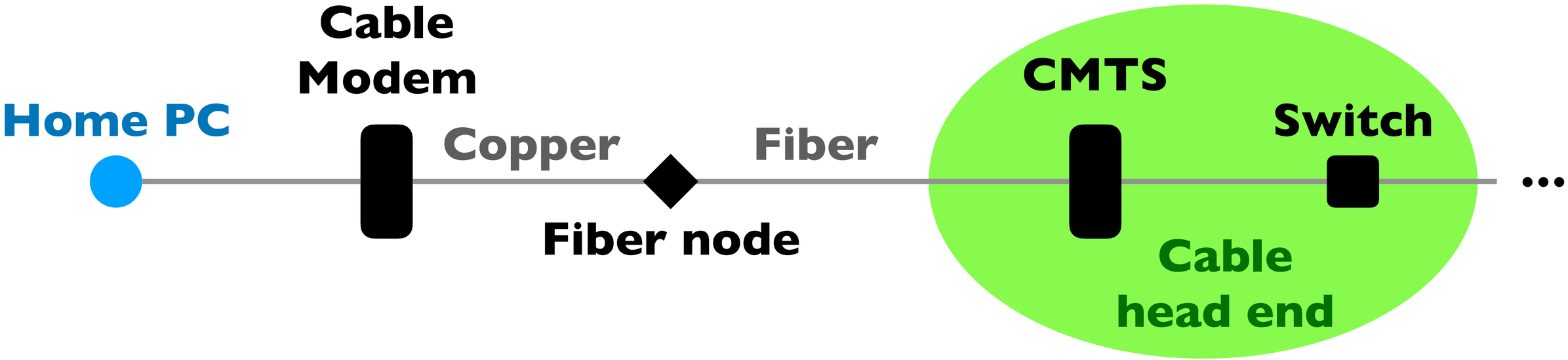


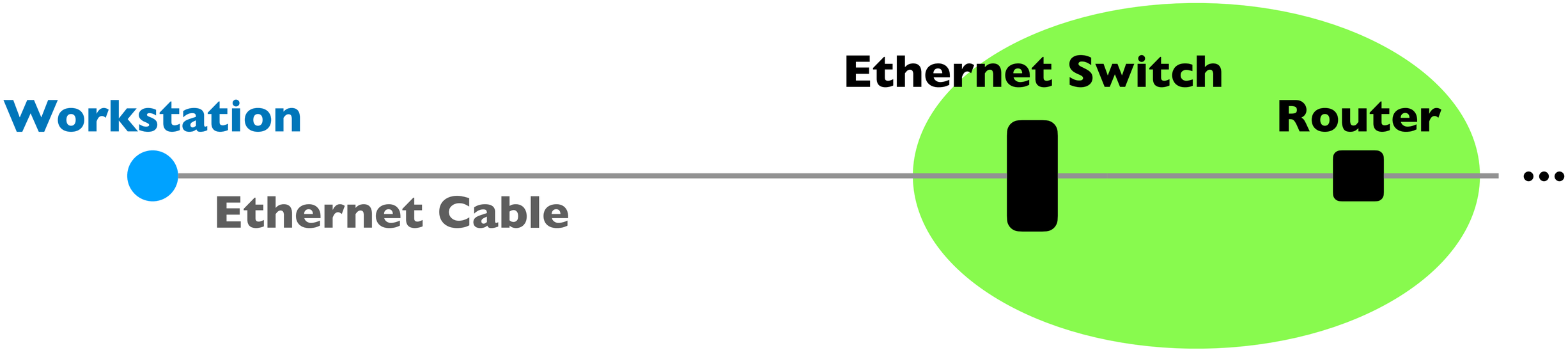
Edge Networks: The Last Mile

Cable Access Technology



Edge Networks: The Last Mile

Ethernet Access Technology



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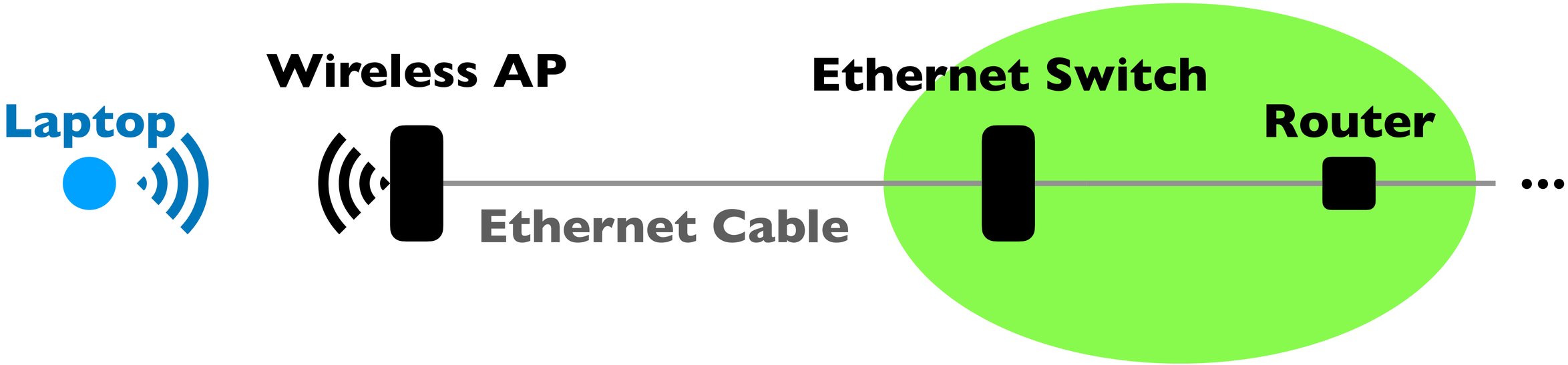
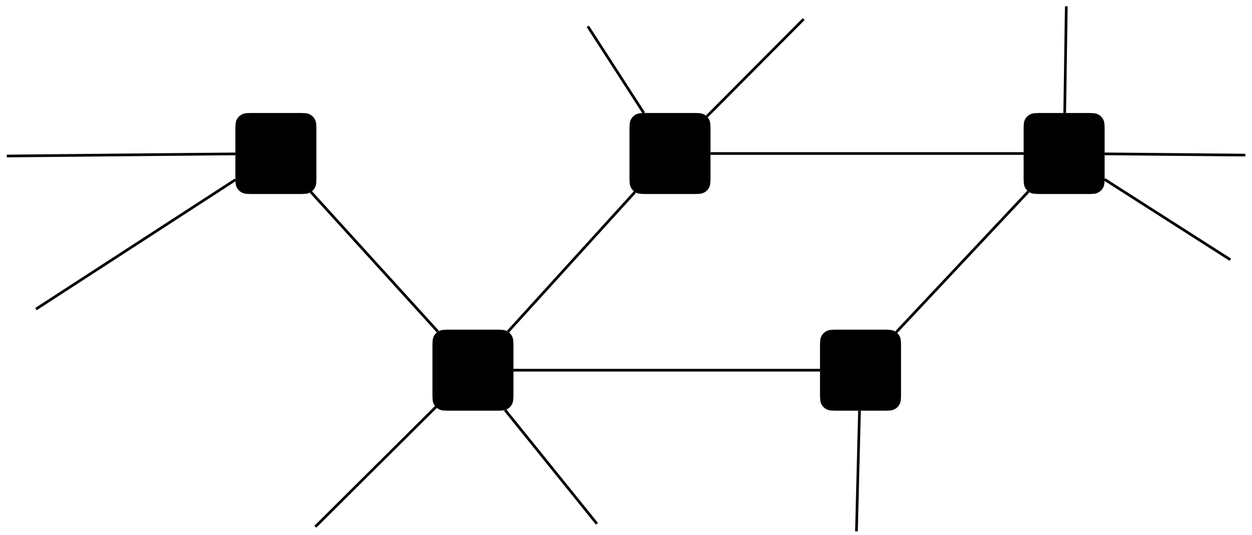
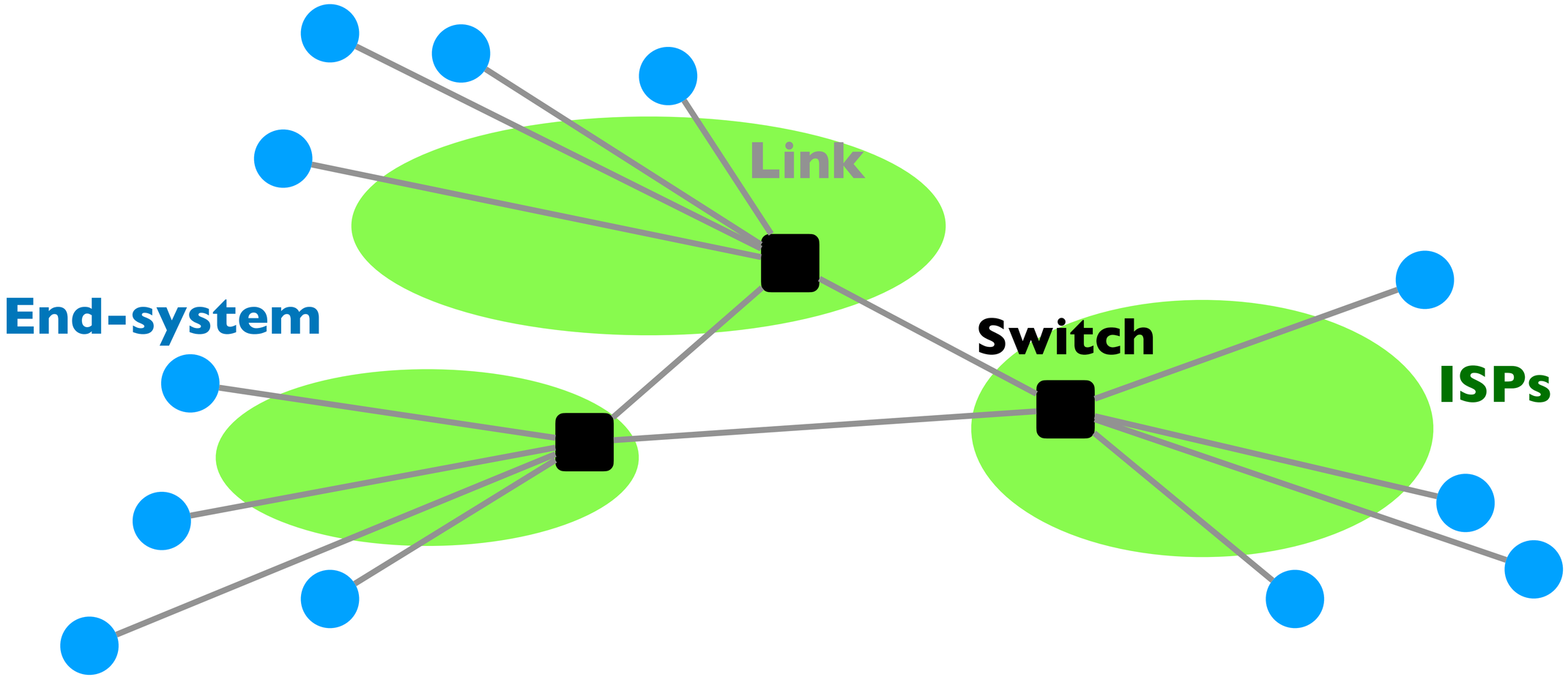


Core Network



Switched networks enable efficient scaling!

The How



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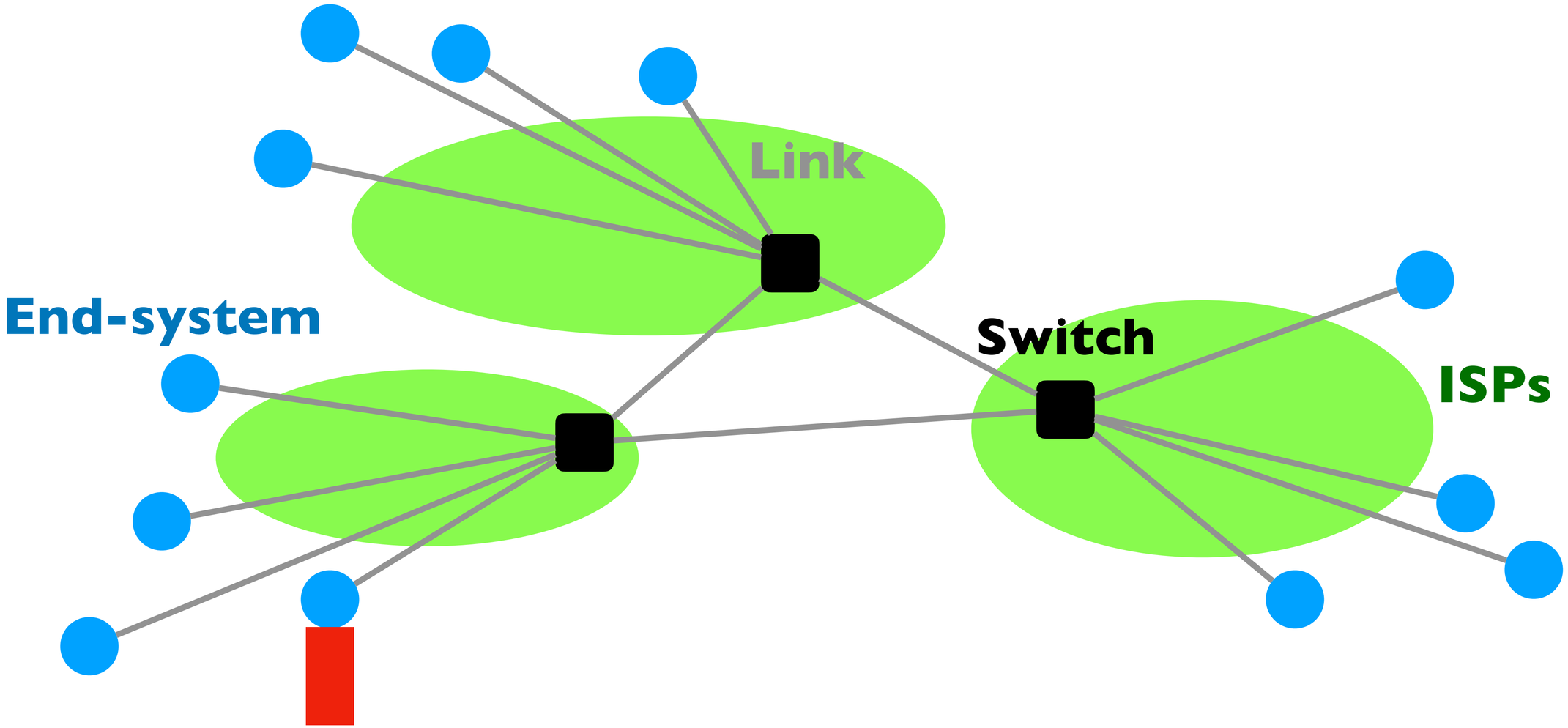

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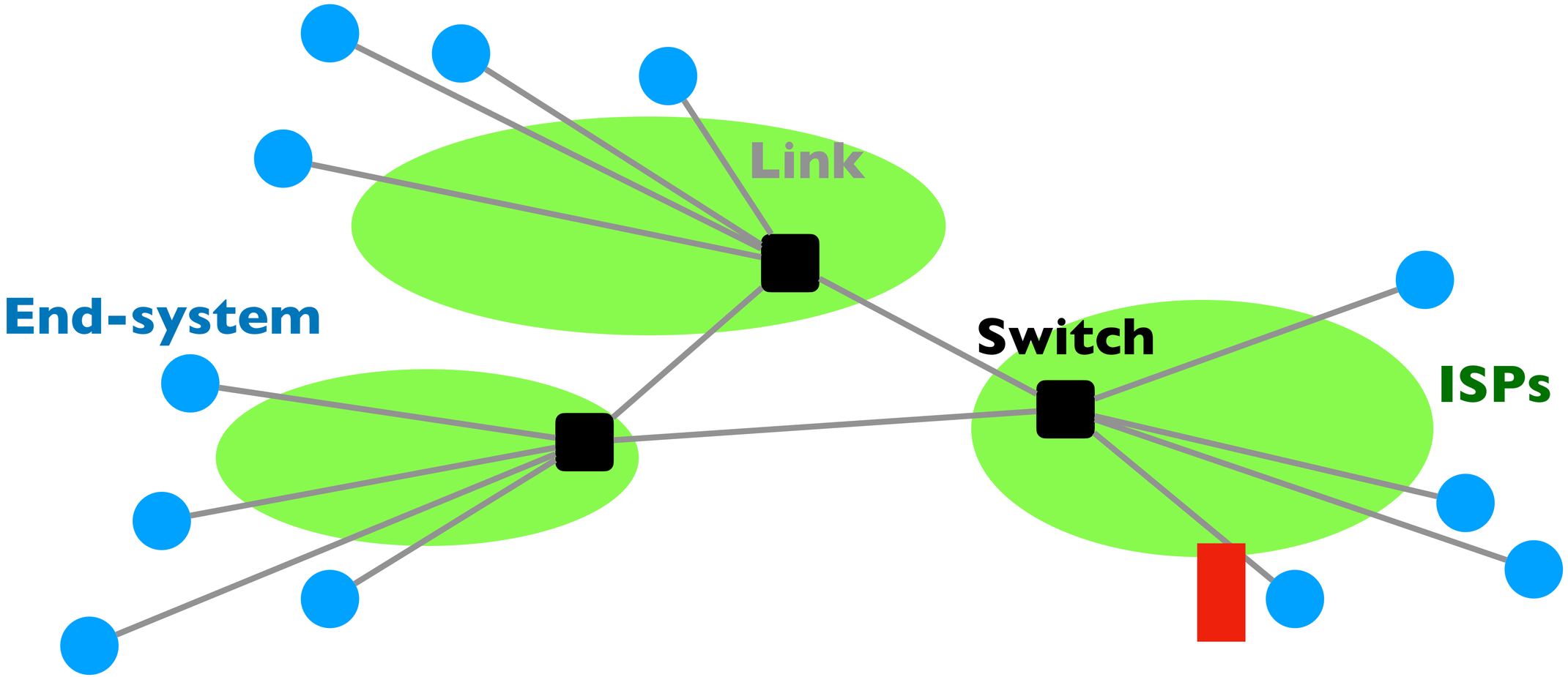

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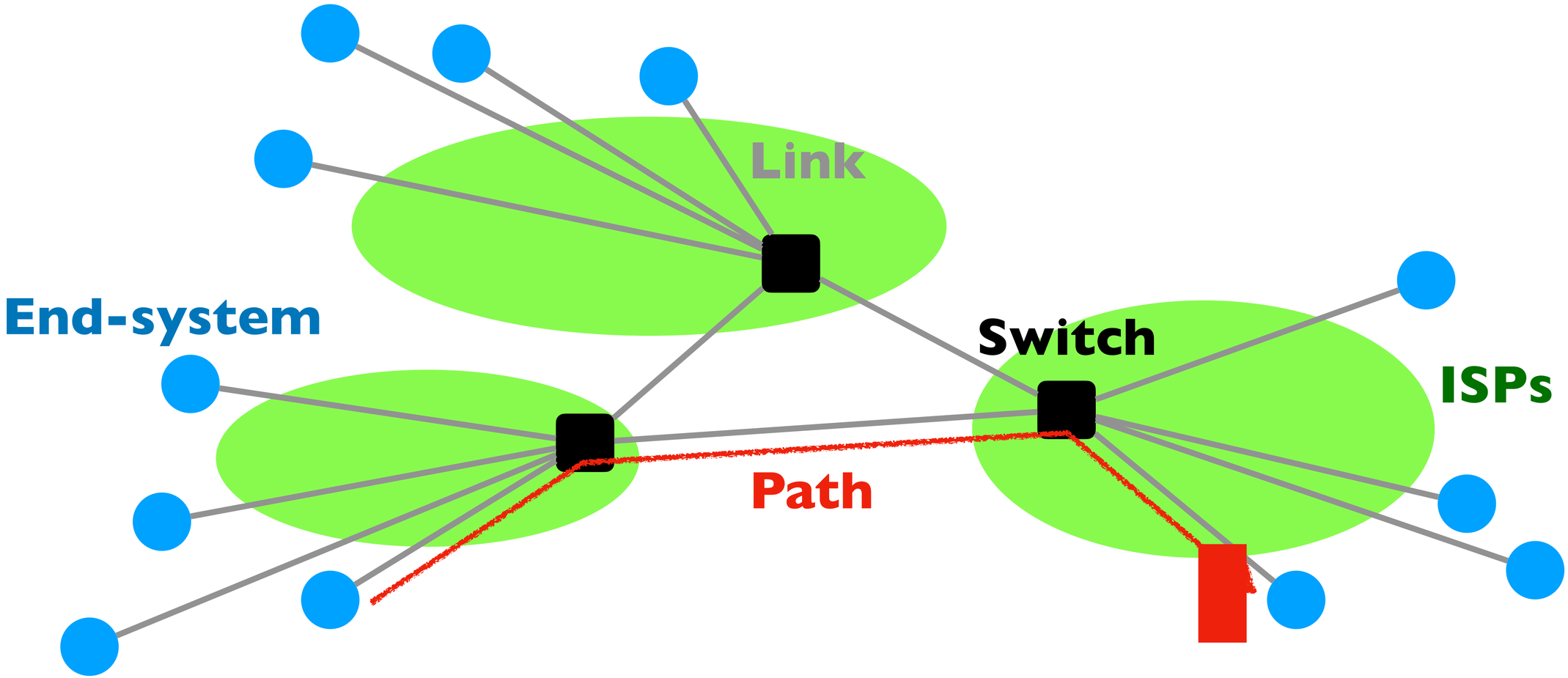

Digging Deeper into the How

- **Locating the destination:** Naming, Addressing
- **Finding a path to the destination:** Routing
- **Sending data to the destination:** Forwarding
- **Handling cases where things go horribly wrong:** Distributed routing, congestion control
- We will spend (almost) the entire course to understand these concepts!

Questions?

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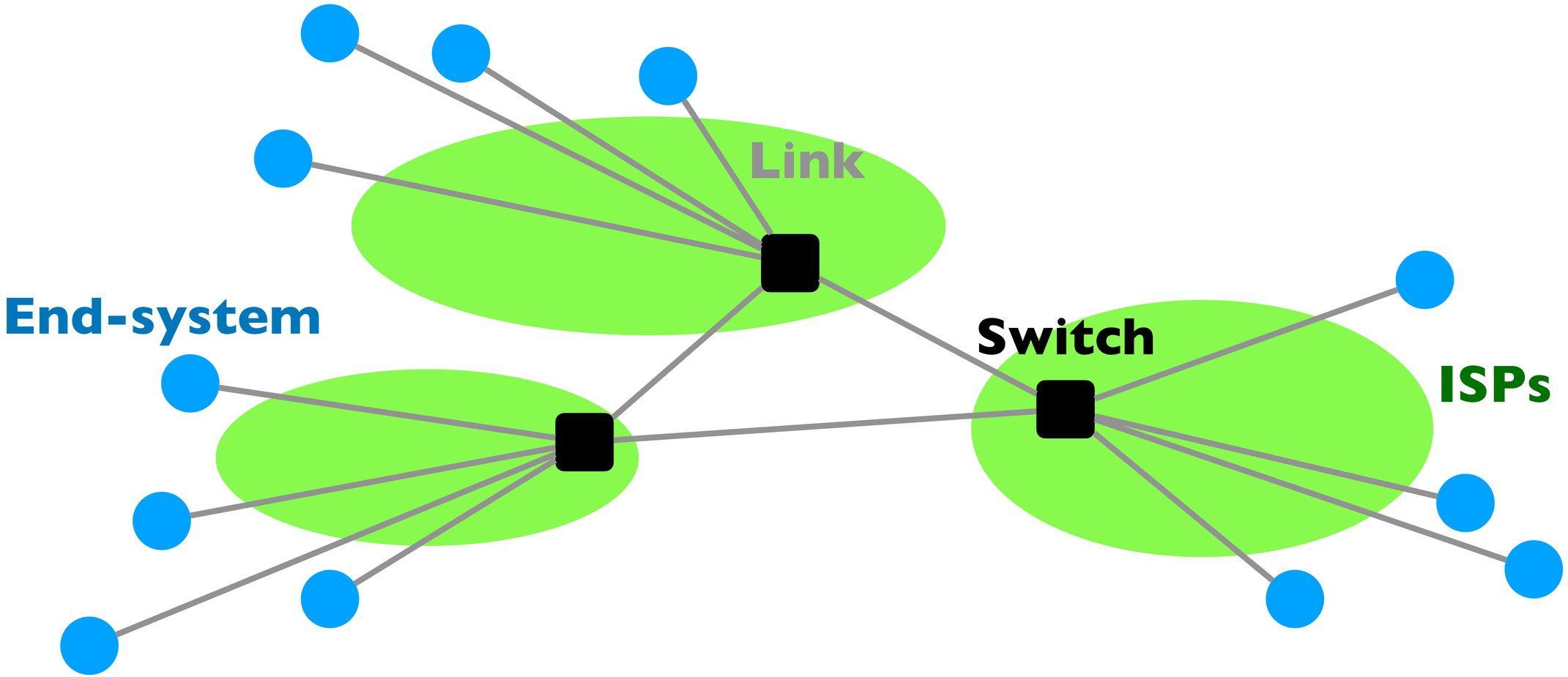
Sharing Network Resources



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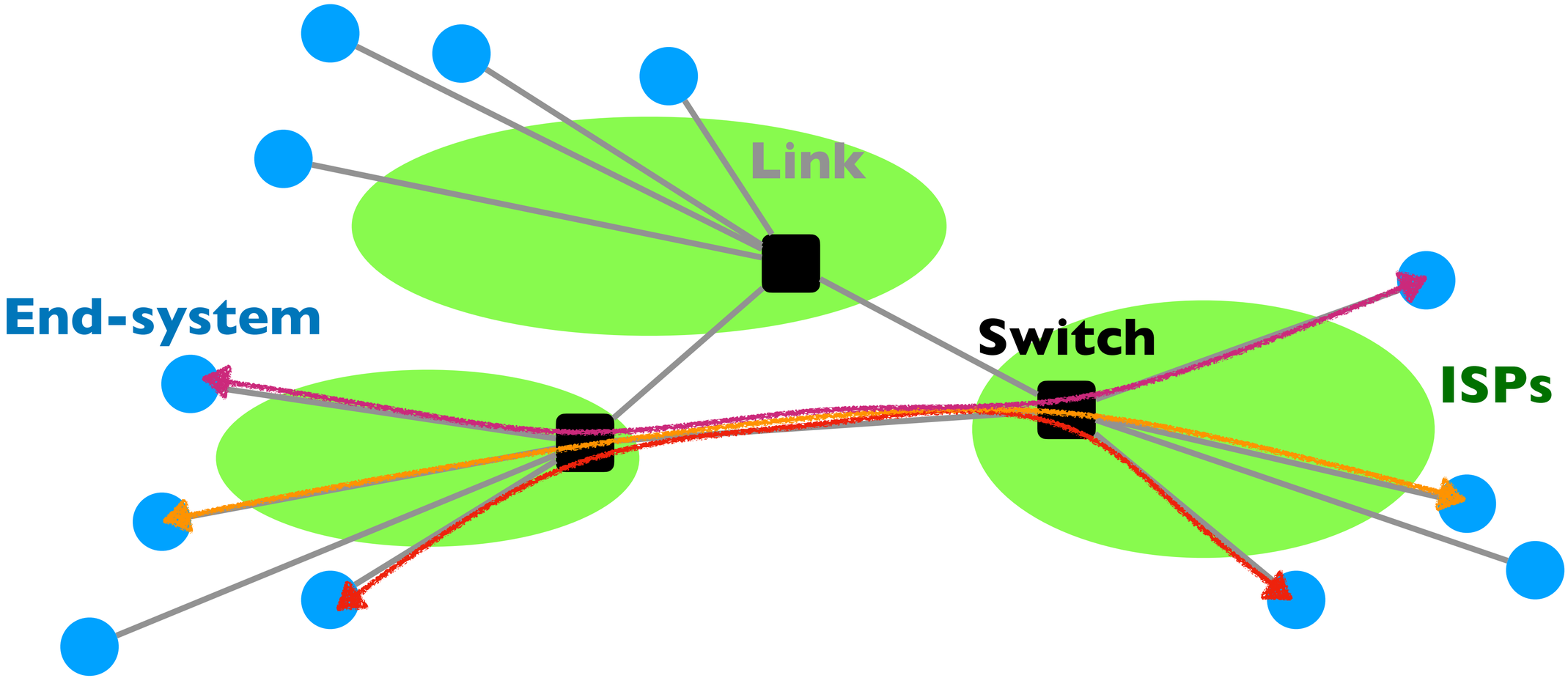

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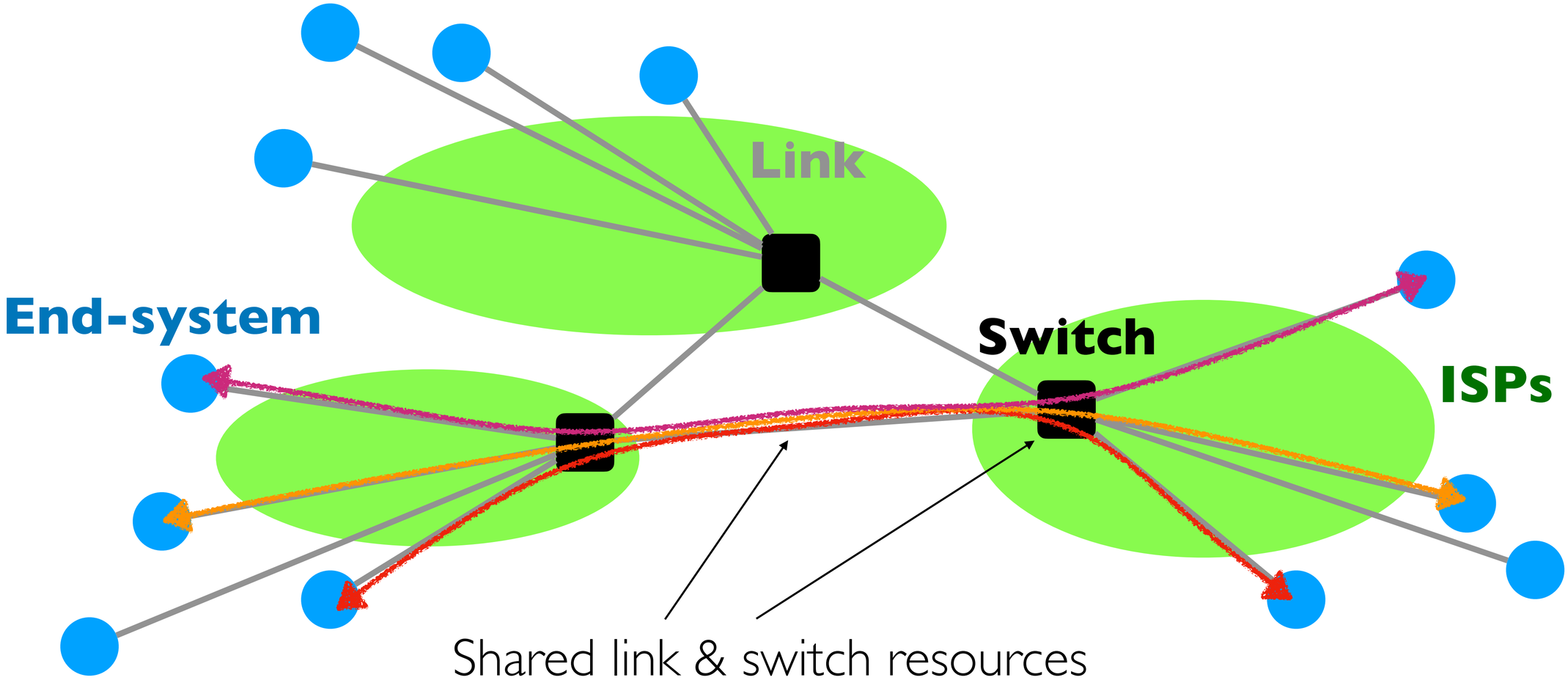

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  - Switch processing resources, link bandwidths
  - **Link:** "Pipe" abstraction
  - **Bandwidth:** Number of bits sent per unit time
  - **Network traffic:** "flows"

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  - Must reserve for peak (e.g., 100MB/s)

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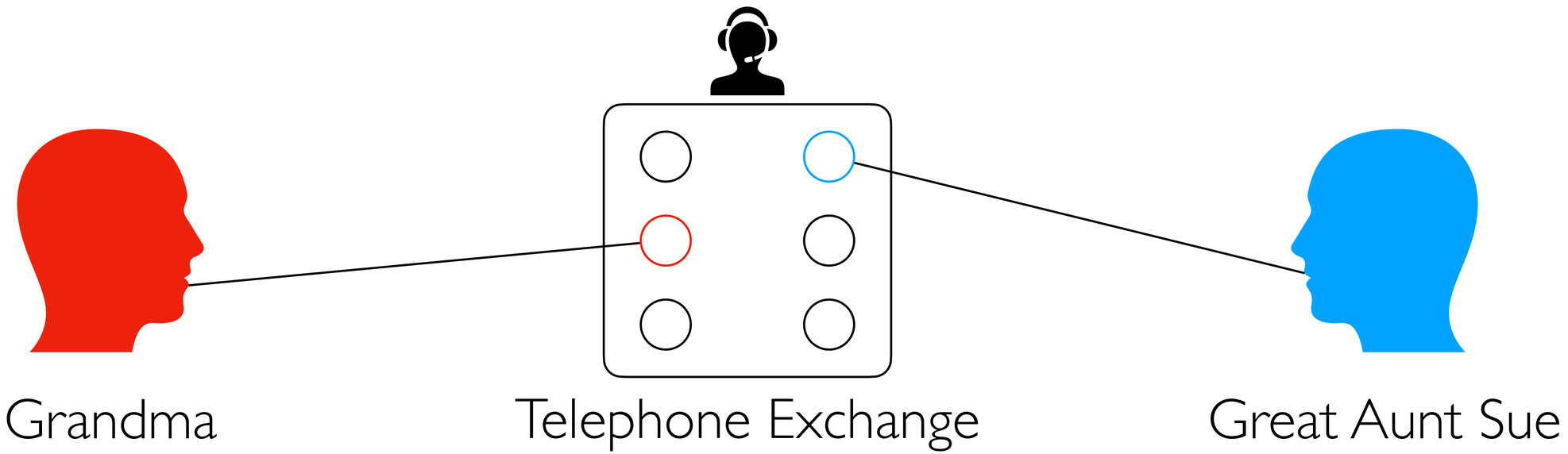

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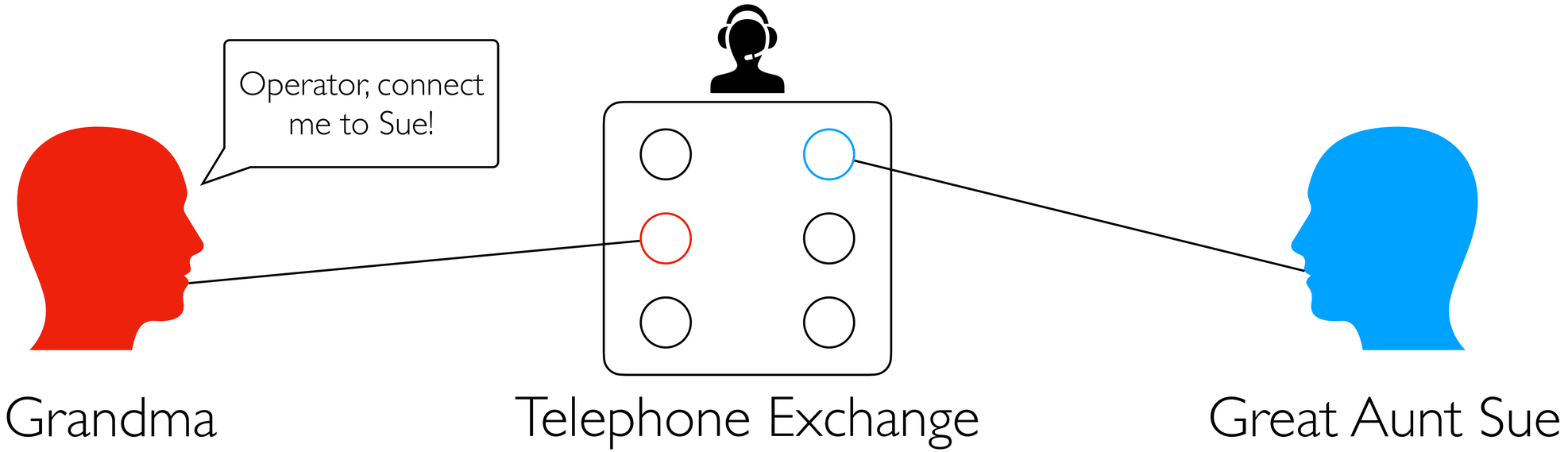

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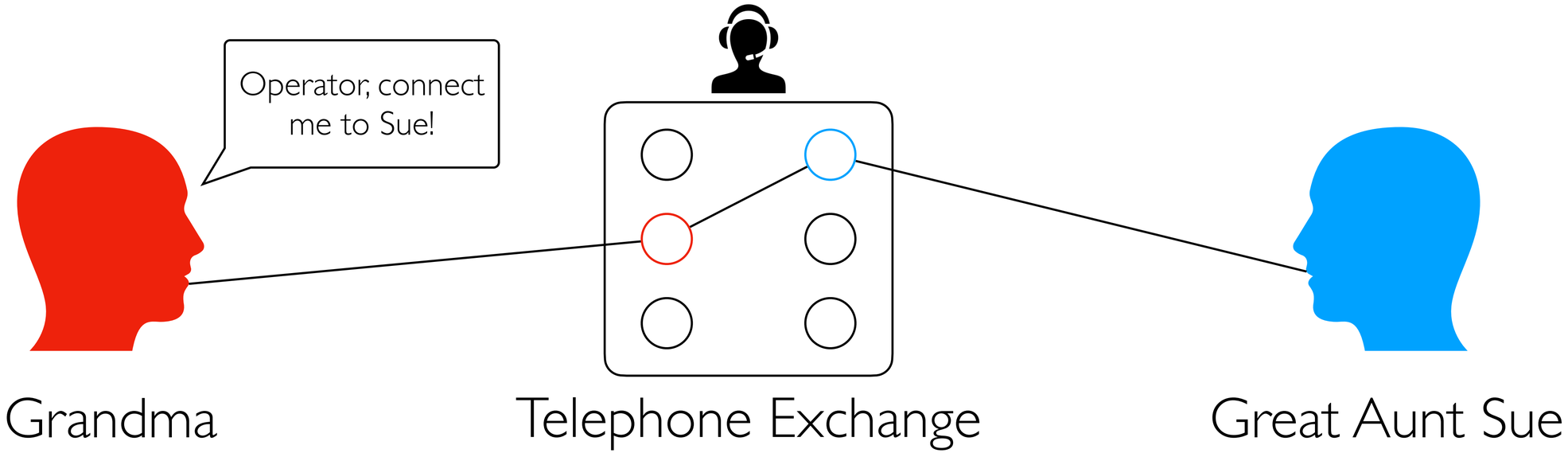

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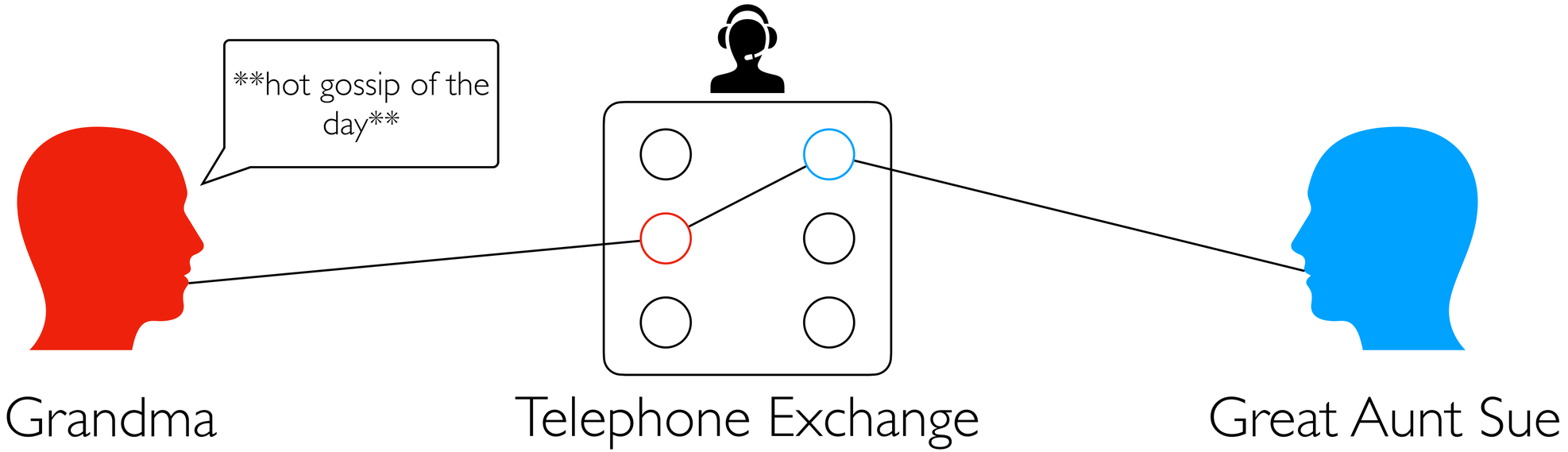

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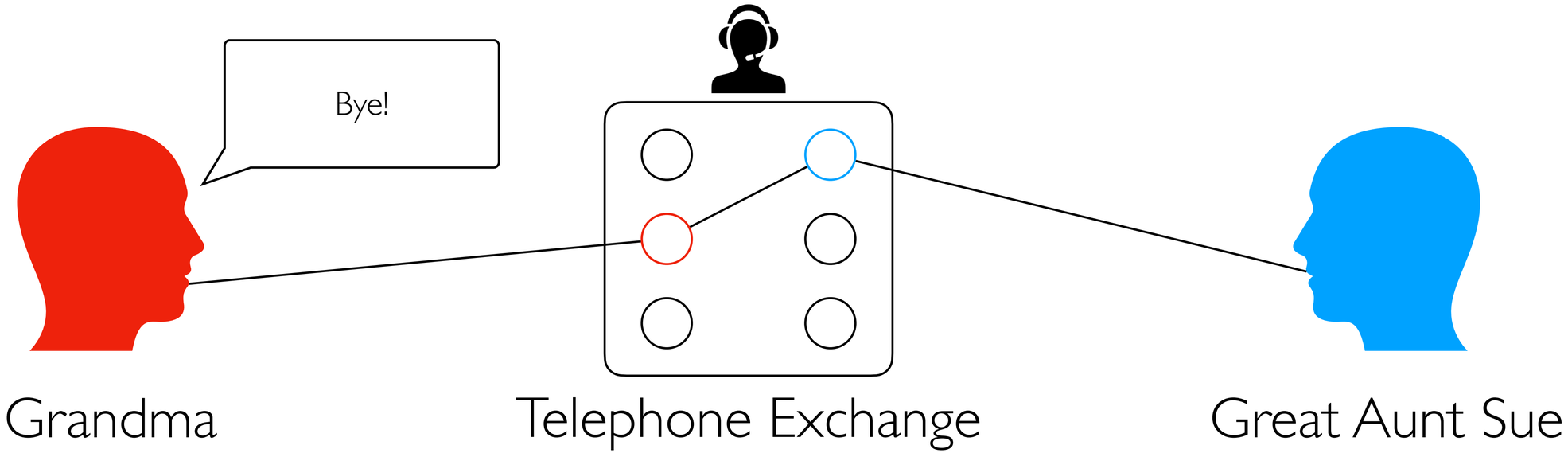

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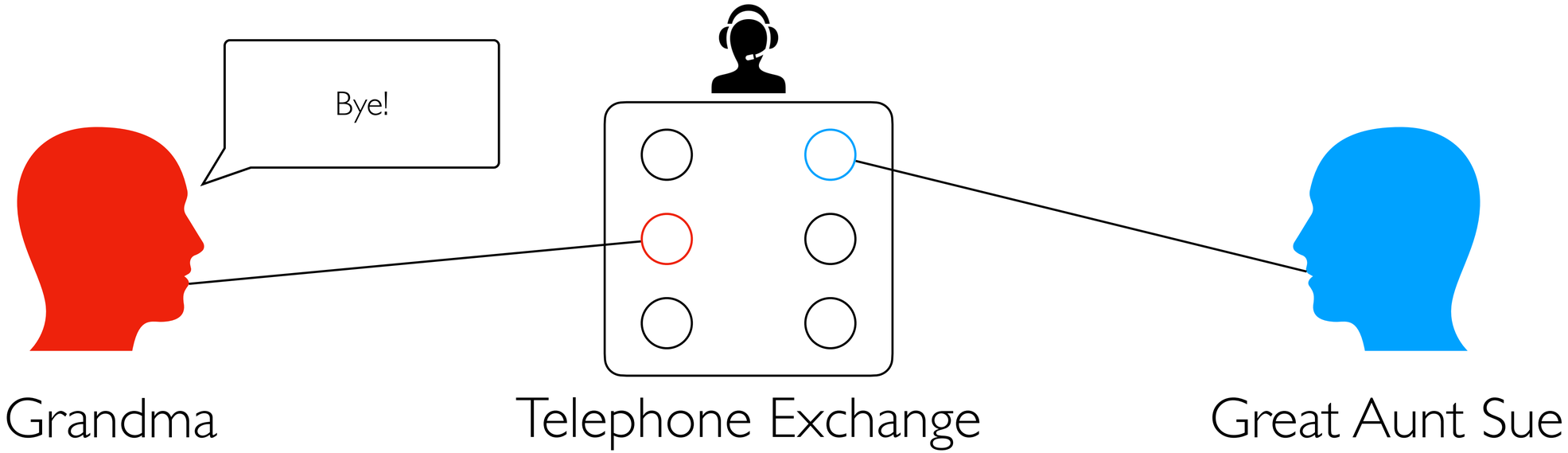

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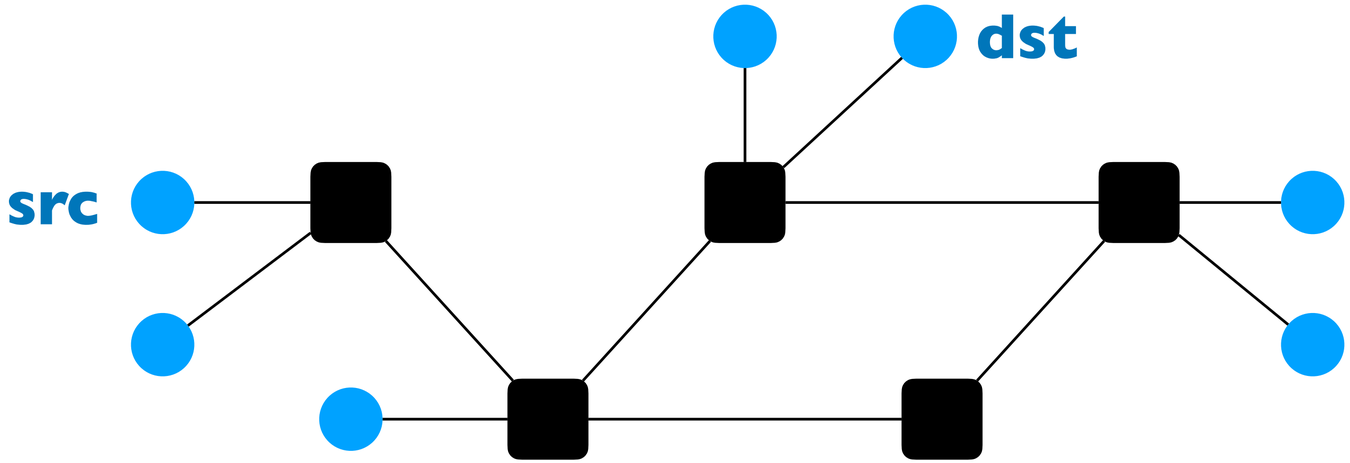

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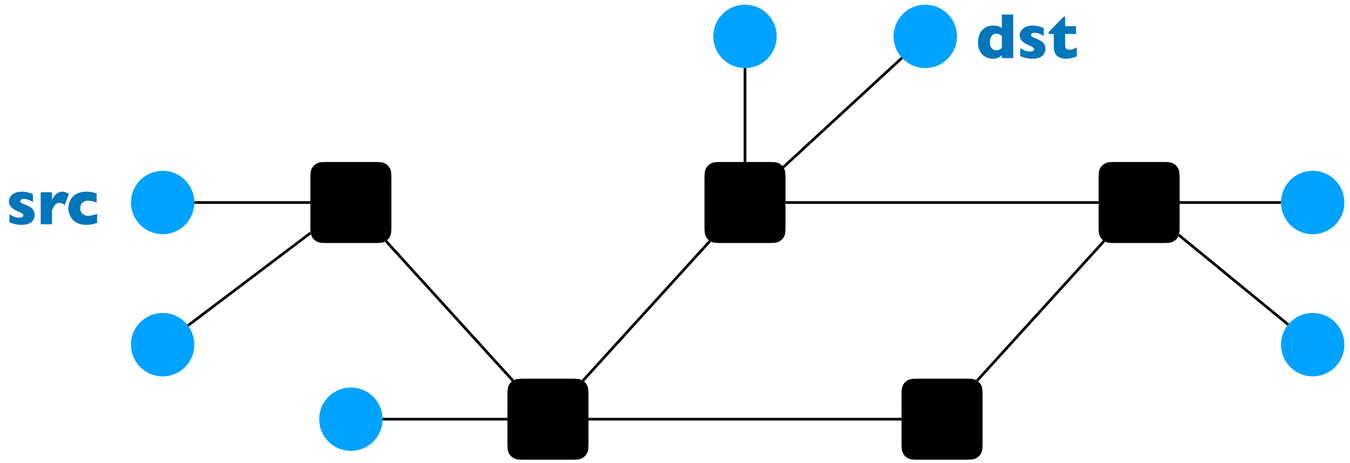

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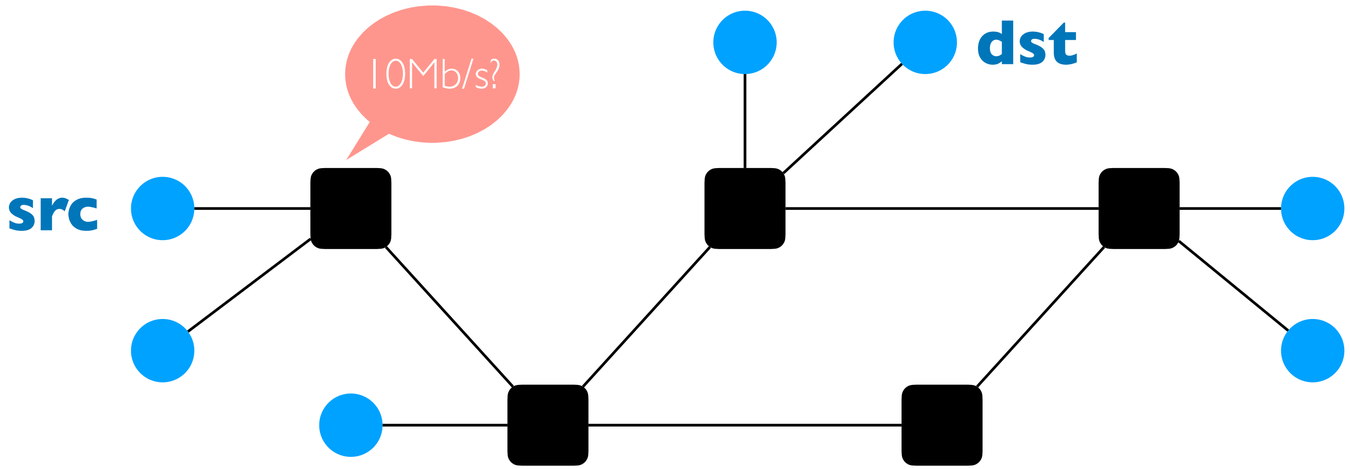

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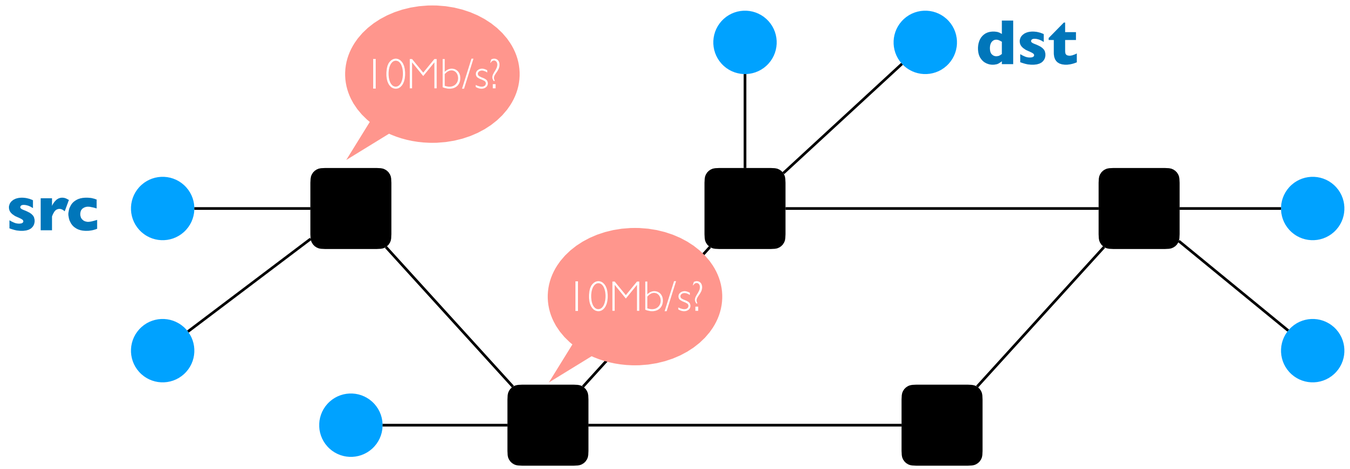

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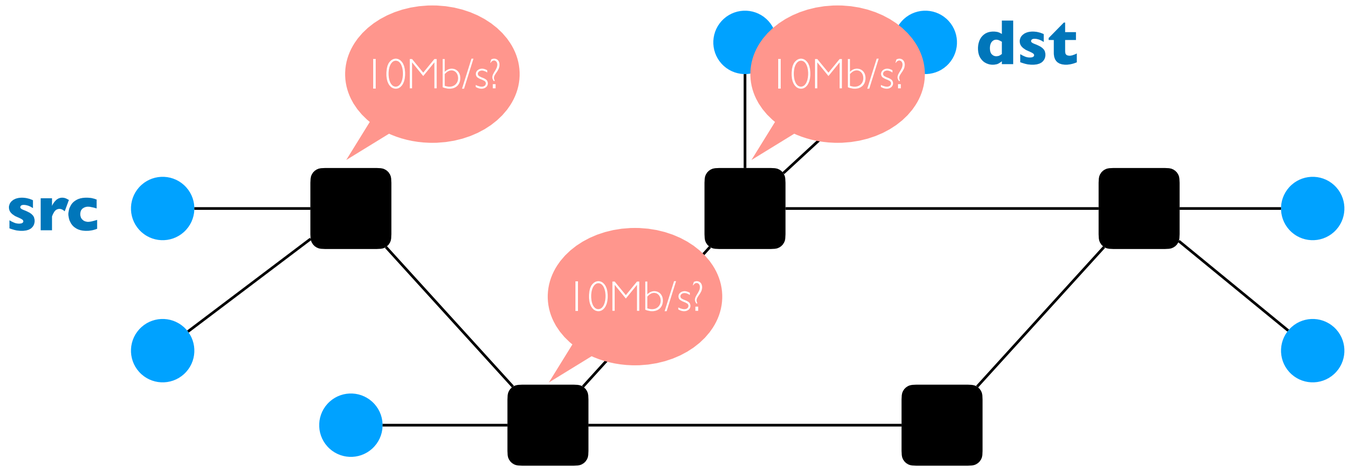

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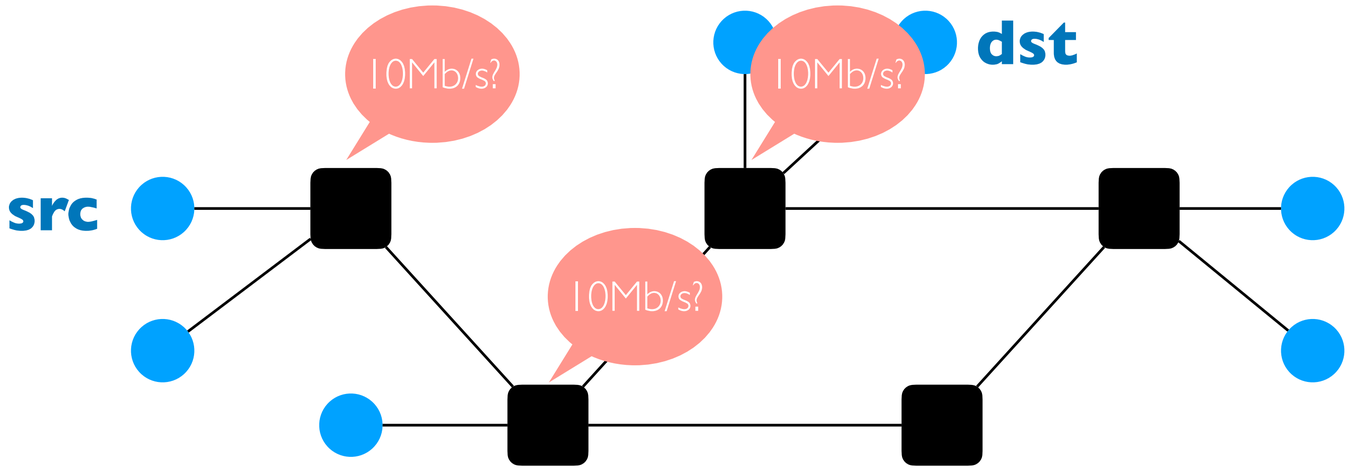

1. The **src** sends a reservation request to **dst**
2. Switches "establish a circuit"

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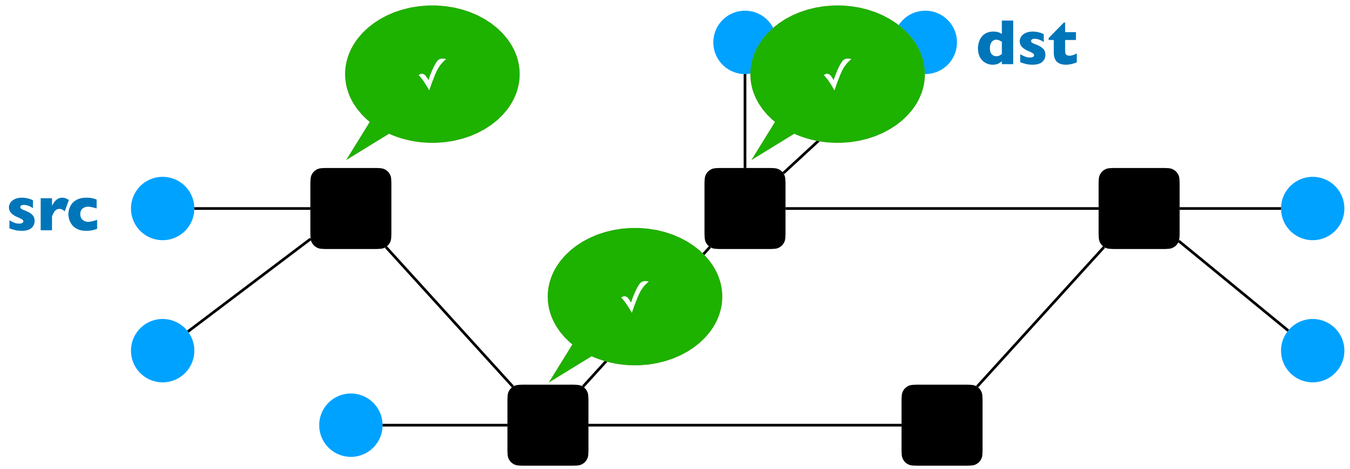

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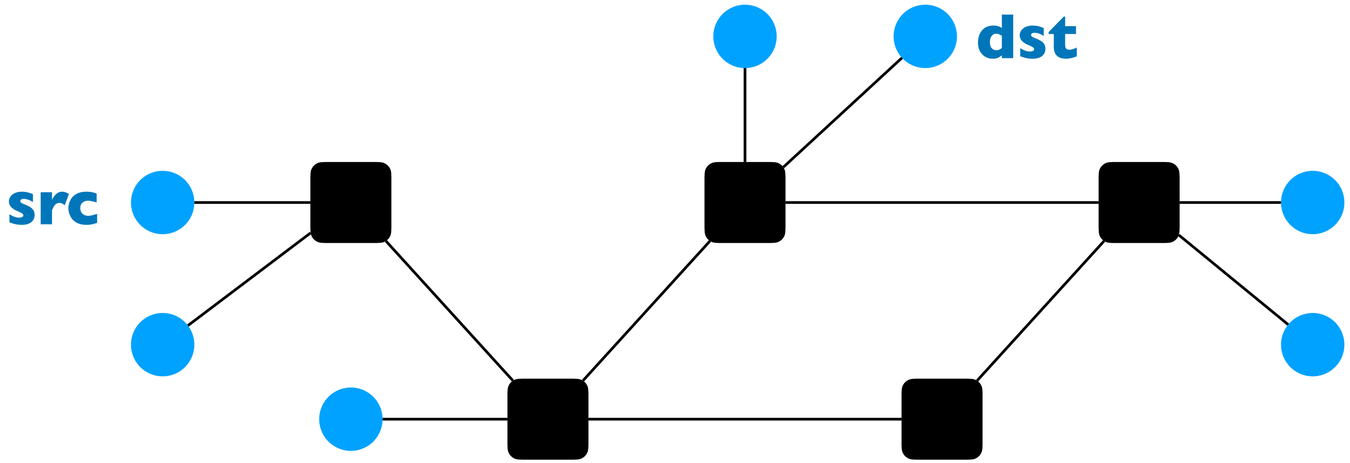

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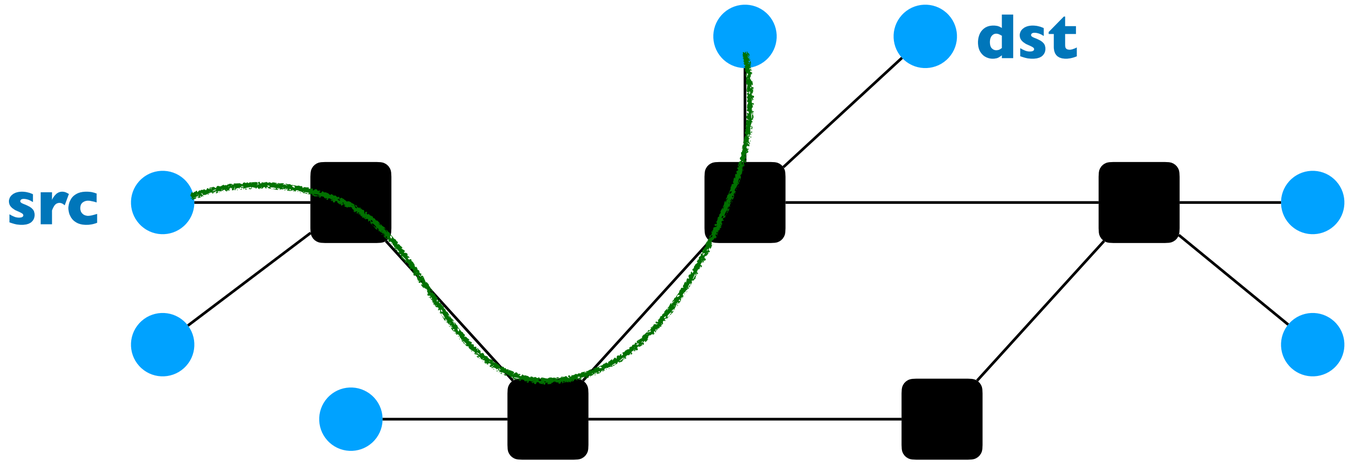

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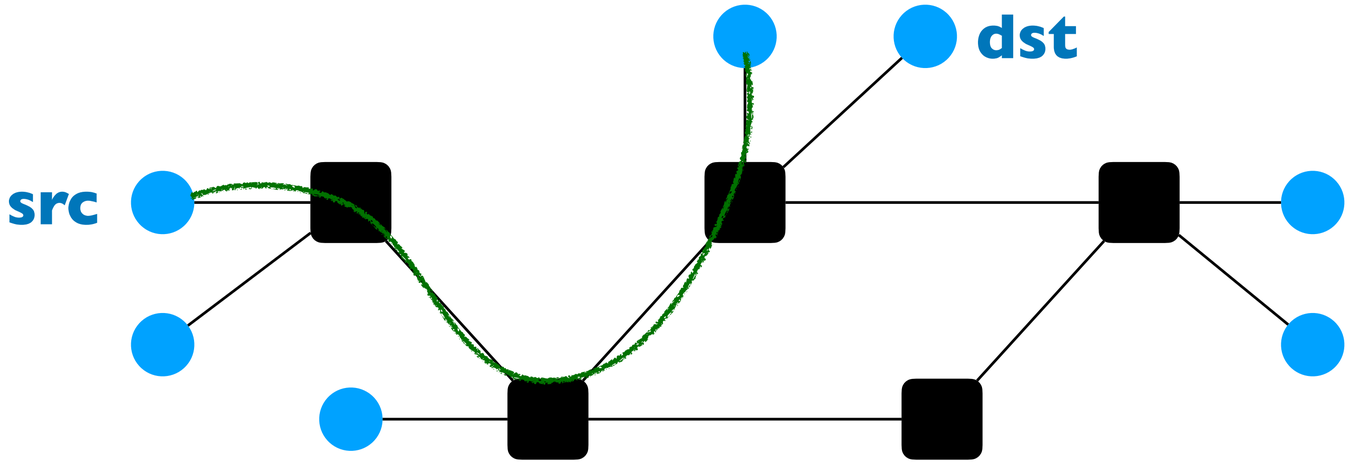

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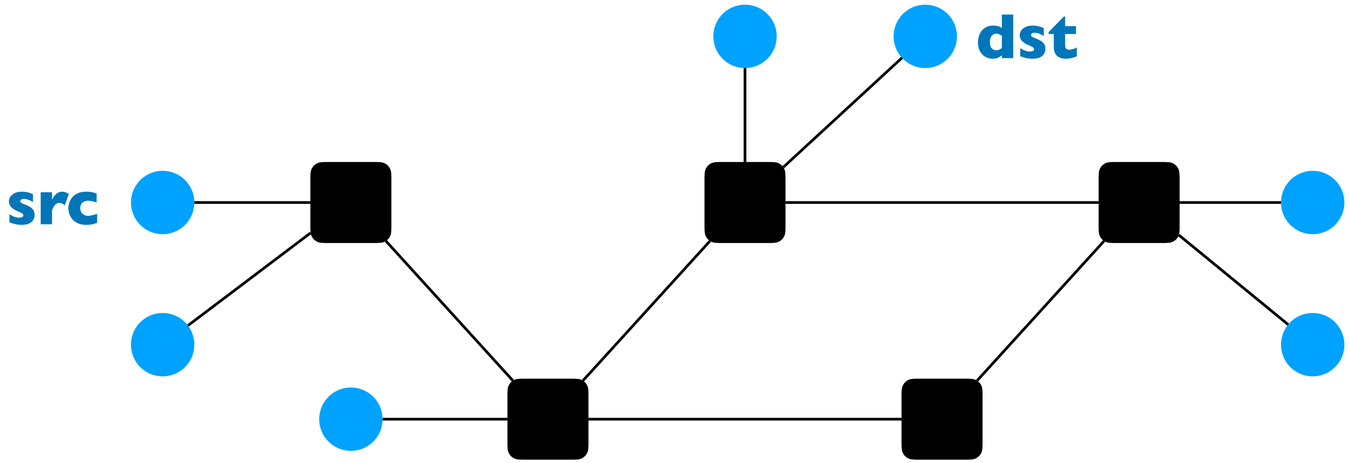

1. The **src** sends a reservation request to **dst**
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3. The **src** starts sending data
4. The **src** sends a "teardown circuit" message

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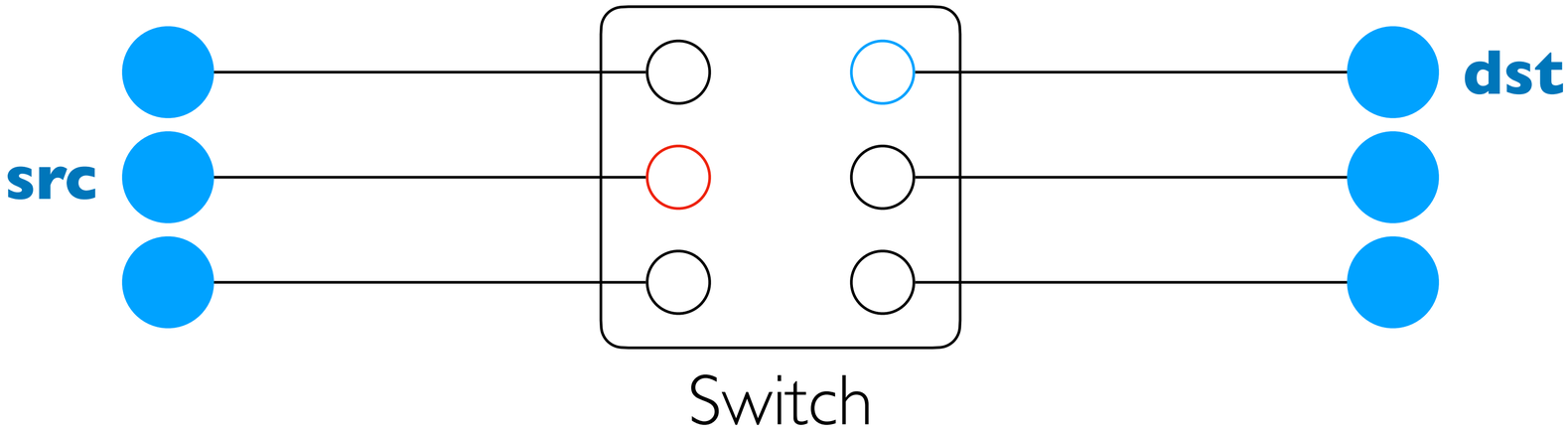

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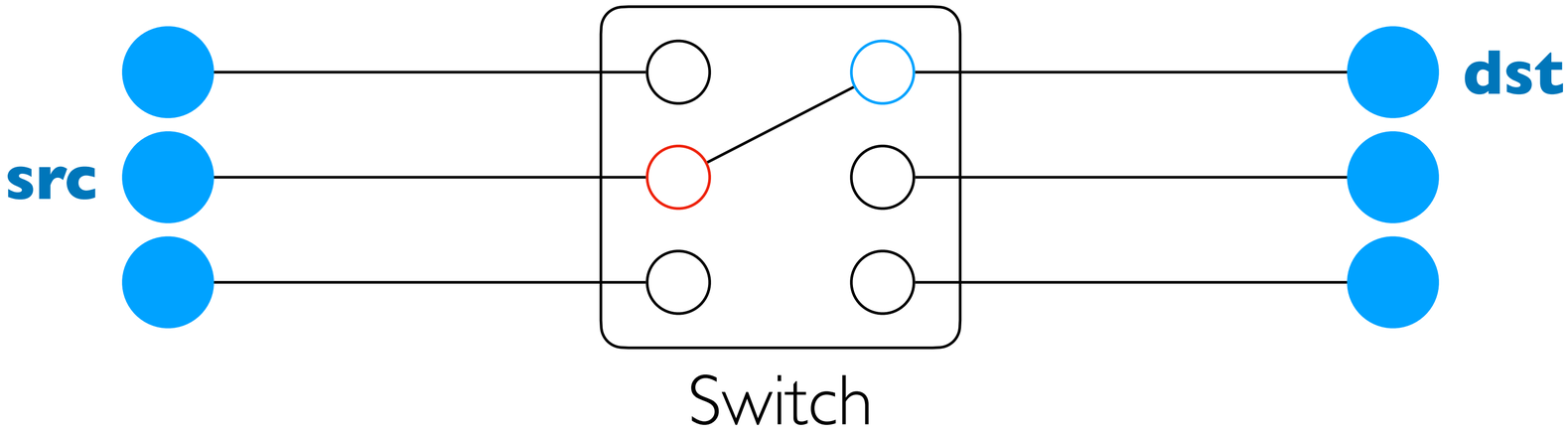
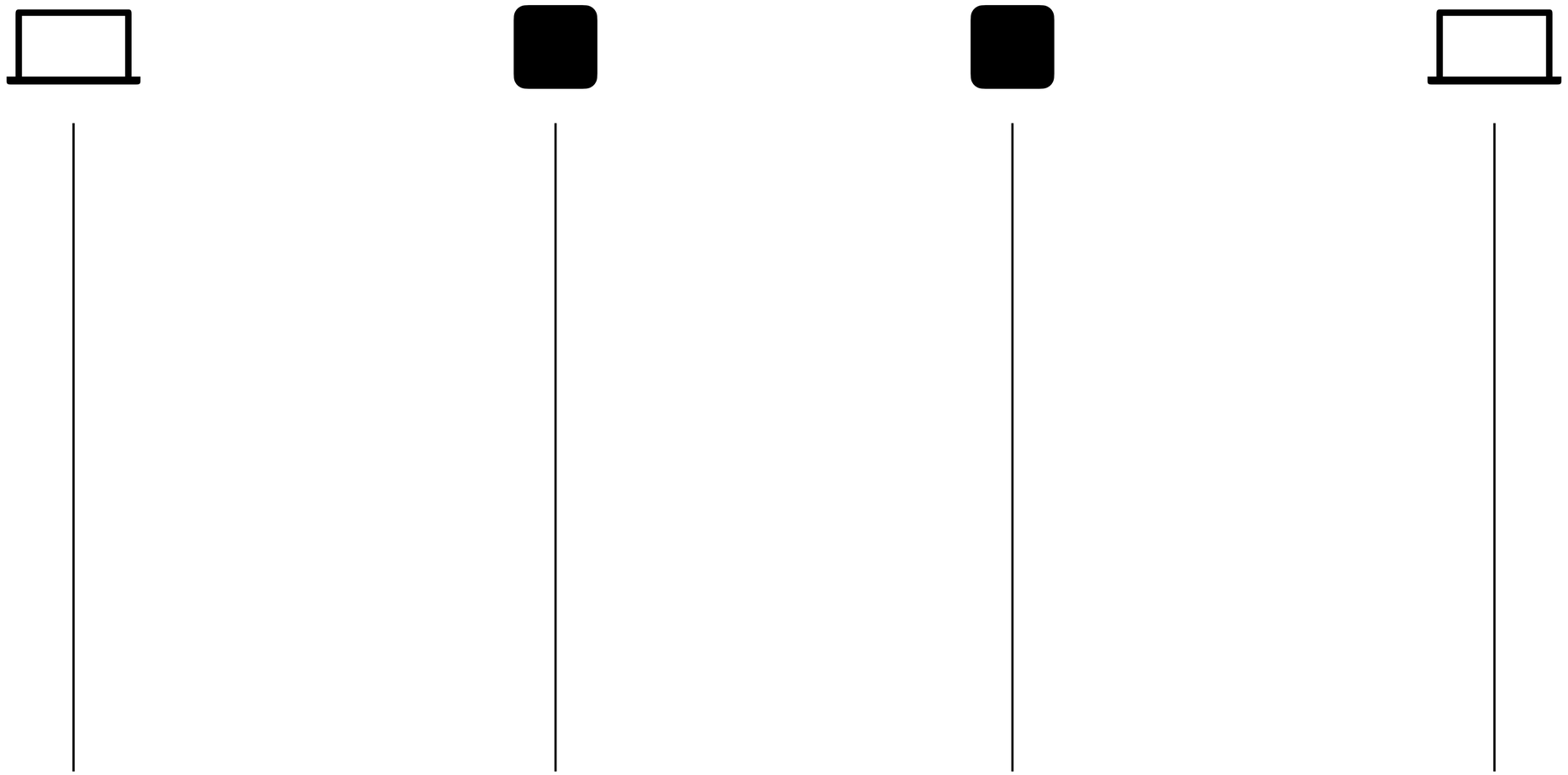


Reservation establishes a "circuit" within a switch

Timing in Circuit Switching



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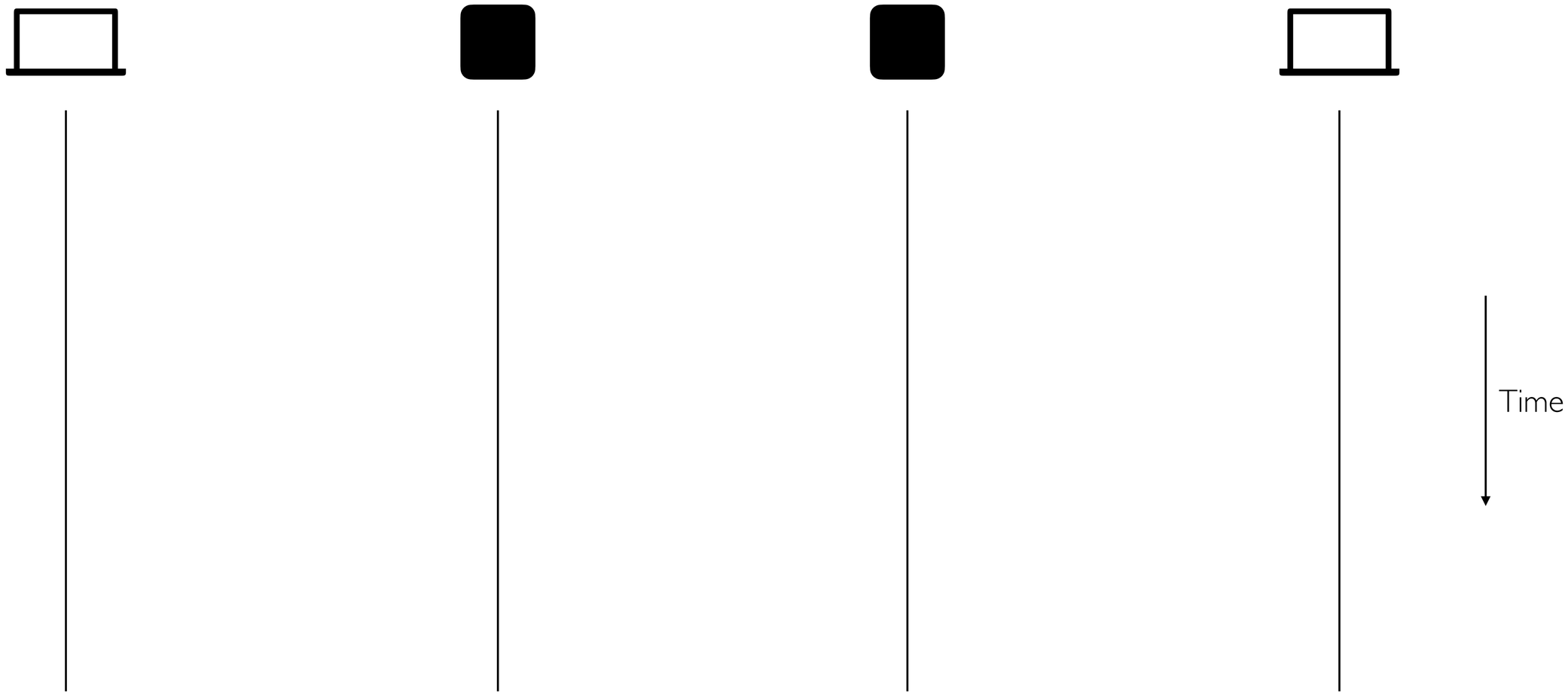

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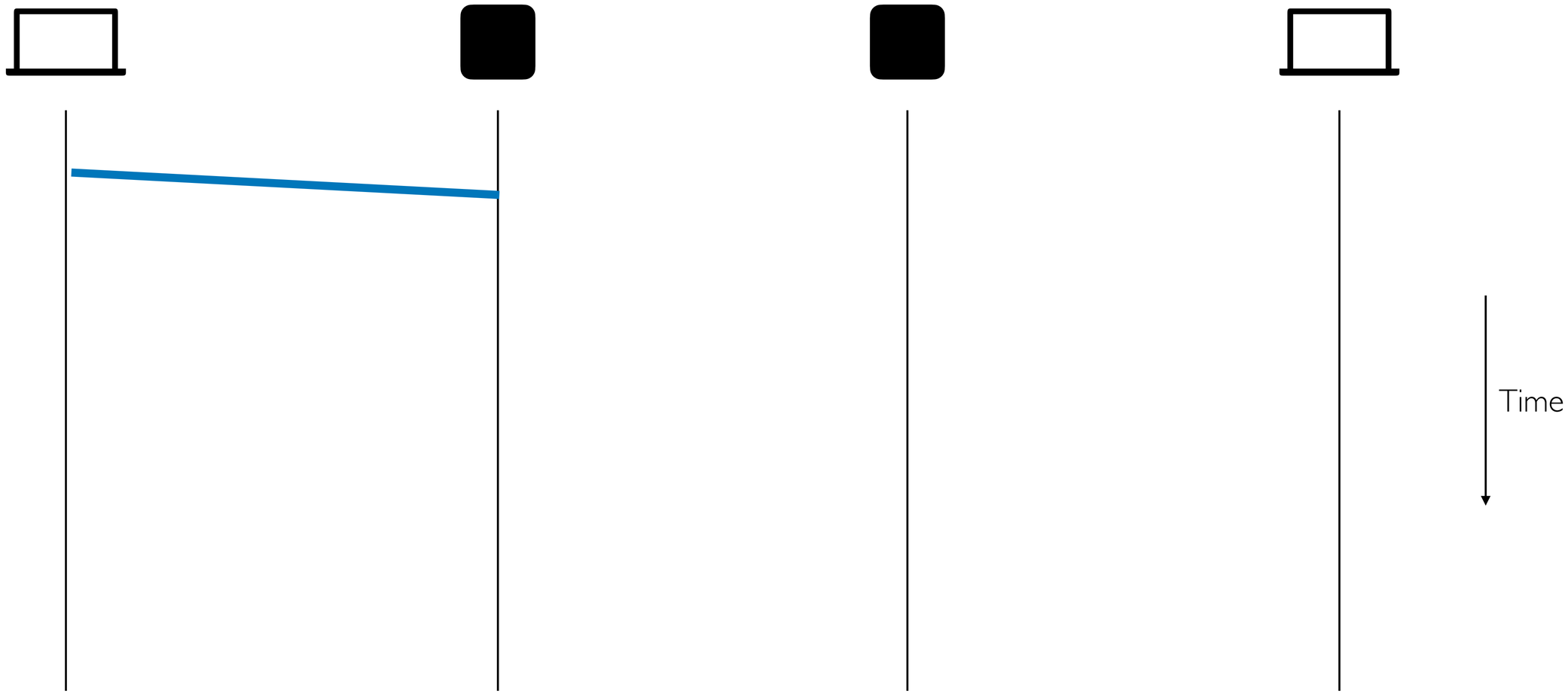

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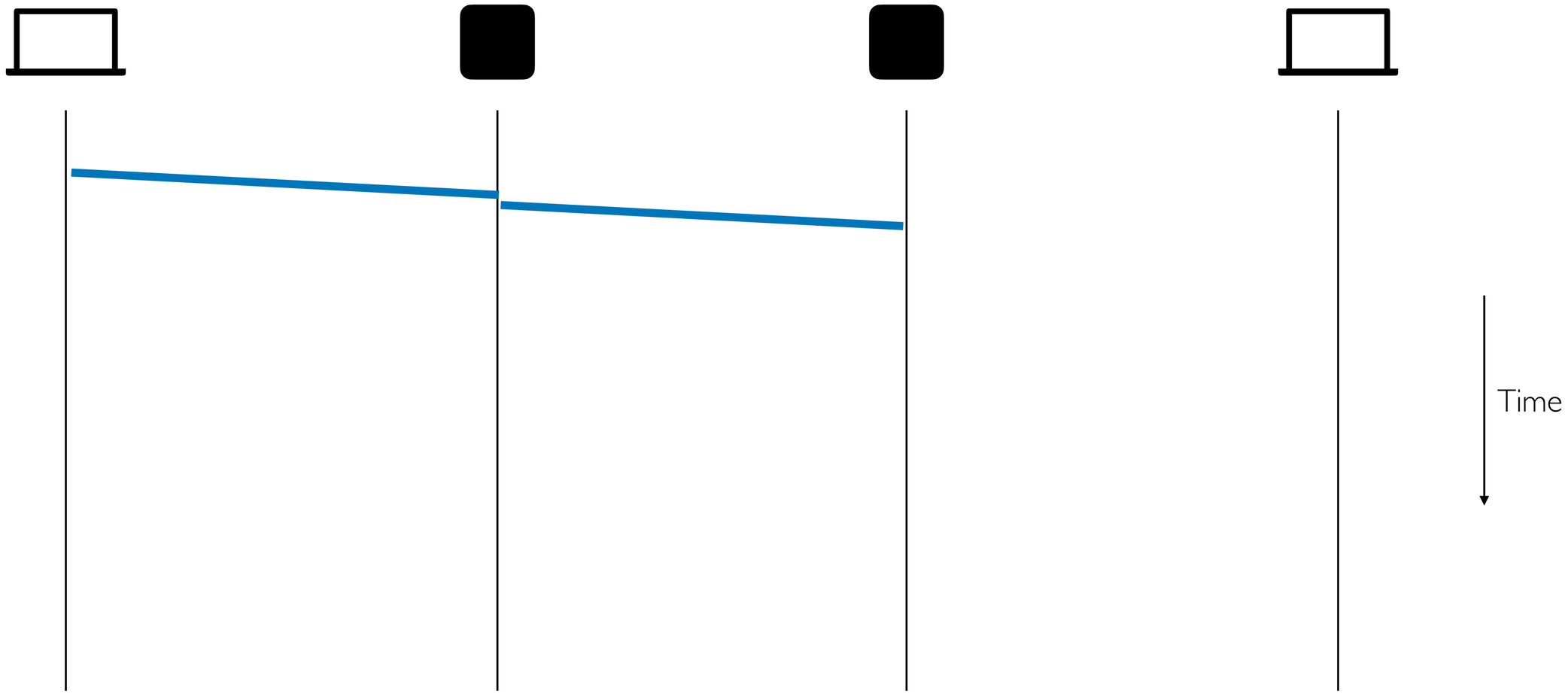

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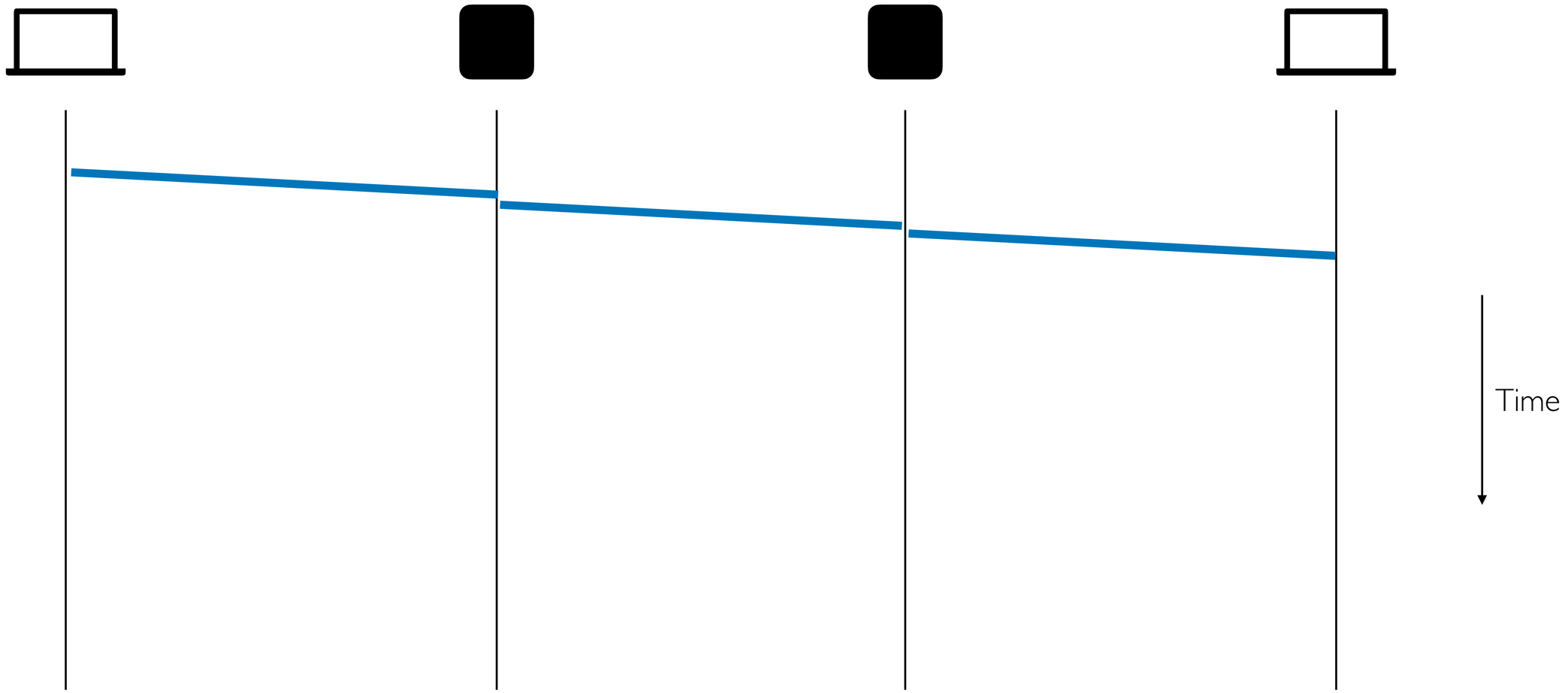

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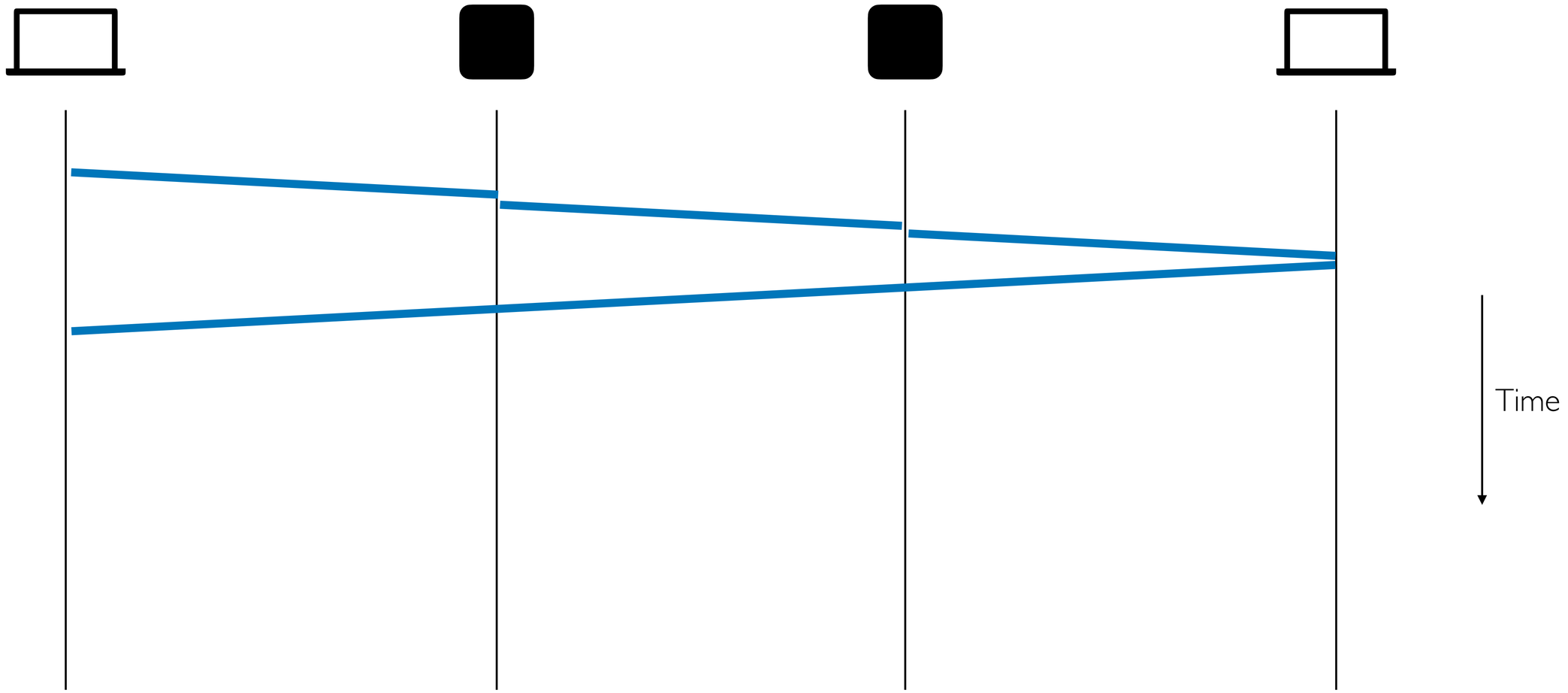

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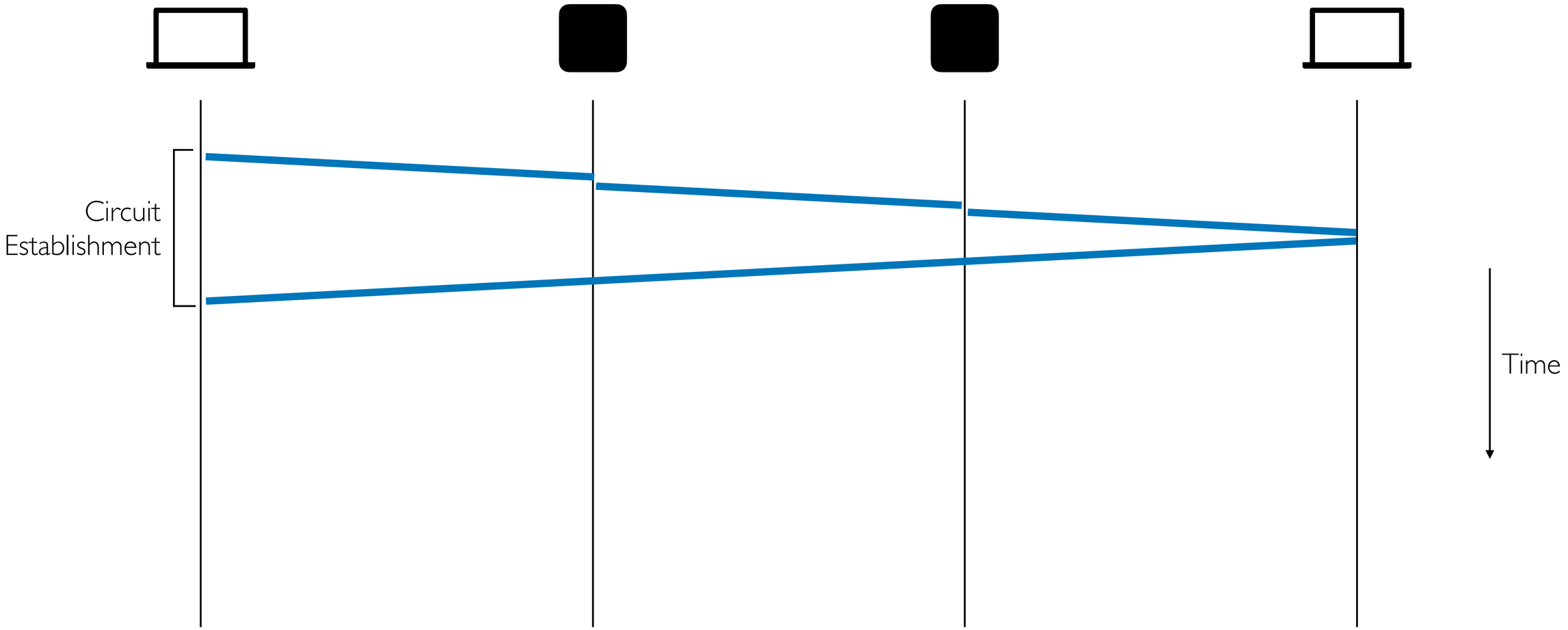

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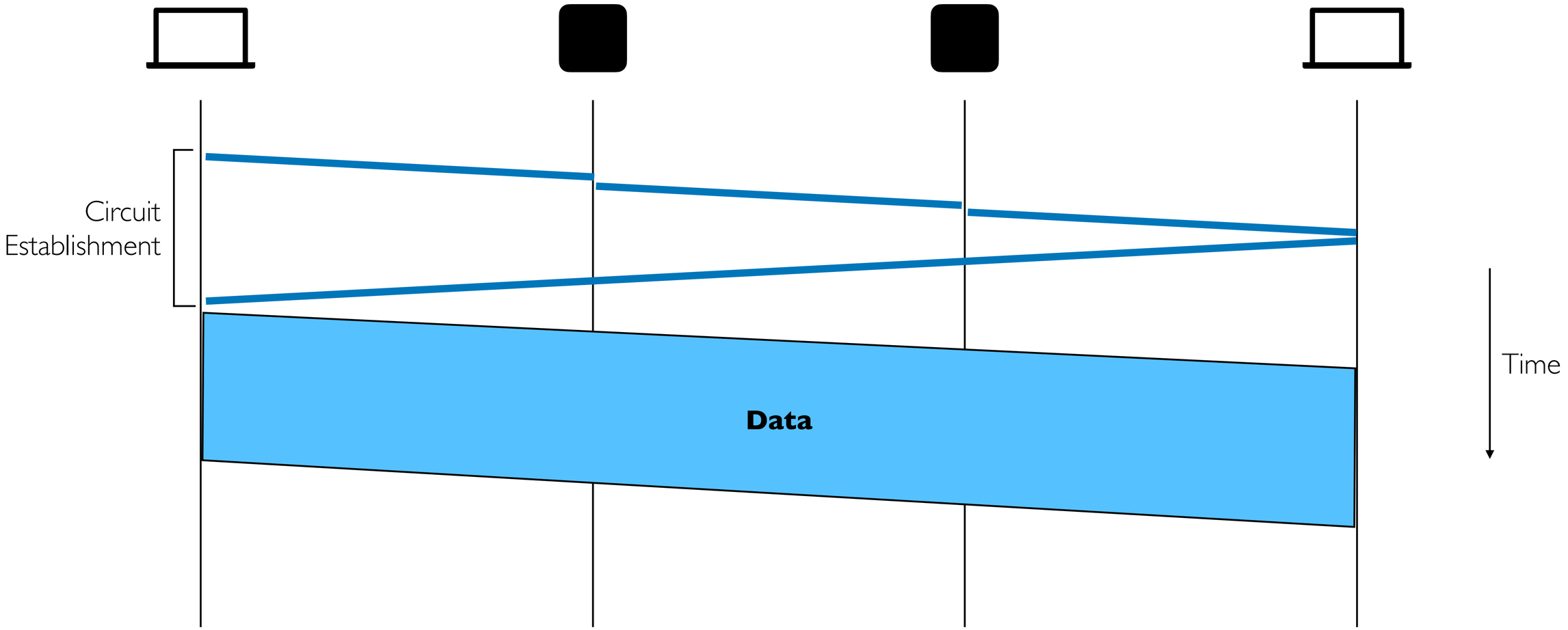

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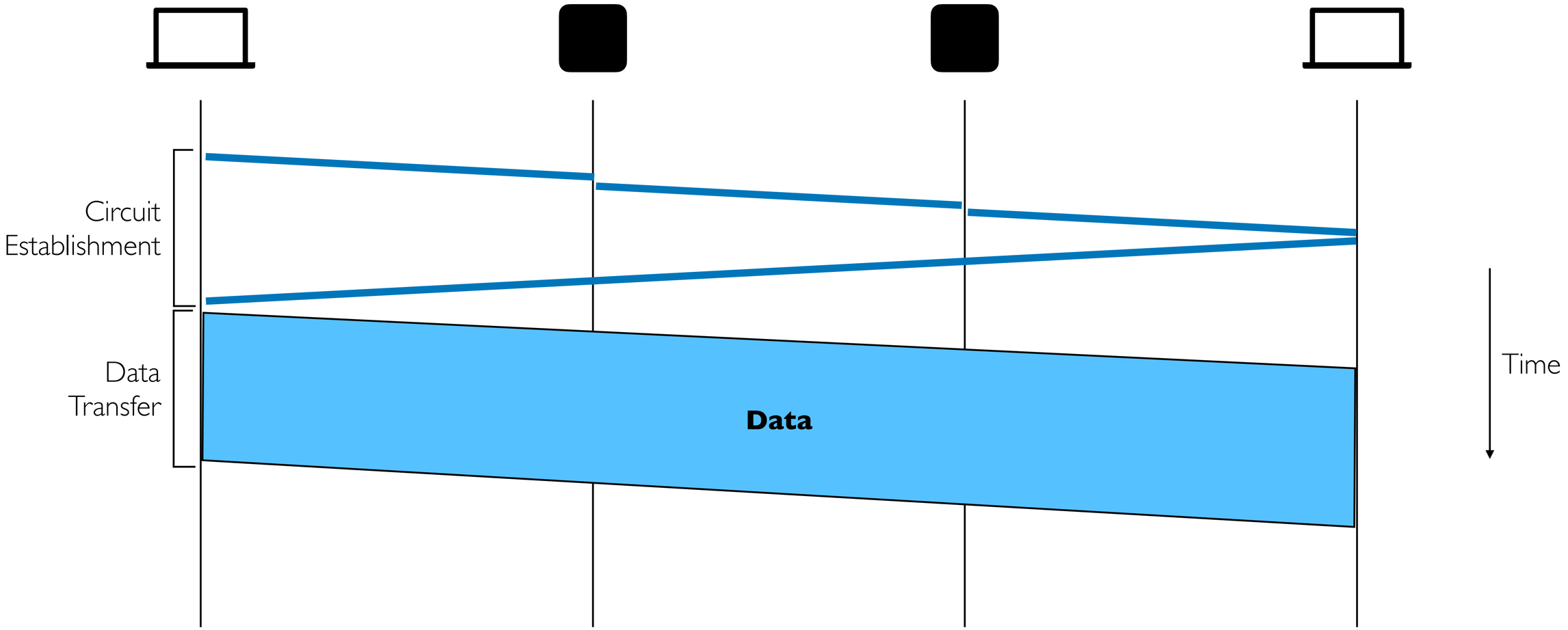

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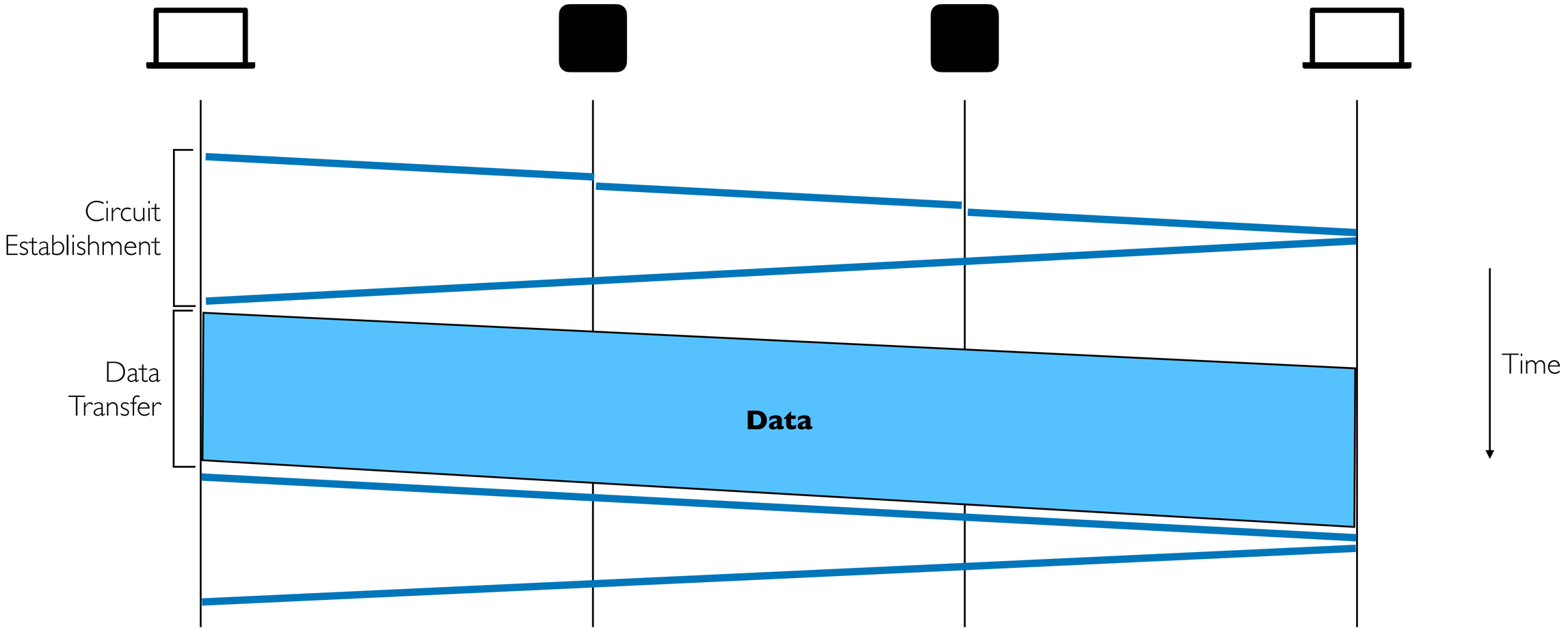

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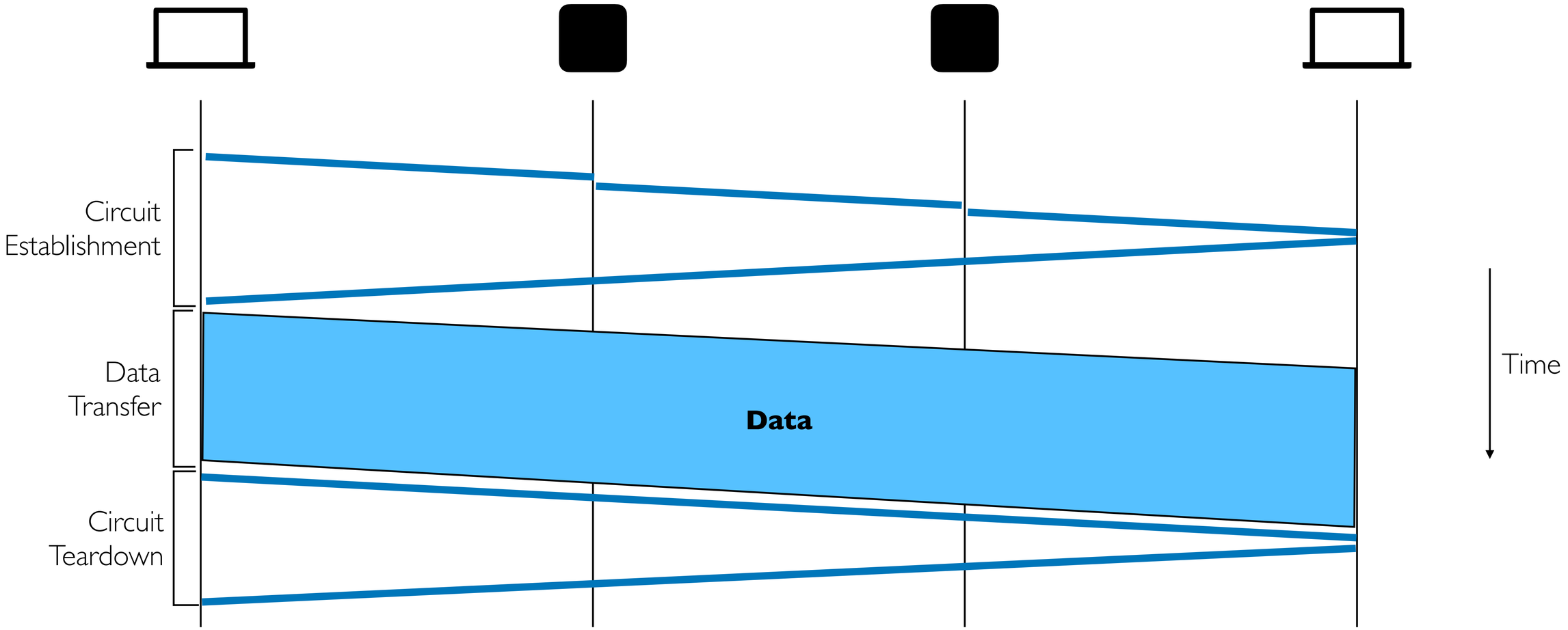
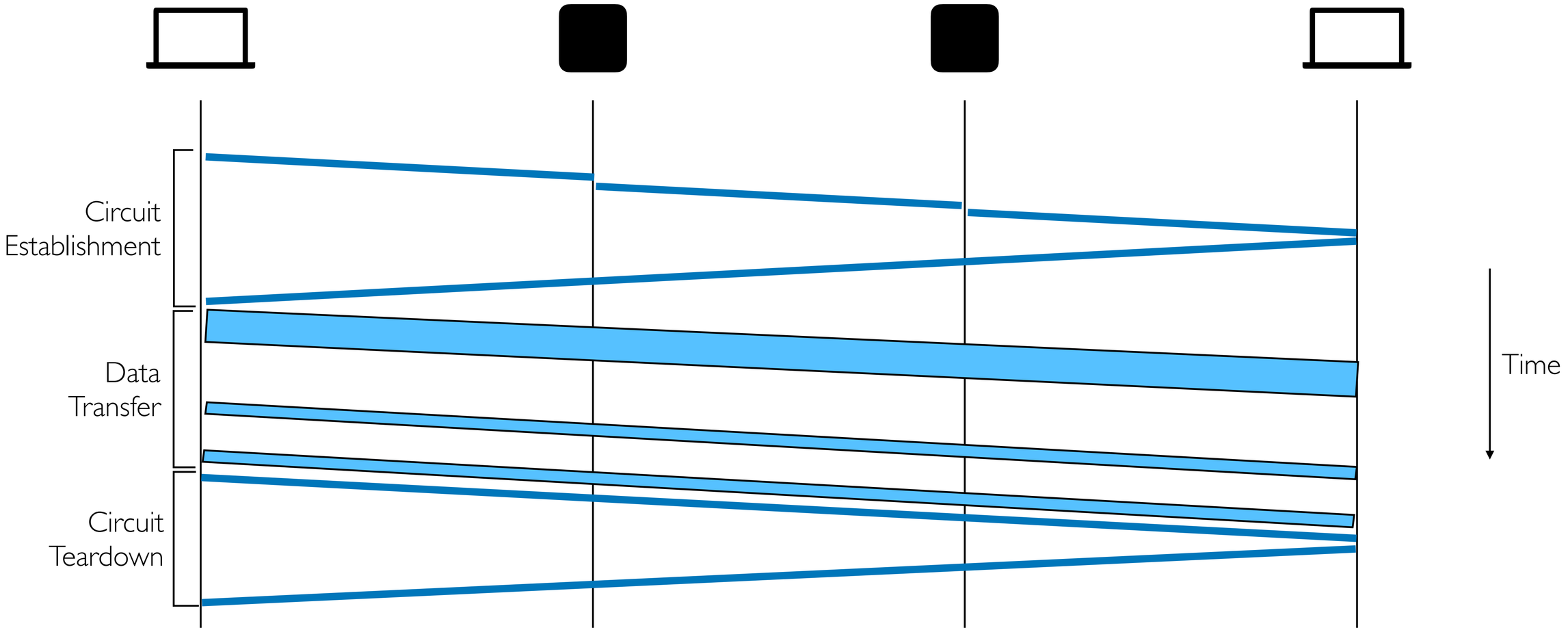
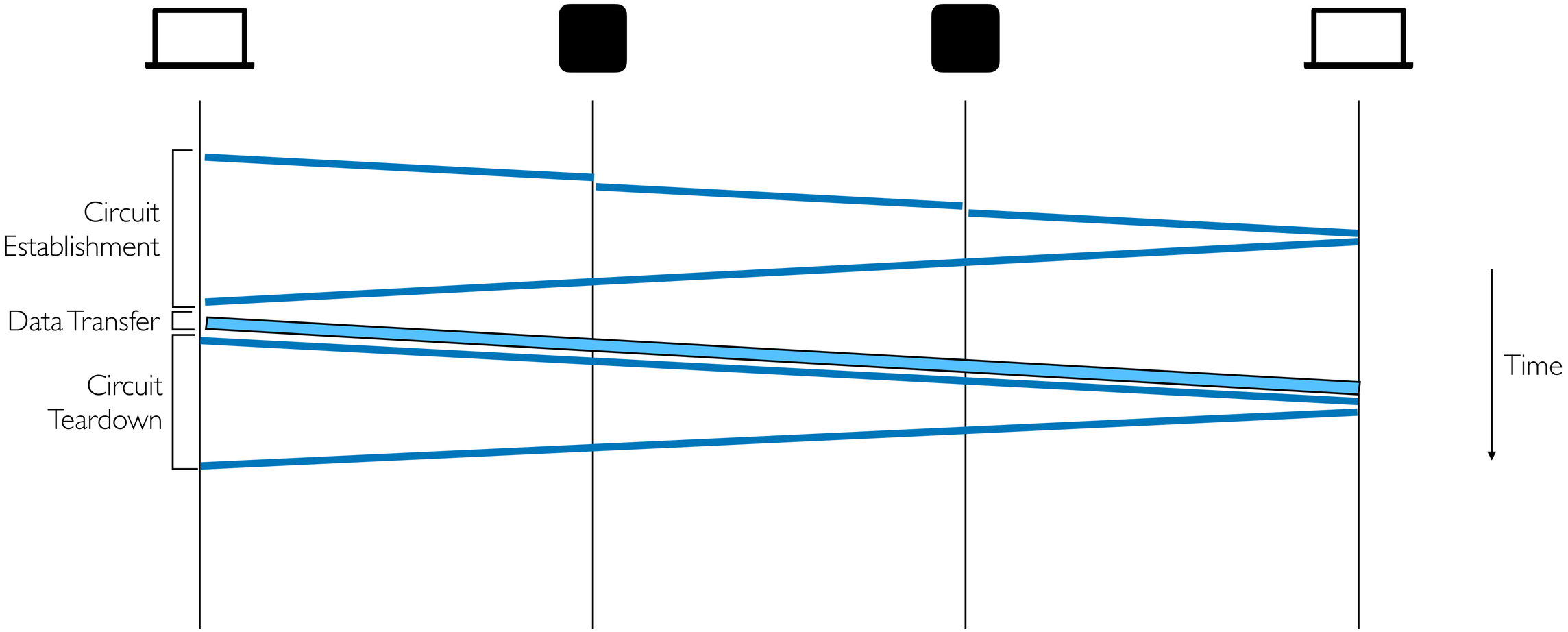


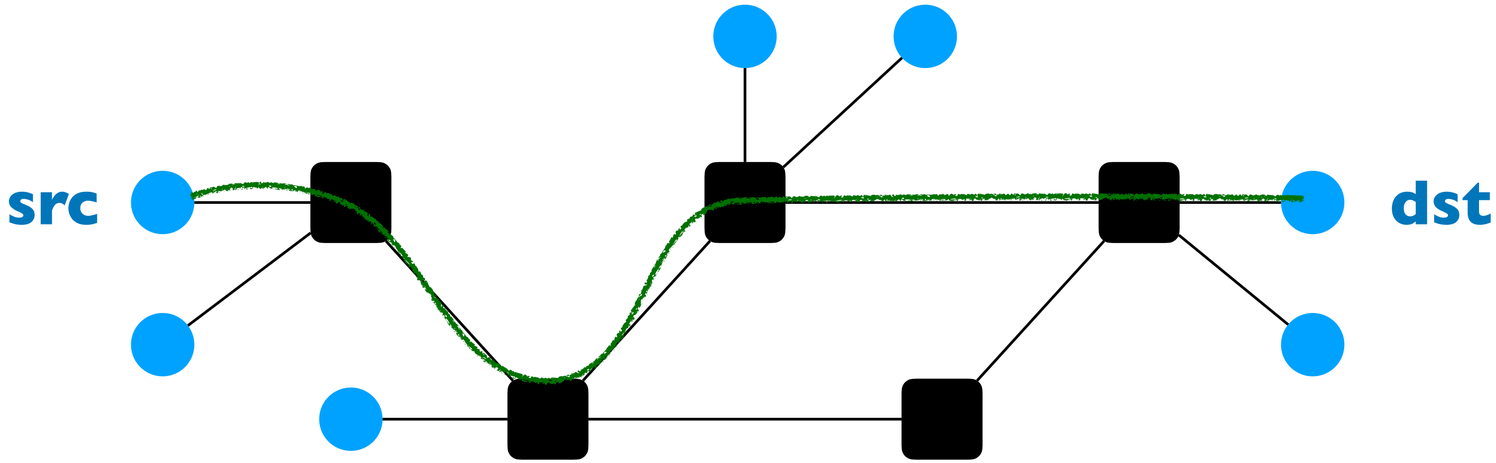
What if there are sporadic periods of data transfer?



What if there is very little data to transfer?



What if switches fail?



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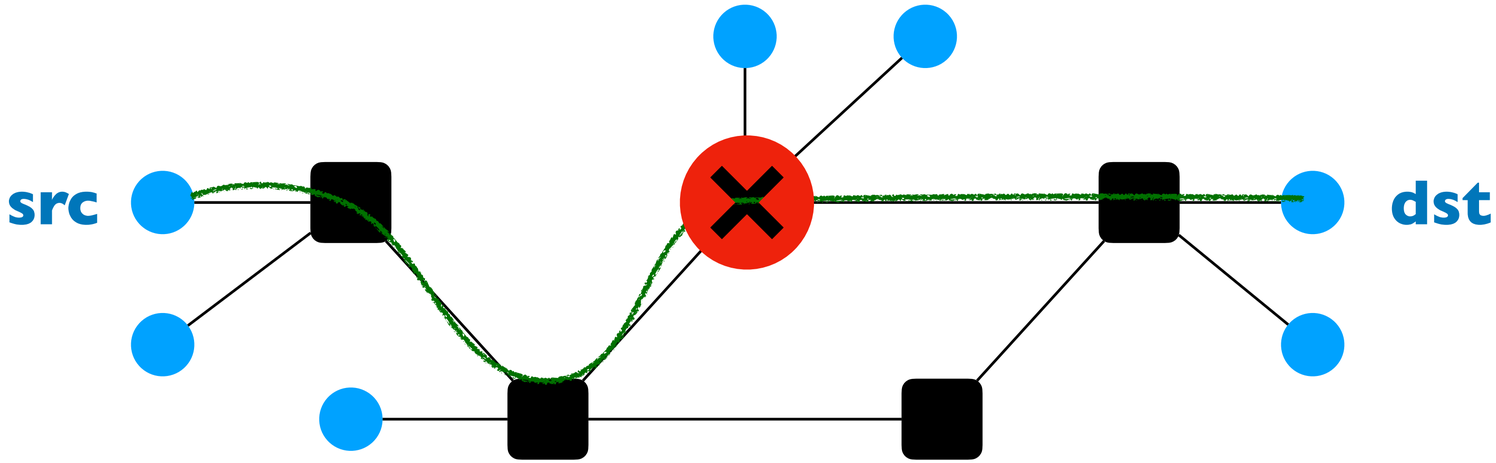

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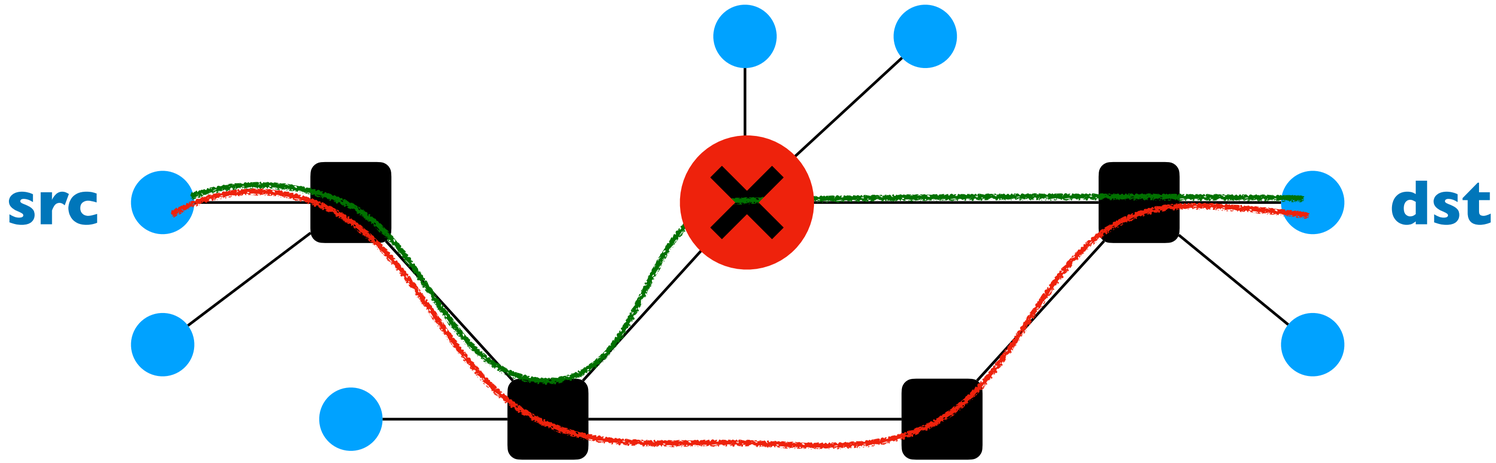

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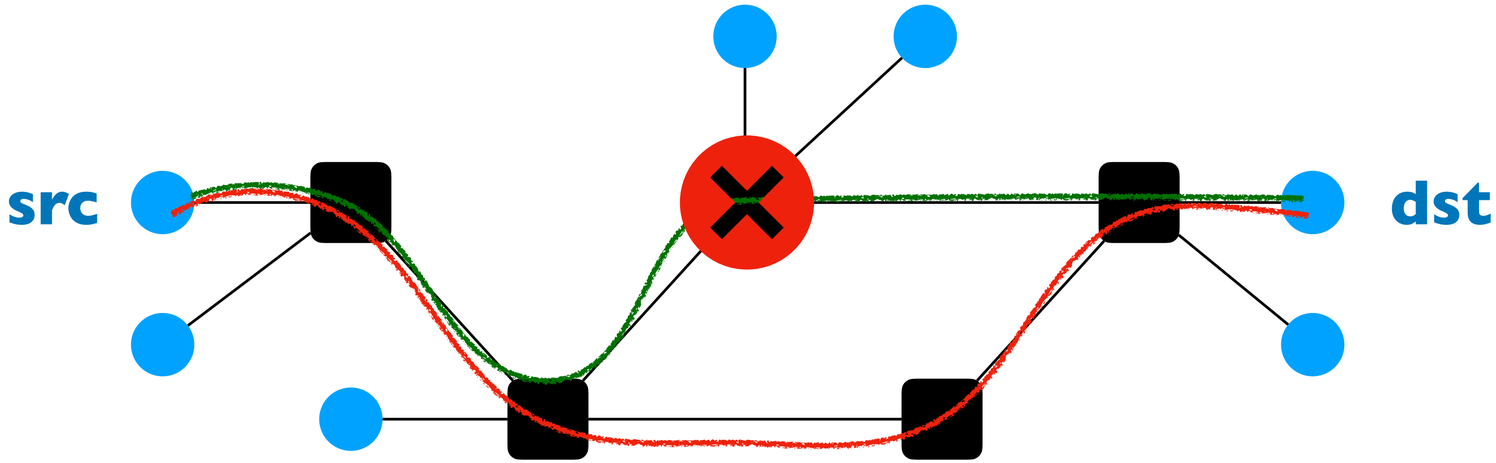

Circuit switching doesn't ***route around trouble***

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- **What's not-so-good?**
  - *Complexity of circuit setup/teardown*
  - *Inefficient when traffic is bursty*
  - *Circuit setup adds delay*
  - *Switch fails -> its circuits fail*

Questions?

How else can we share?

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- **Second approach:** *On demand* (aka "best-effort")

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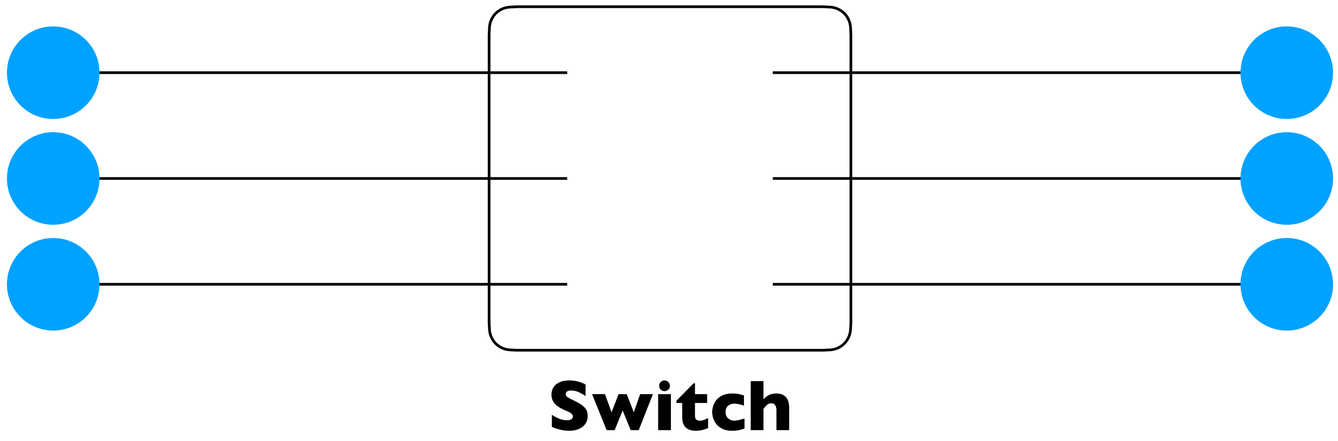
- **Mechanism:**
  - Break down data into packets
  - Send packets when you have them
  - Hope for the best…

Best-effort: Packet Switching



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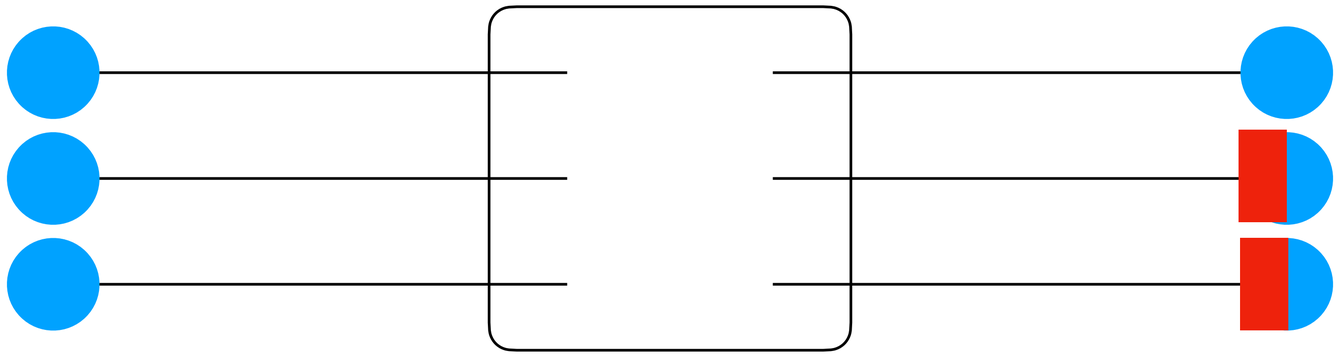

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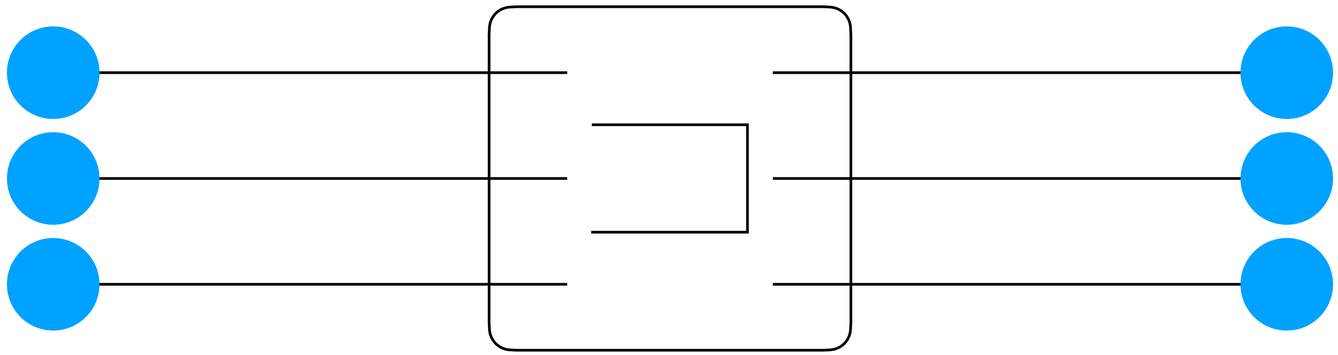

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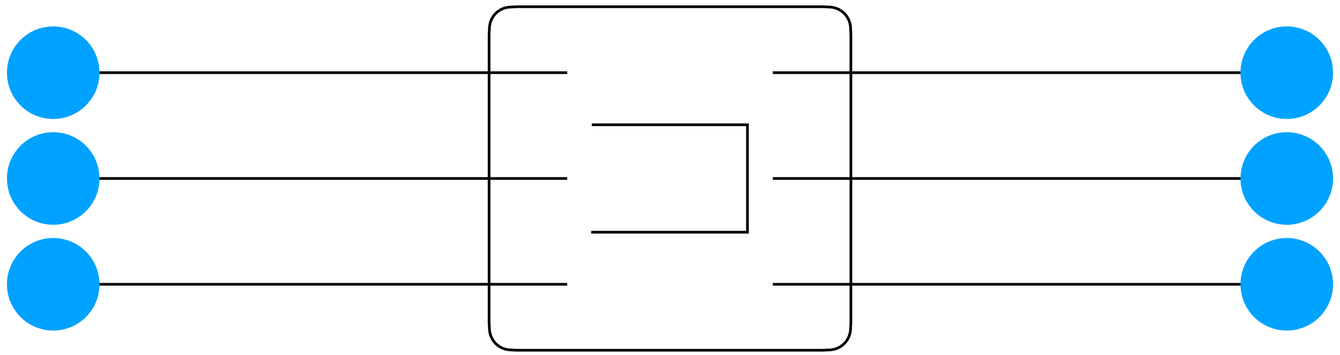

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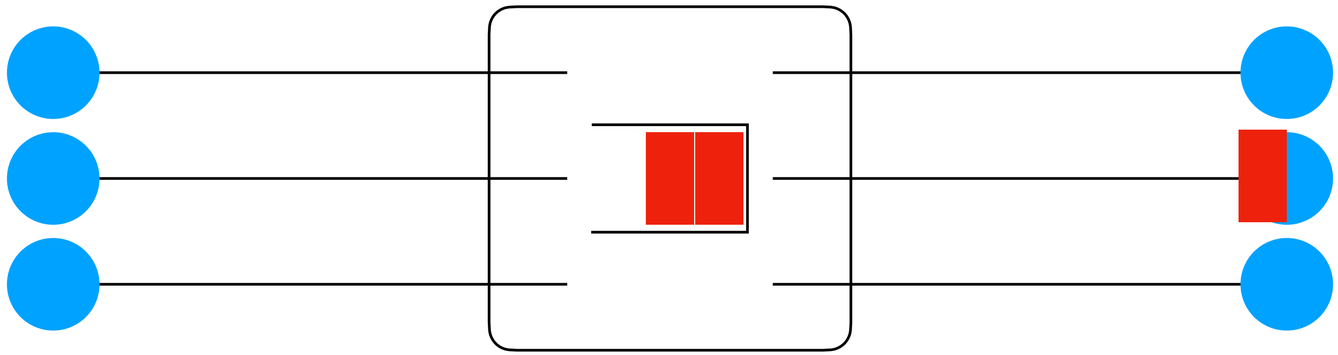

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Circuits vs Packets

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- Internet chose to go for packets: ***why?***

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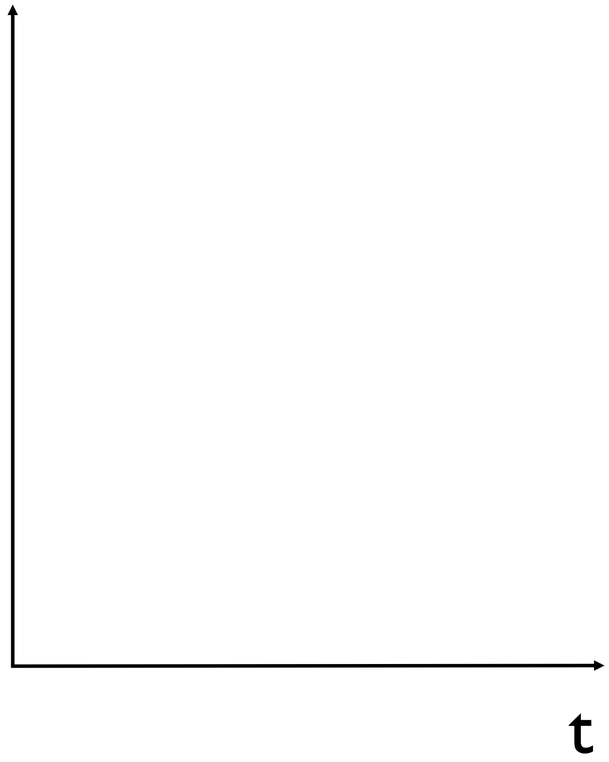

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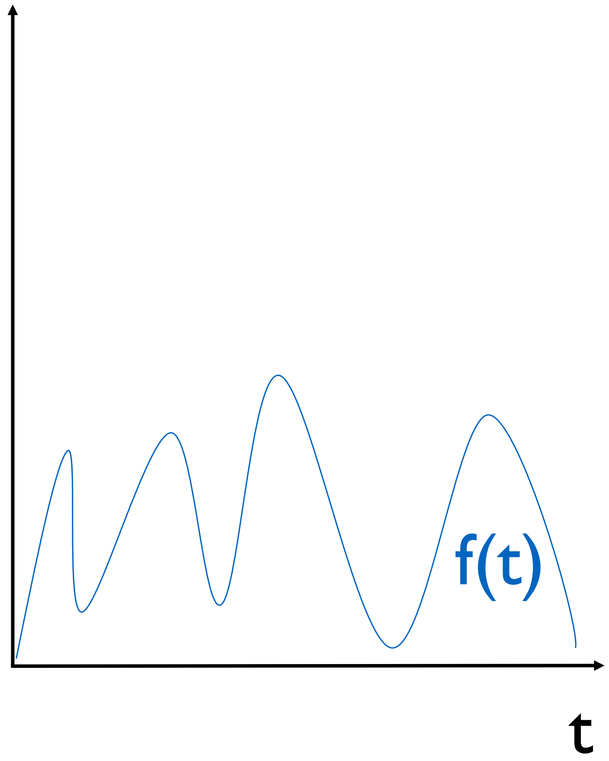

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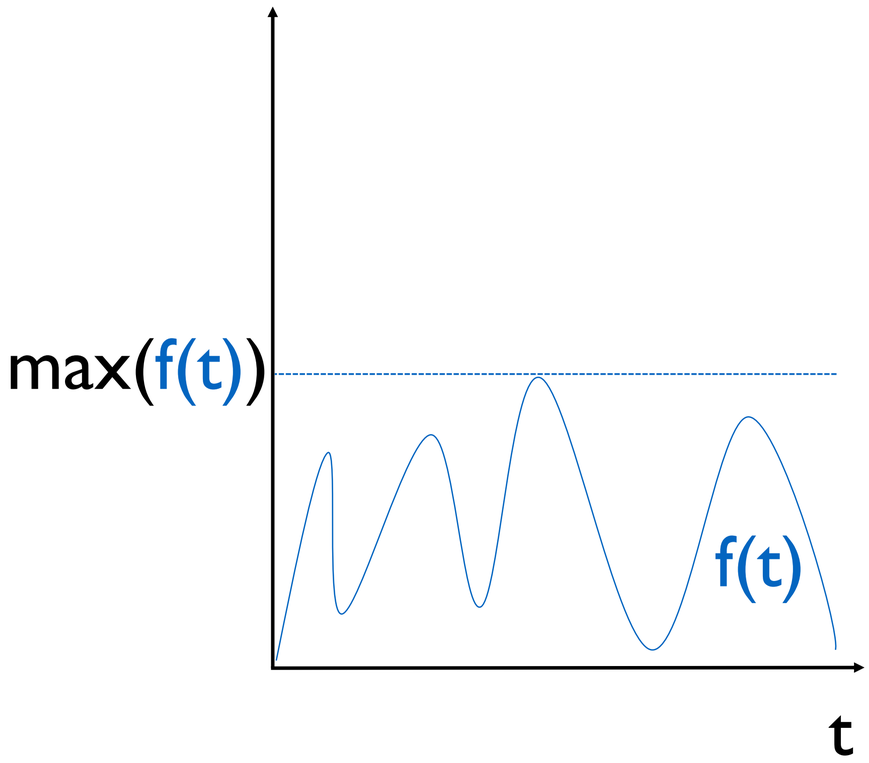

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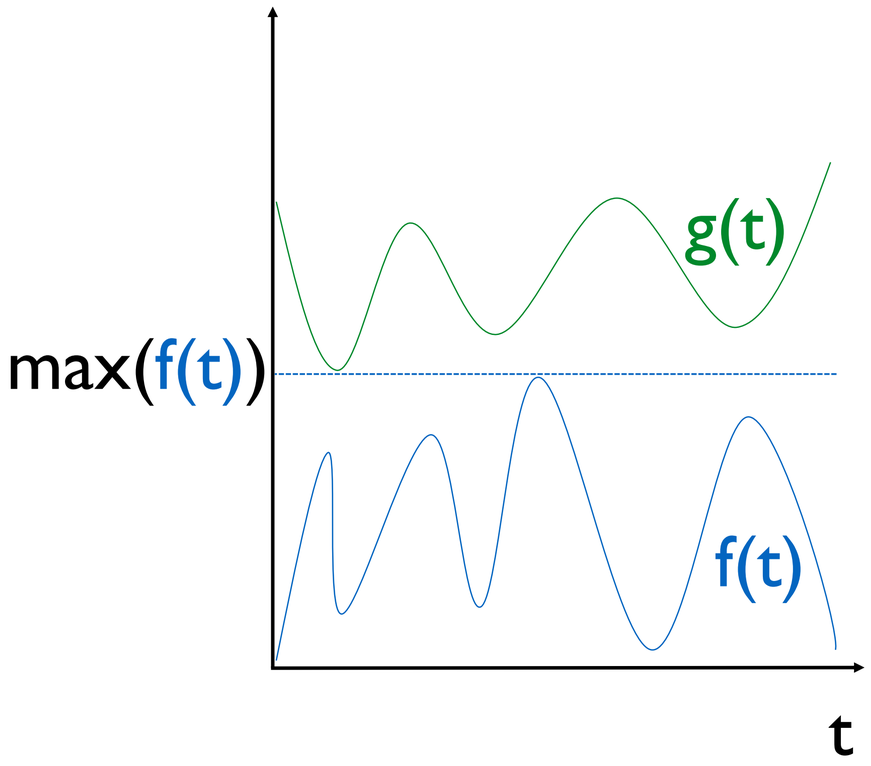

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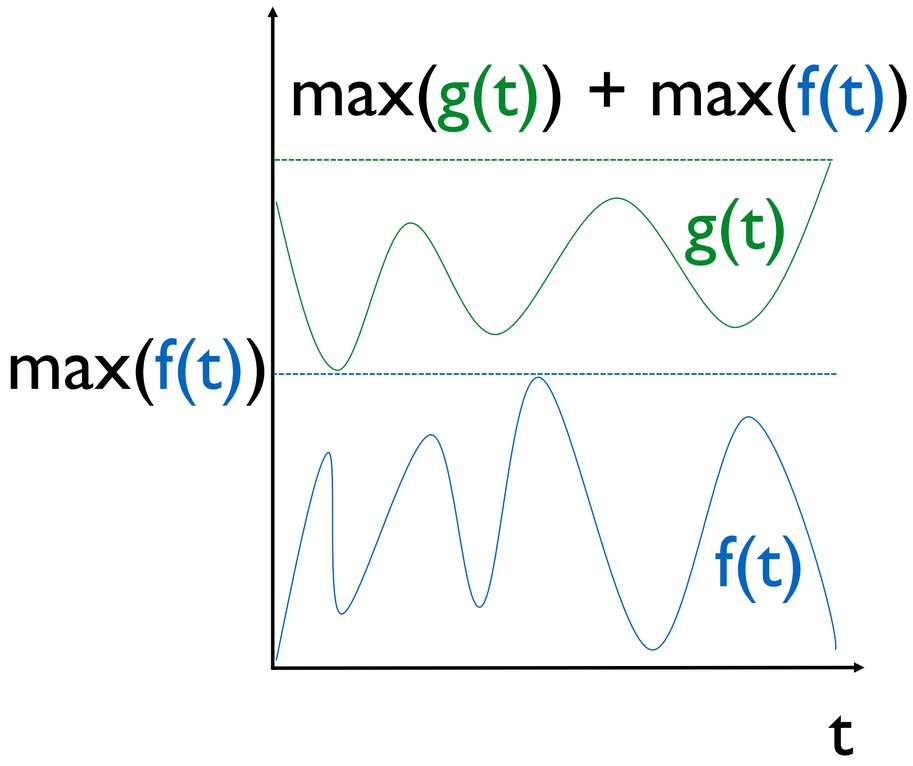

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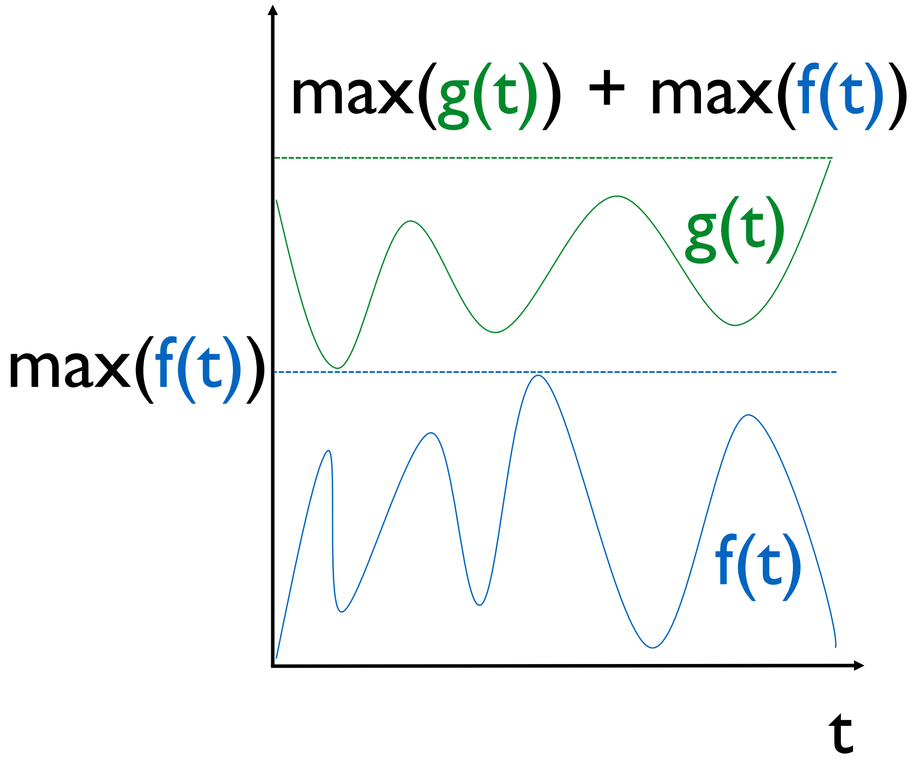

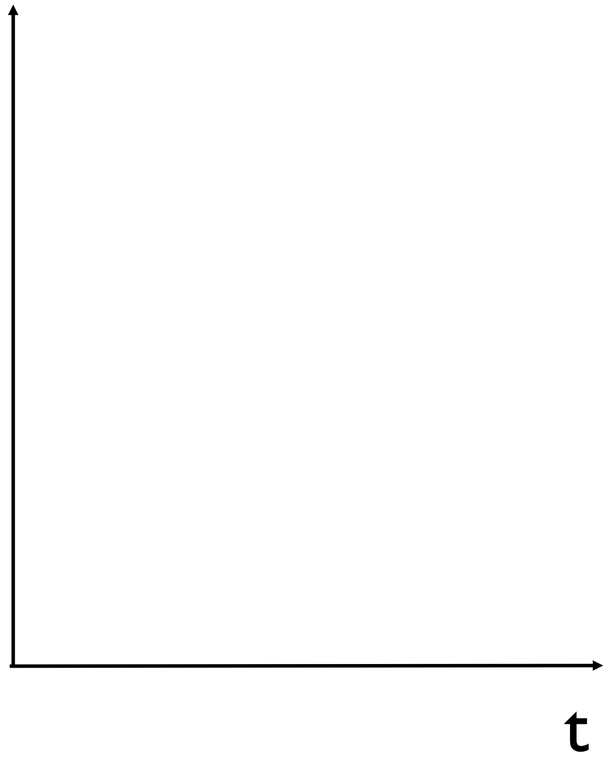

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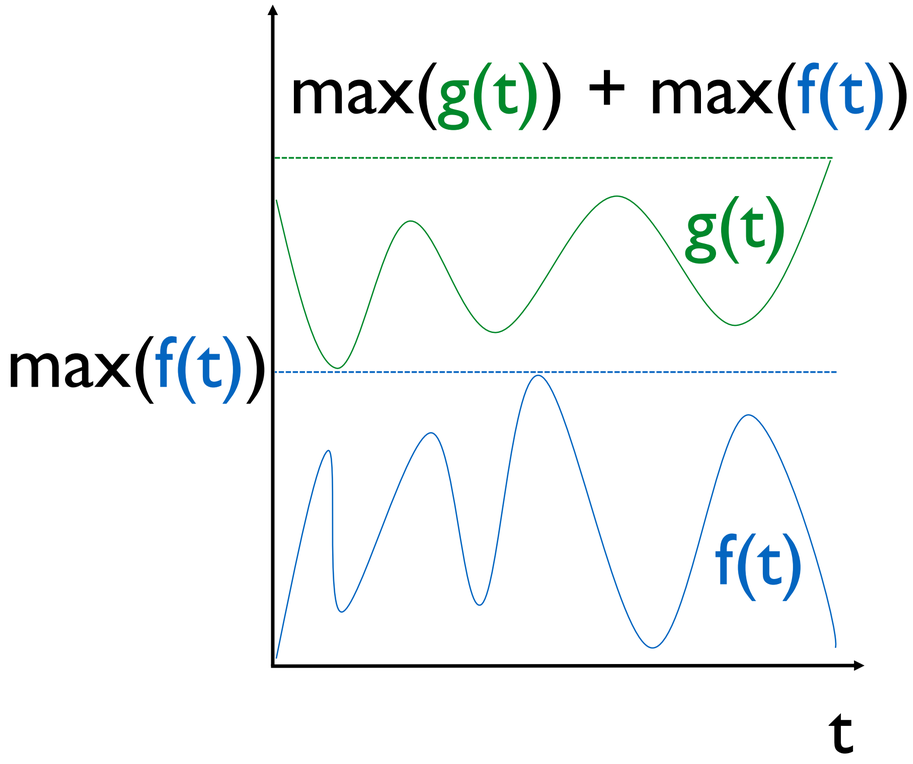

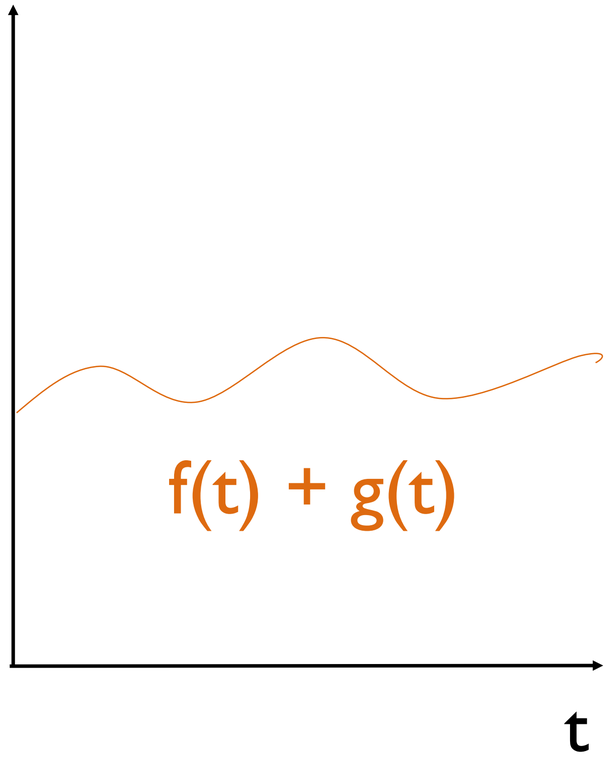

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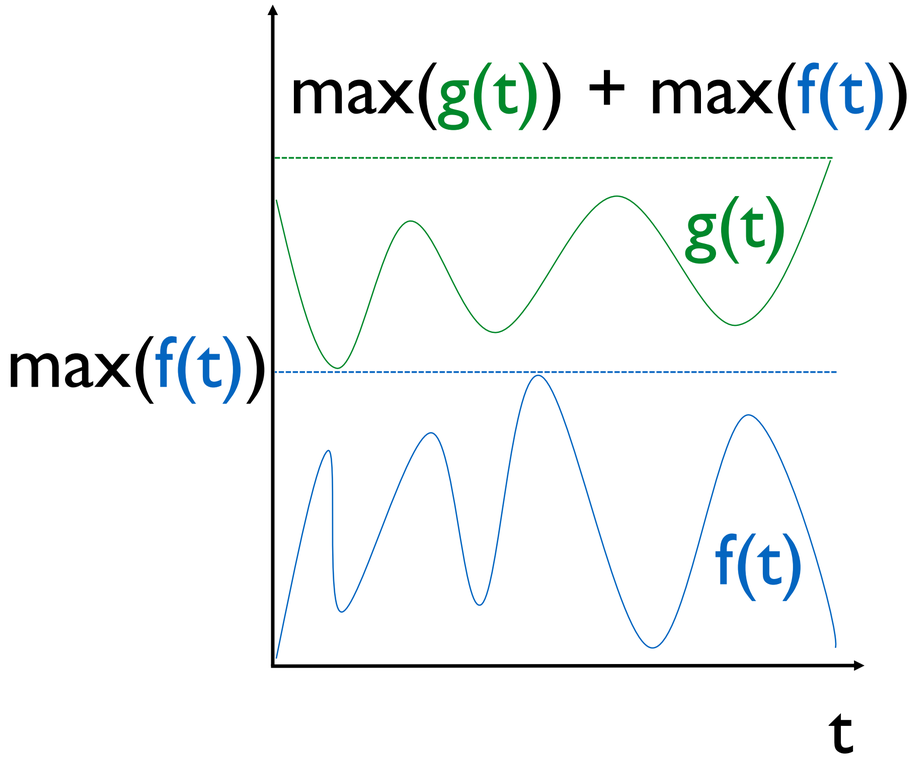

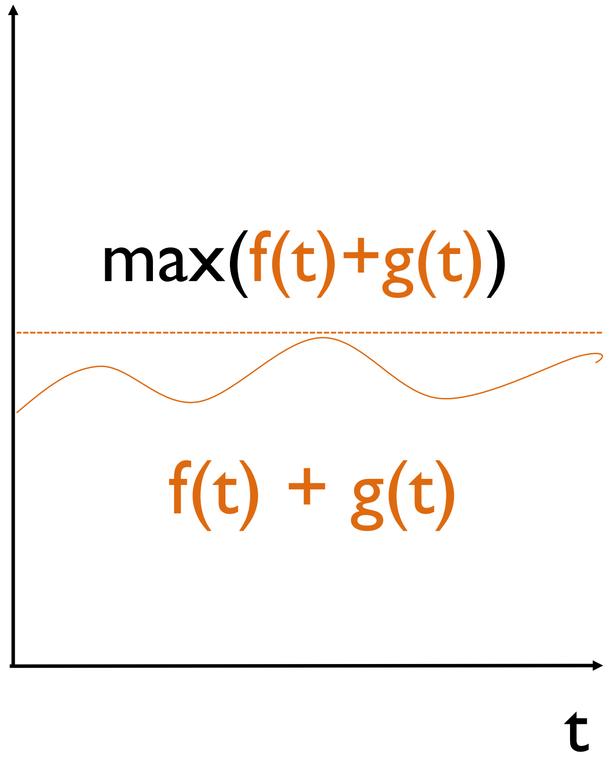

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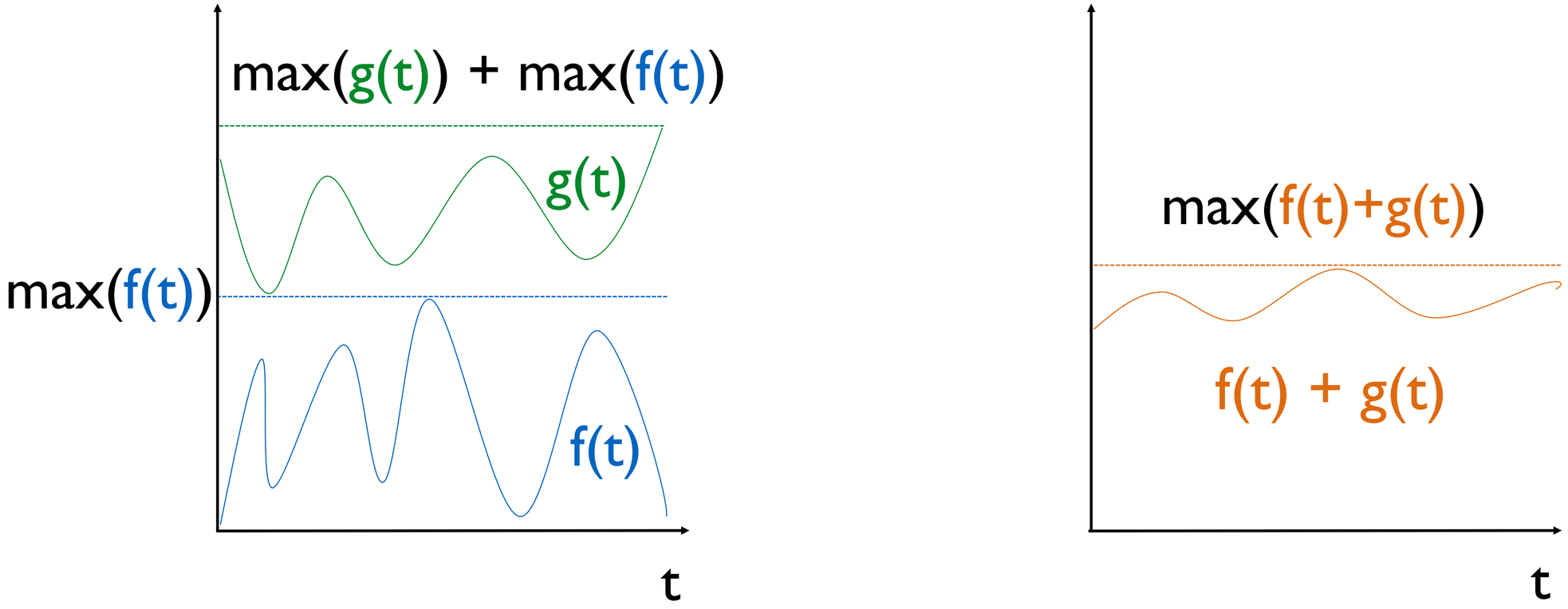

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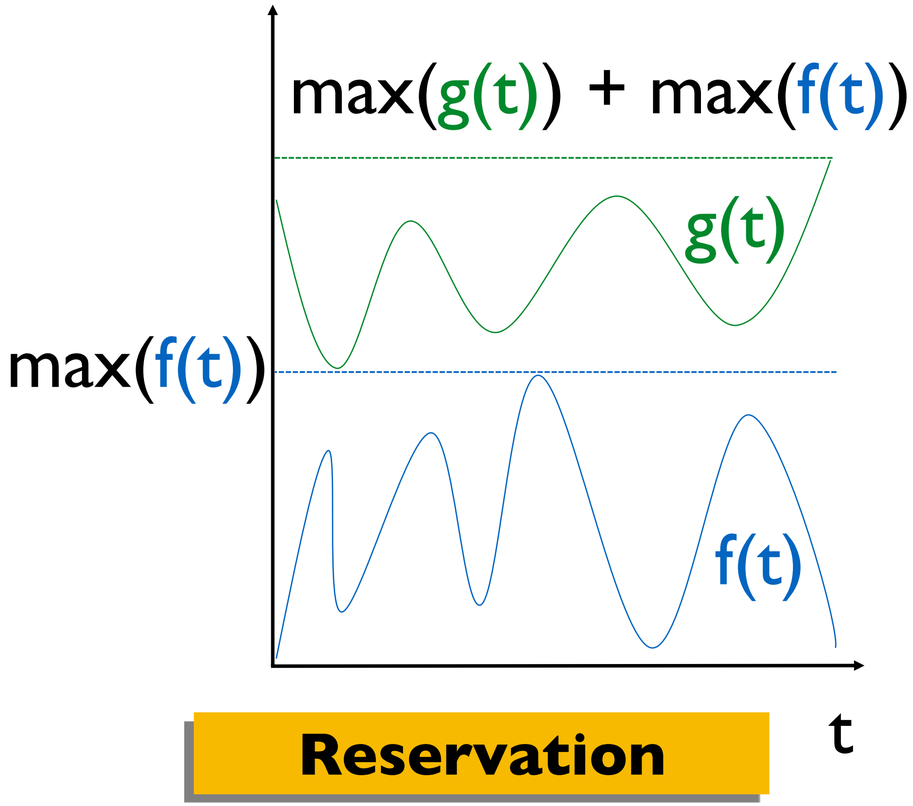

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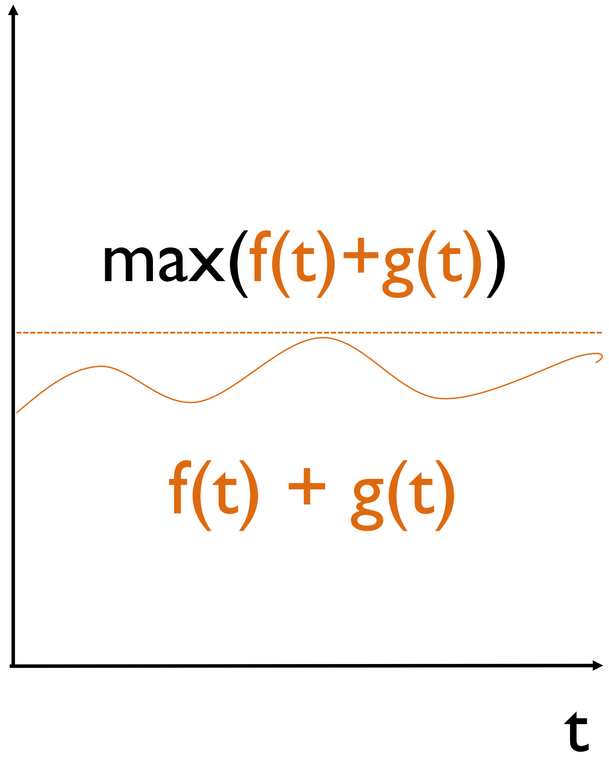

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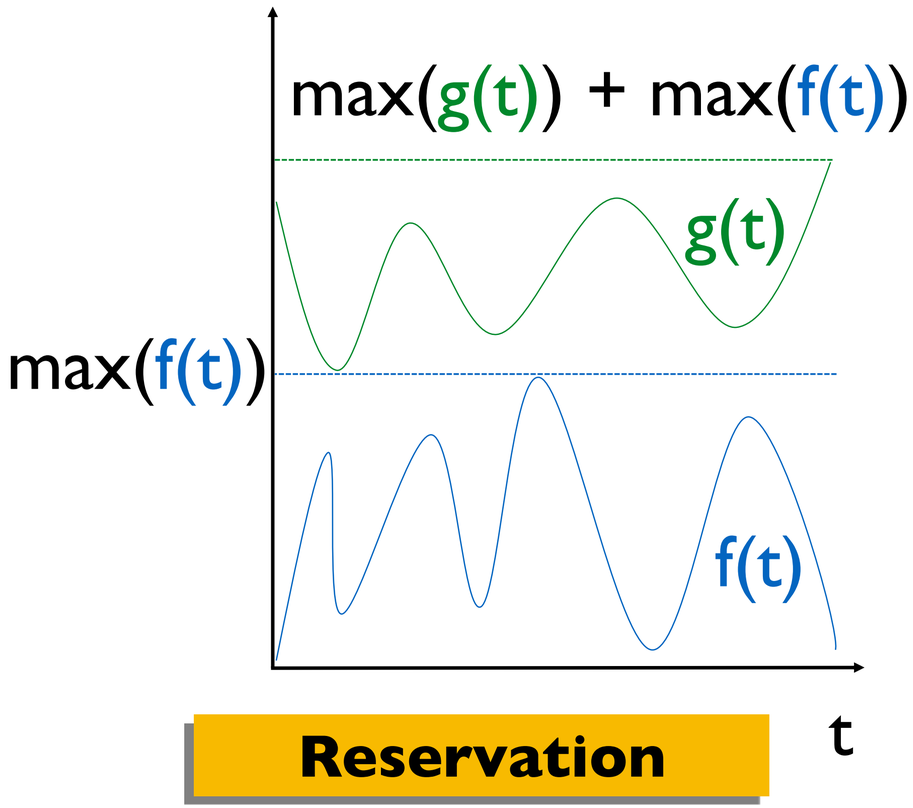

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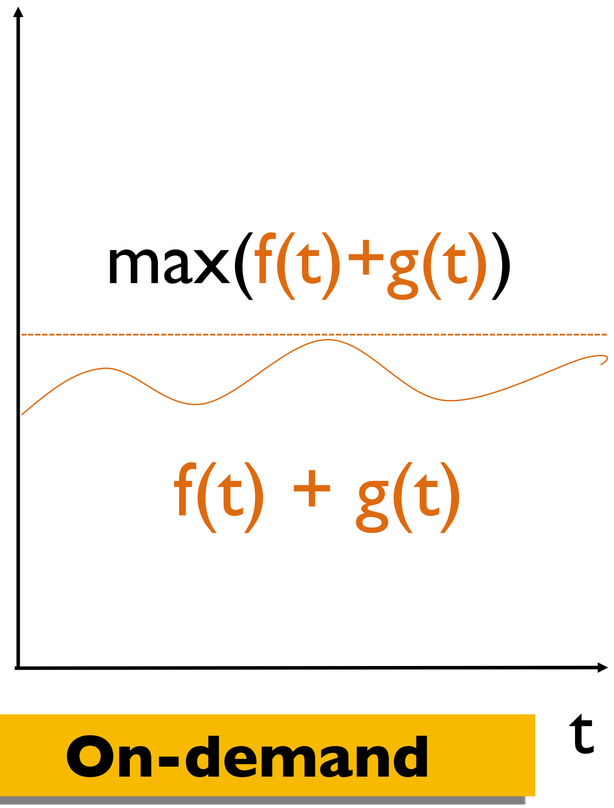

On-demand

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Questions?

Today's Agenda

- More details on What & How of the Internet
- Sharing a network
- Evaluating a network

Performance Metrics

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- **Loss:** What fraction of the packets sent to the destination are dropped?
- **Throughput:** At what rate is the destination receiving data from the source?

Delay

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- Consists of four components

Delay

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  - **Transmission Delay**

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Due to link properties

Due to traffic matrix and switch internals

A Network Link

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- **Bandwidth-Delay Product (BDP)**
  - Number of bits "in flight" at any time
  - BDP = Bandwidth x Propagation delay

Examples

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- **Same city over a slow link:**
  - **Bandwidth:** ~100Mbps
  - **Propagation delay:** ~0.1ms
  - **BDP:** 10,000 bits (1.25KB)

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- **Cross country over a fast link:**
  - **Bandwidth:** ~10Gbps
  - **Propagation delay:** ~10ms
  - **BDP:** 10^8 bits (12.5MB)

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- **Example:**
  - **Packet size:** 1000 bits
  - **Rate:** 100 Mbits/s
  - **Delay:** 1000 bits / (100 * 10^6 Mbits/s) = 10^{-5} s

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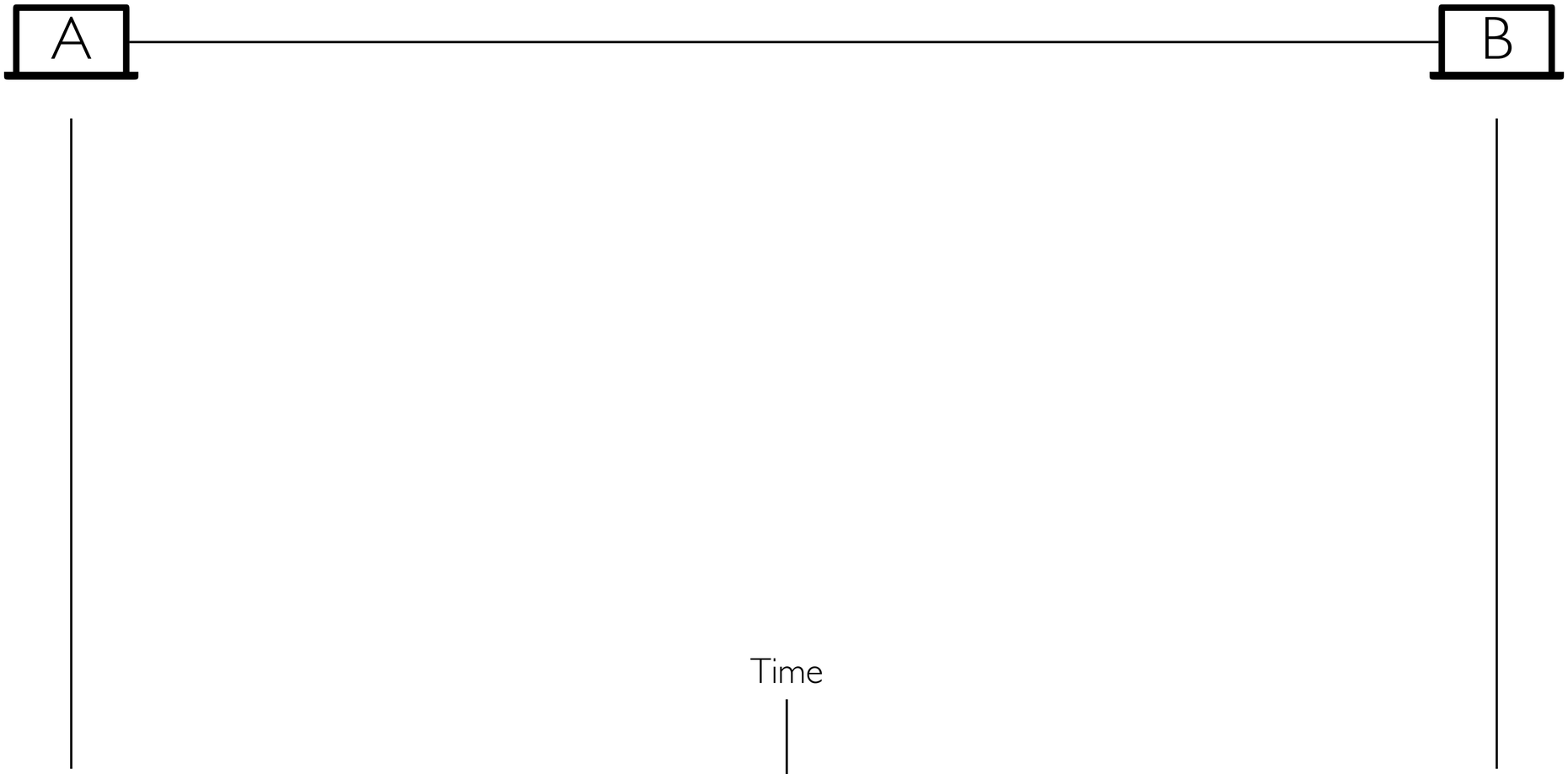
- **Example:**
  - **Length:** 30 km = 30,000 m
  - **Delay:** 30,000 m / ($3 * 10^8$ m/s) = 10^{-4} s

Packet Delay

Sending 100B packets from A to B?



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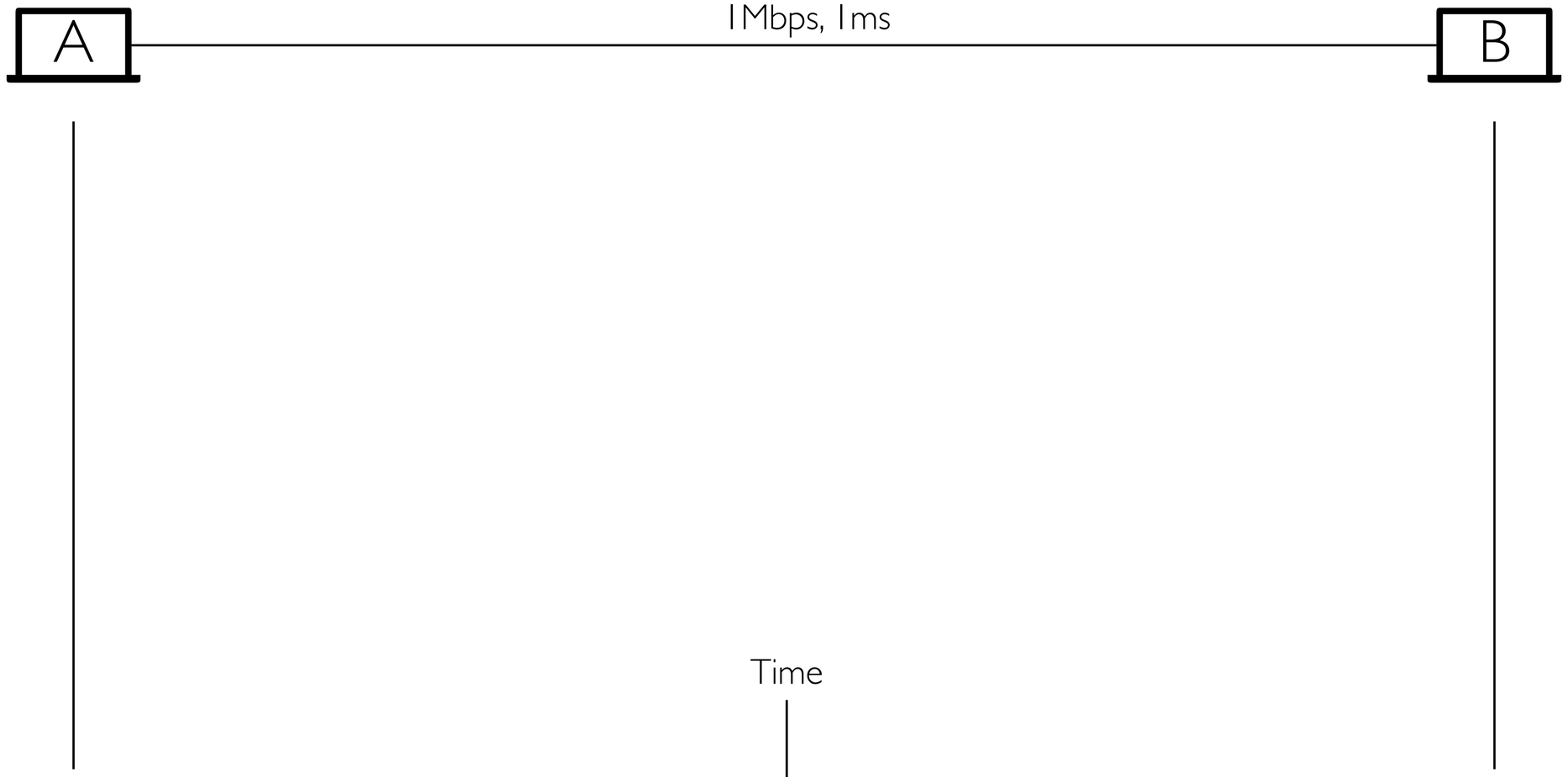

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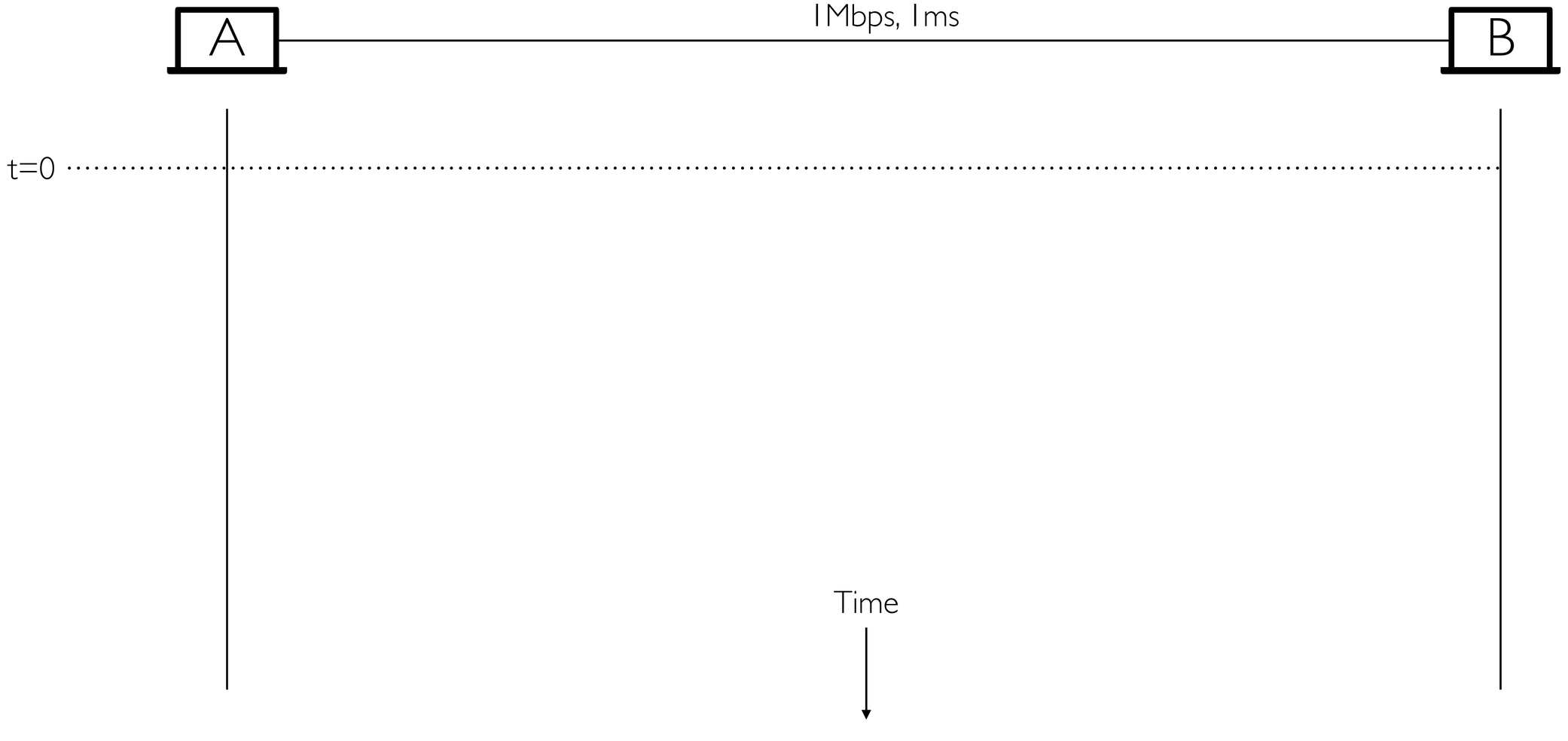

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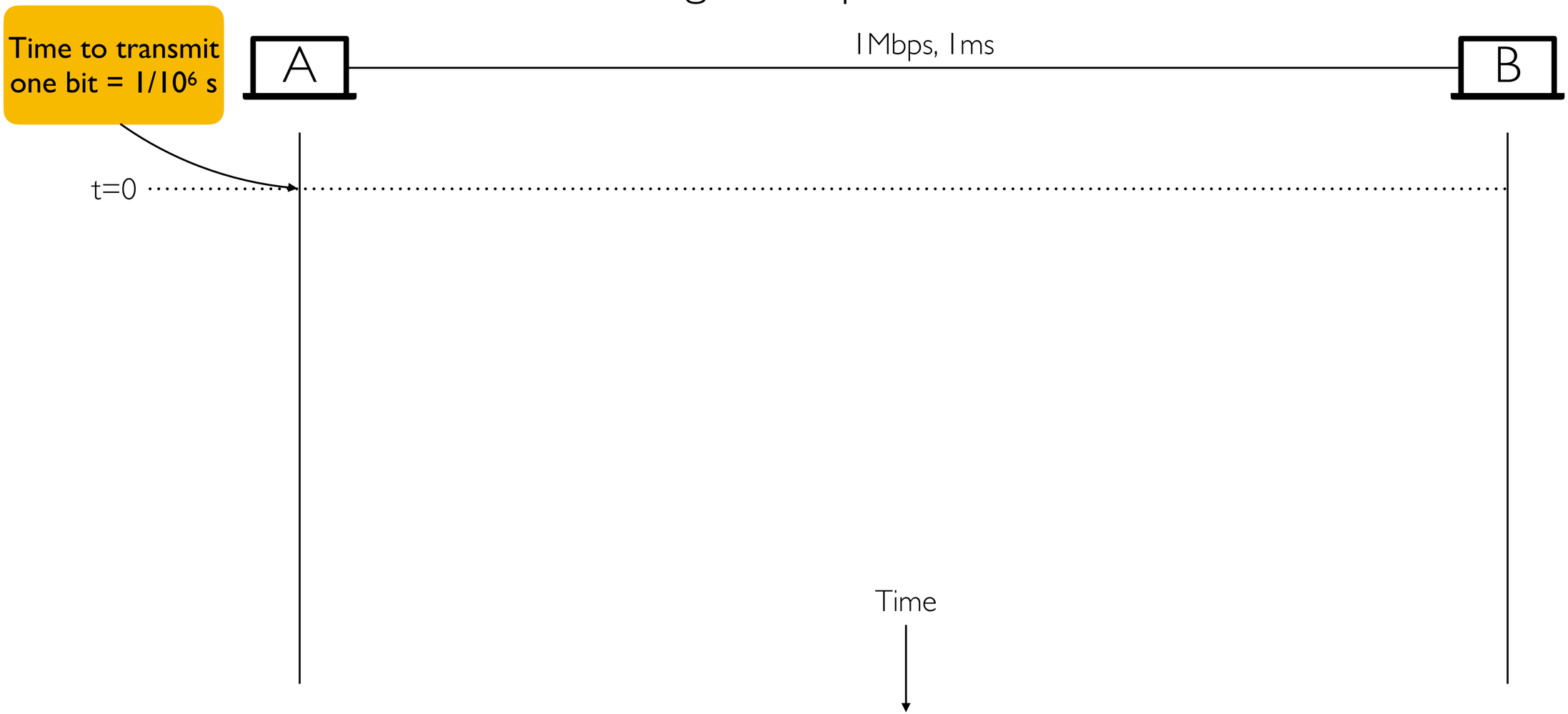

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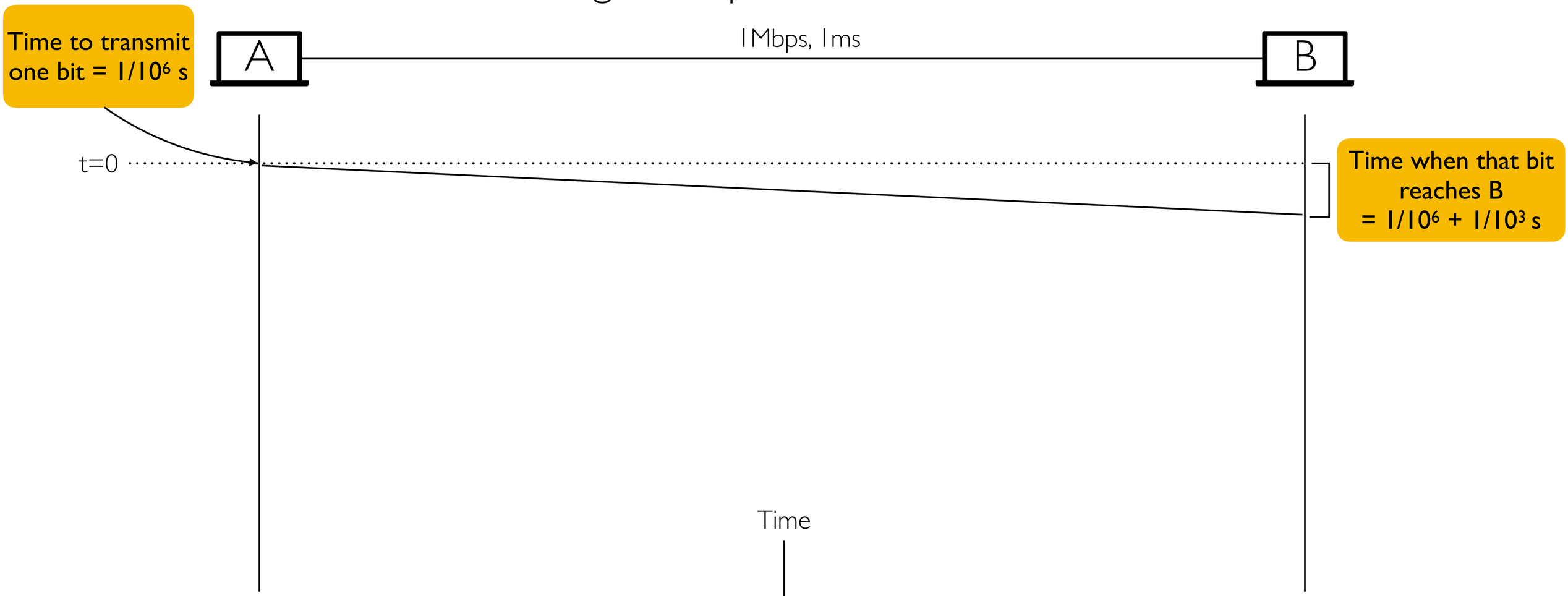

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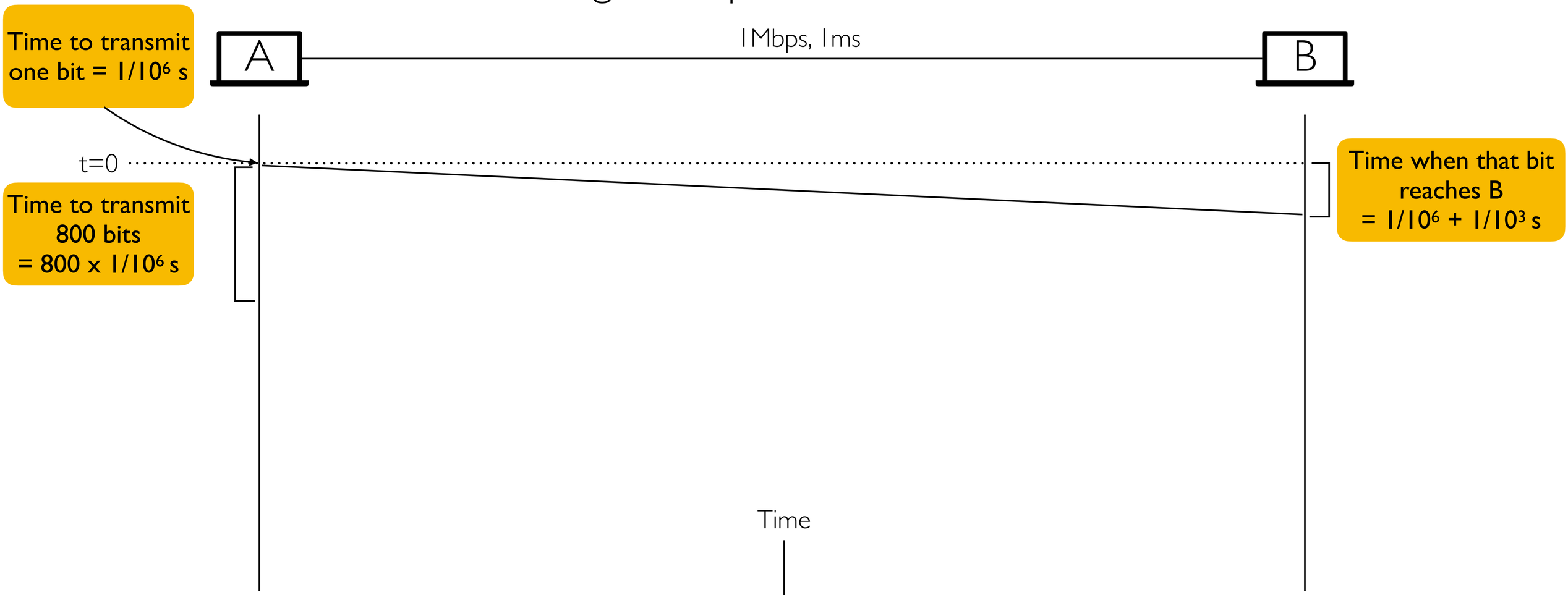

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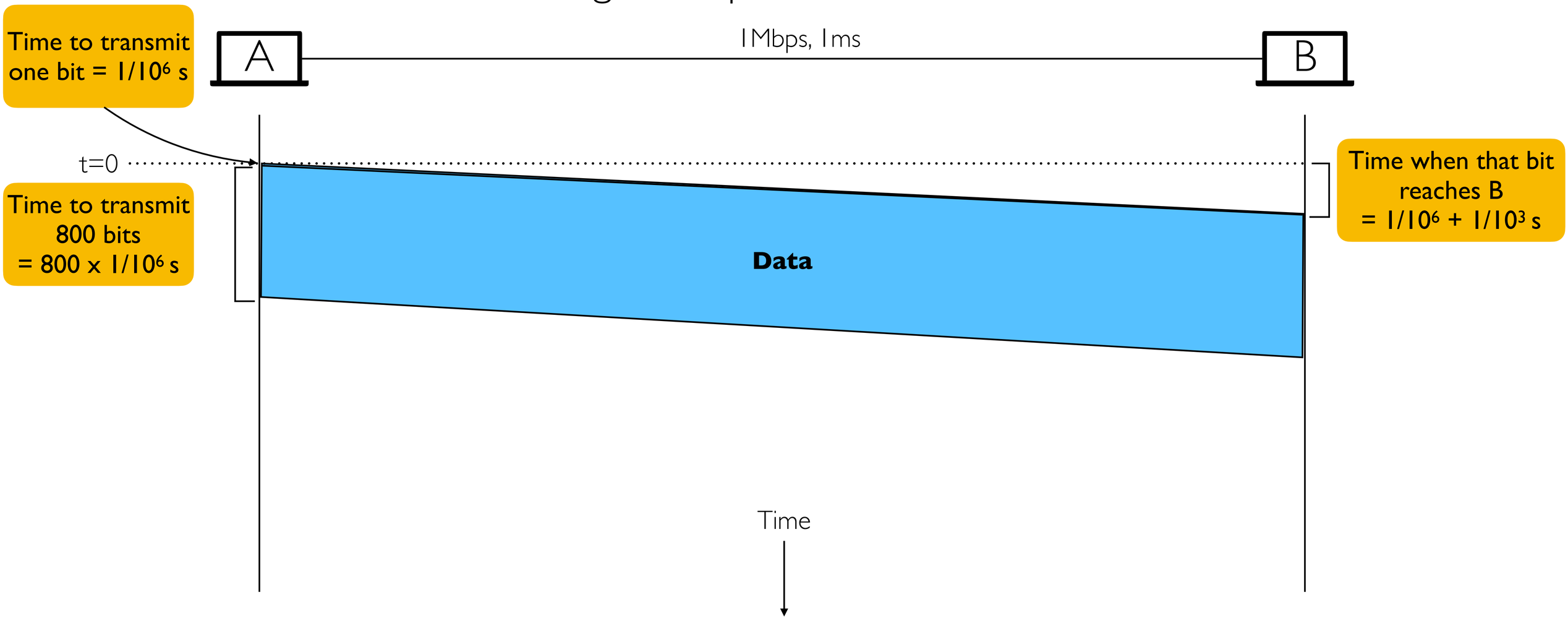

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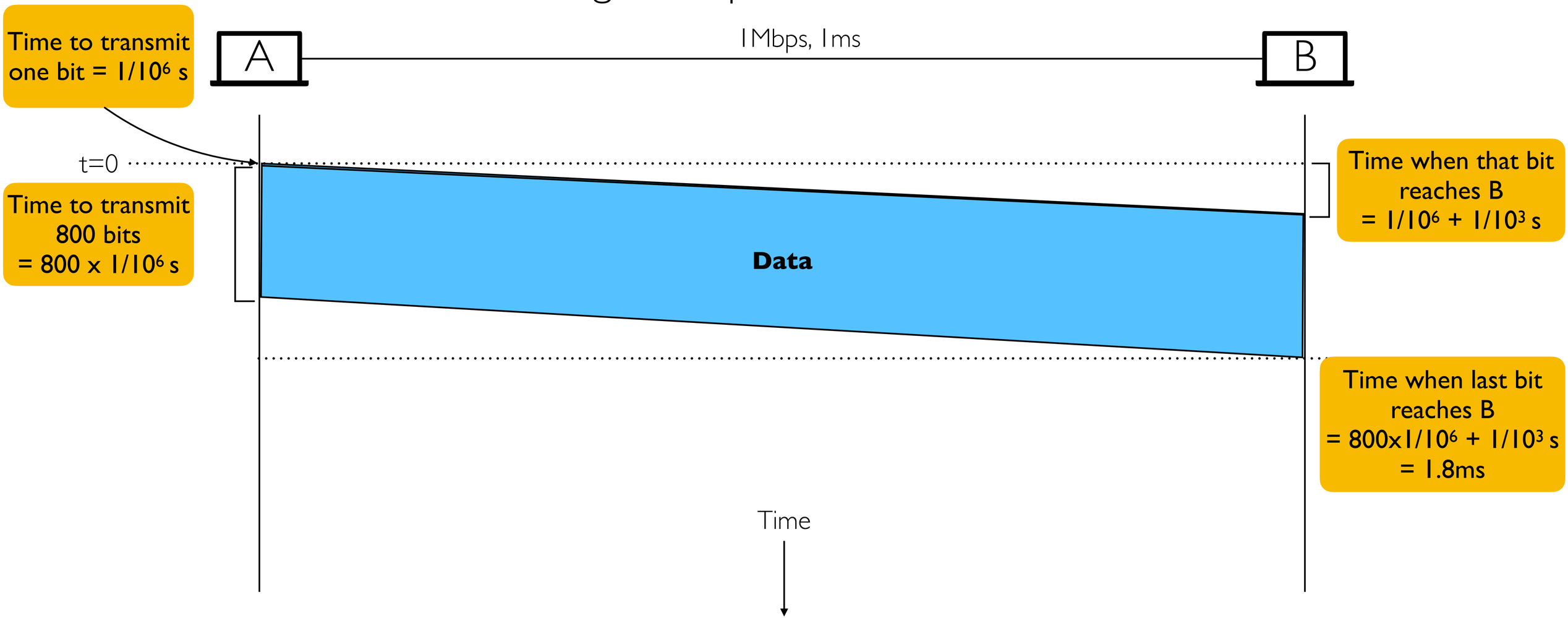

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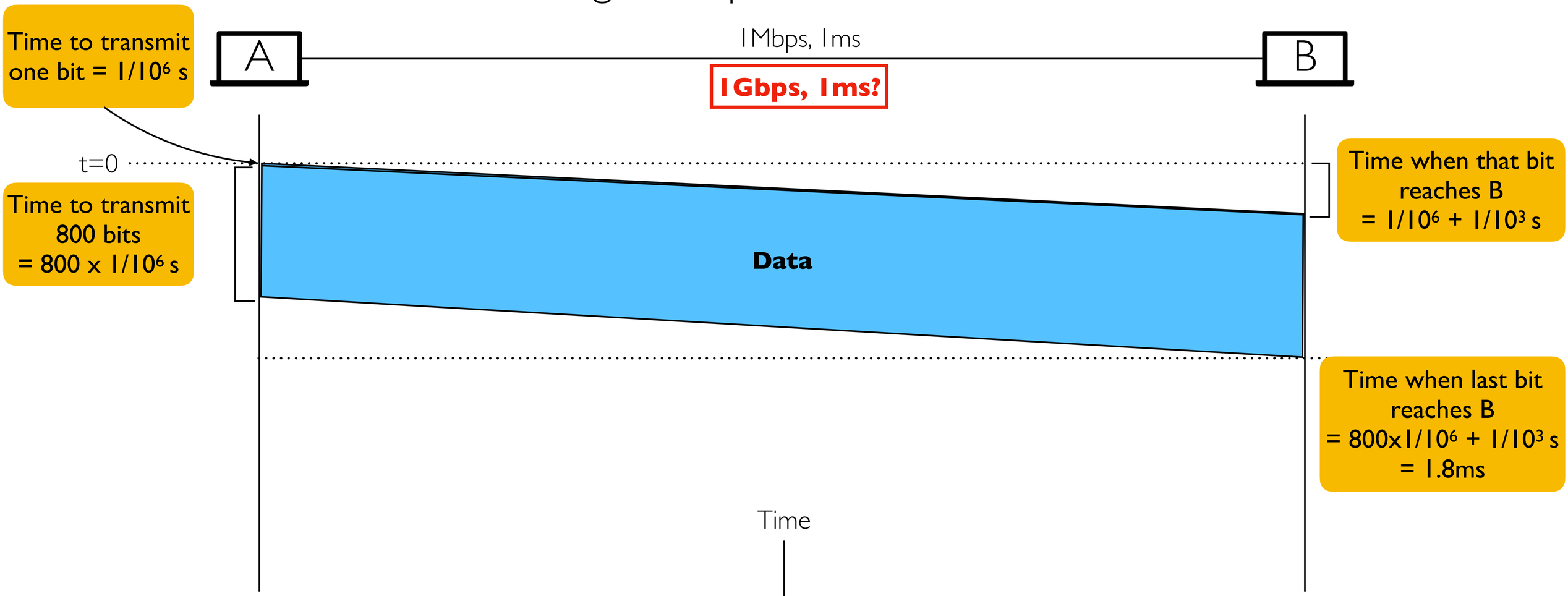

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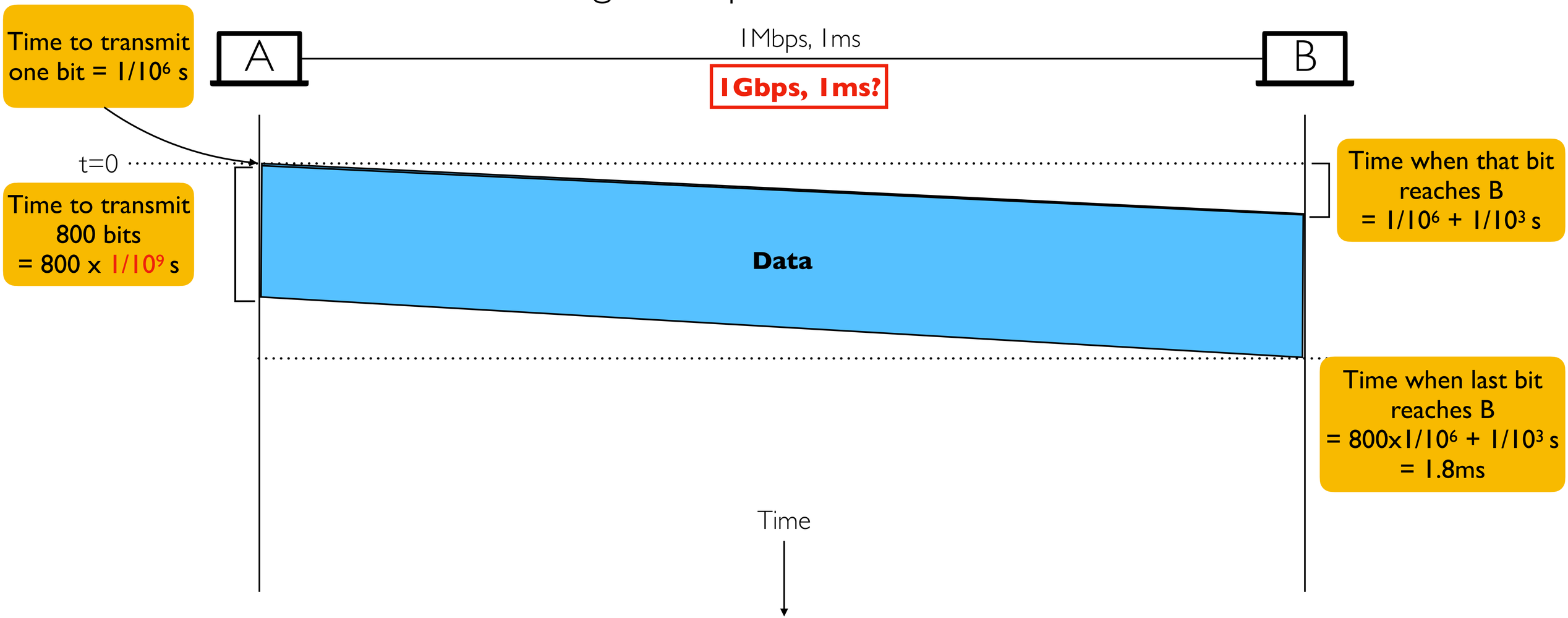

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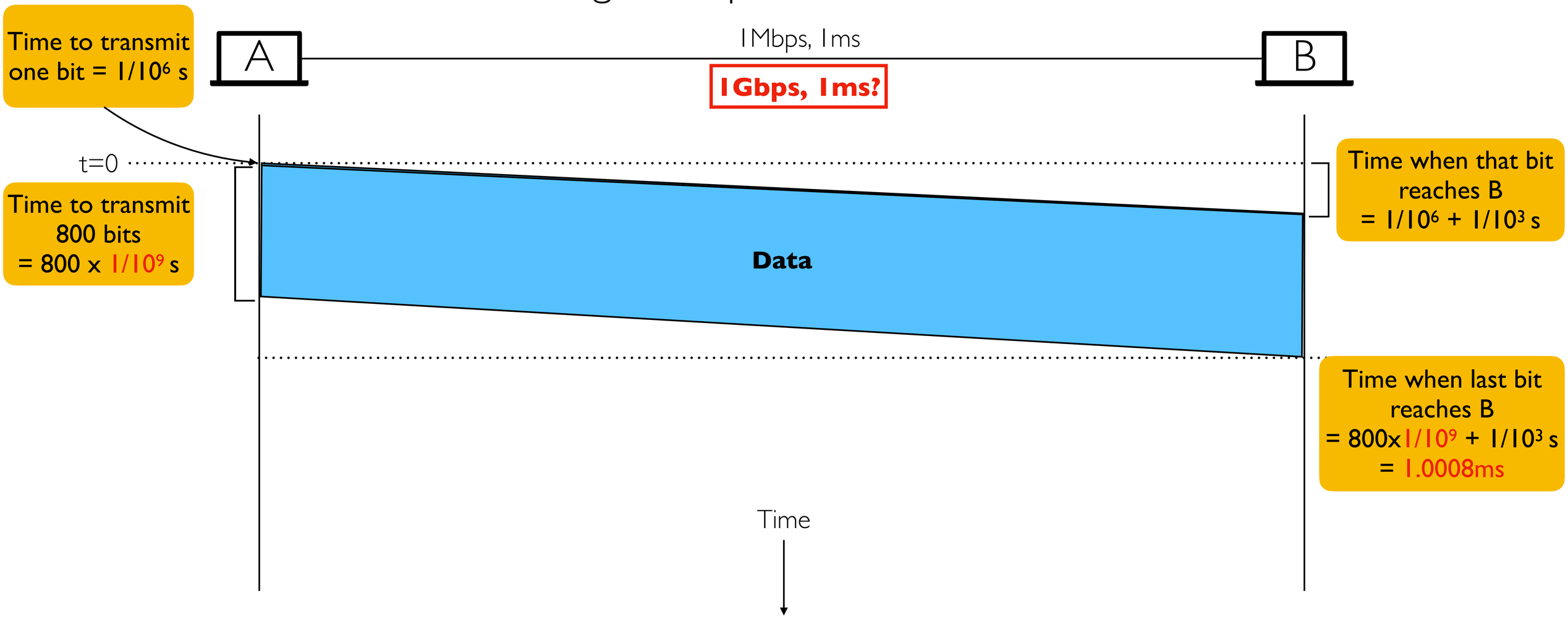

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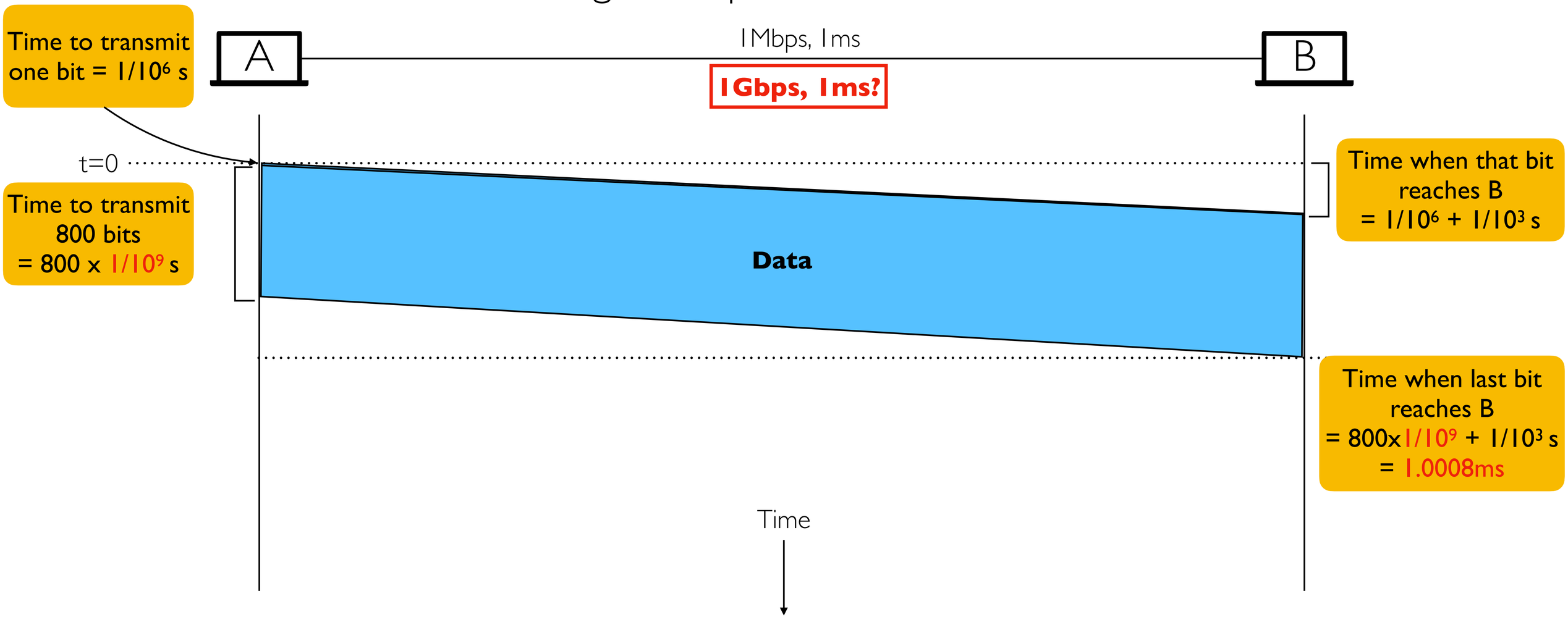

Packet Delay

1GB file in 100B packets

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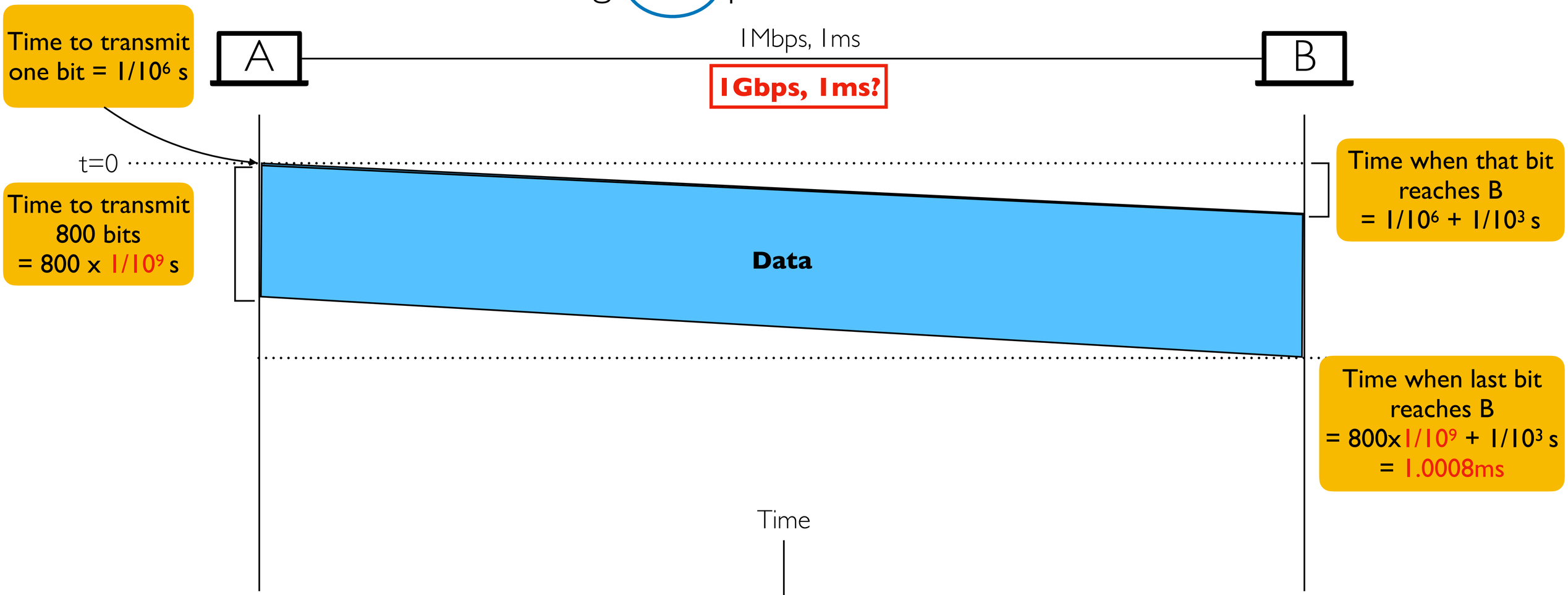

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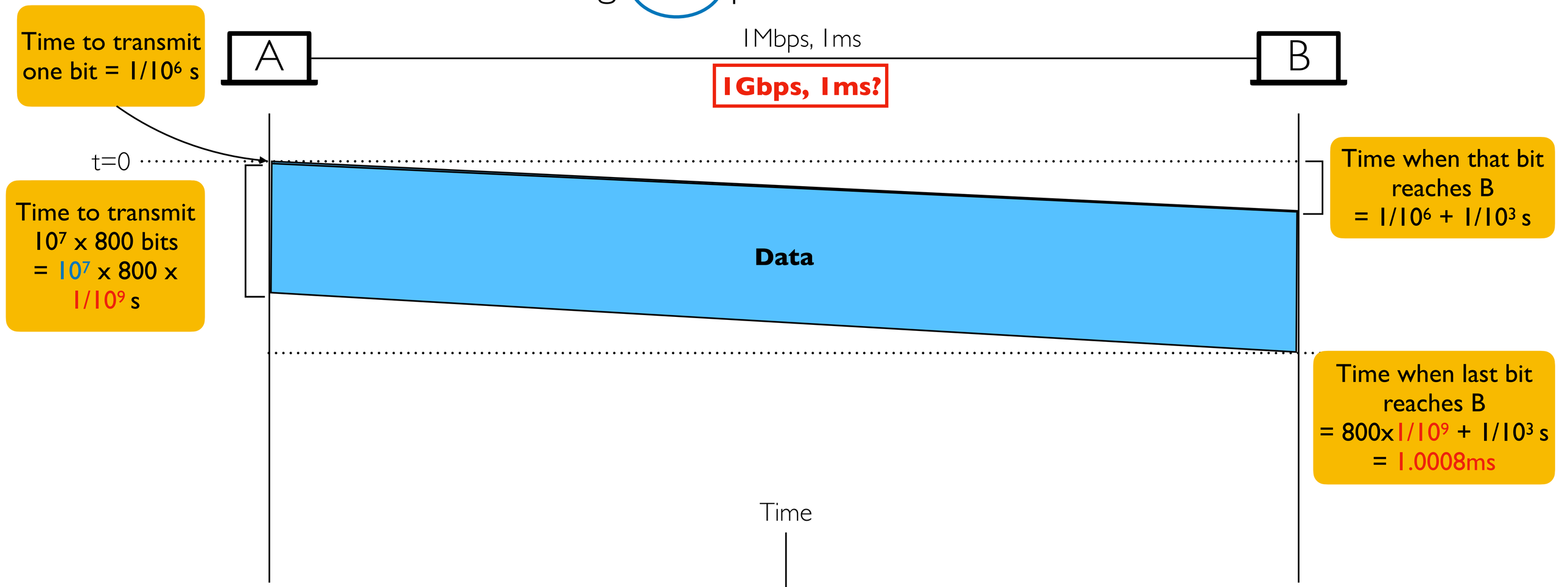

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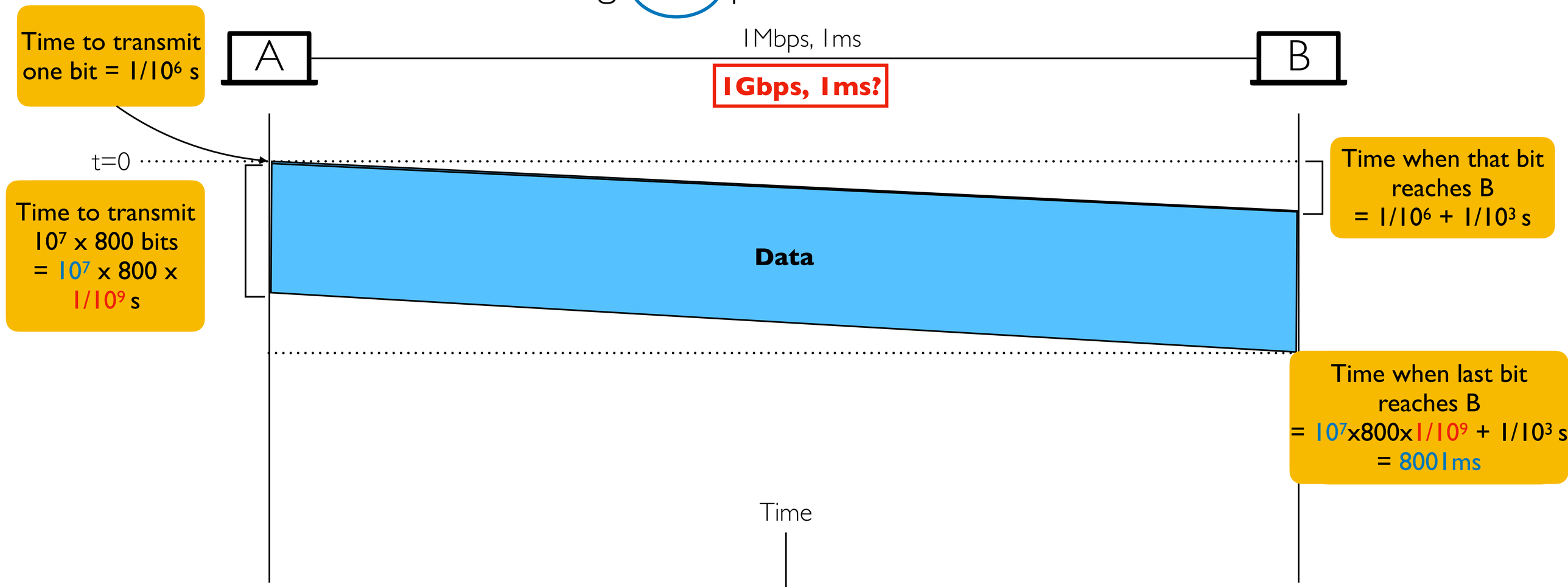
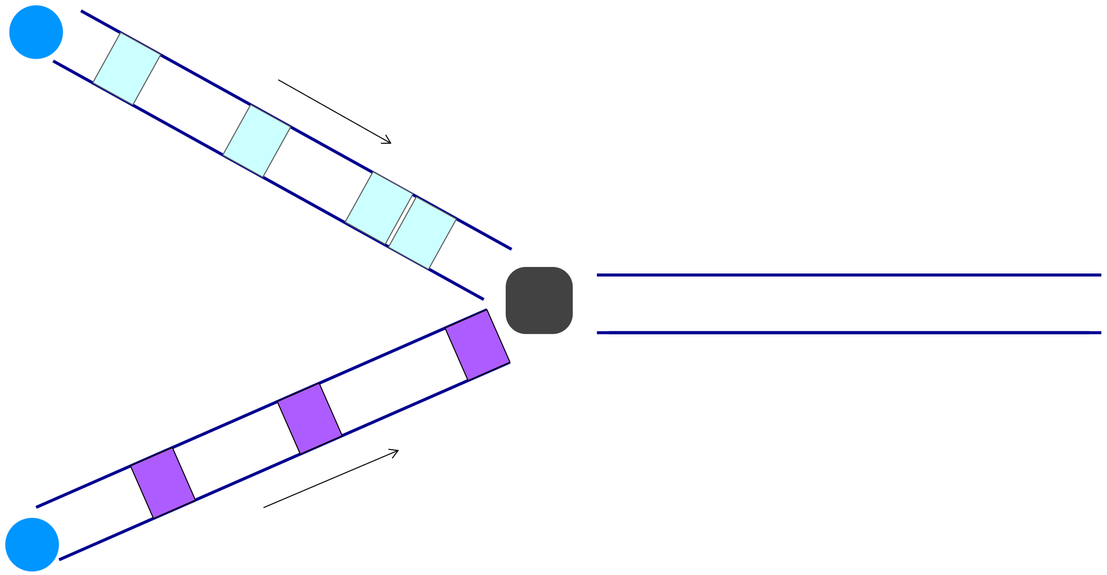


Questions?

Queueing Delay: "Pipe" View

- How long does a packet have to sit in a buffer before it is processed



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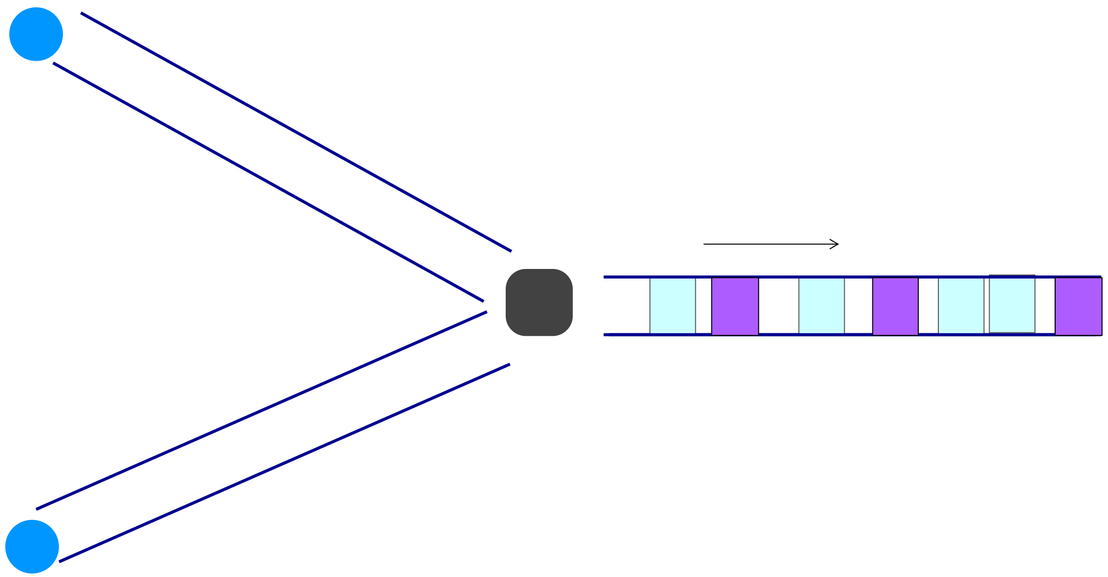

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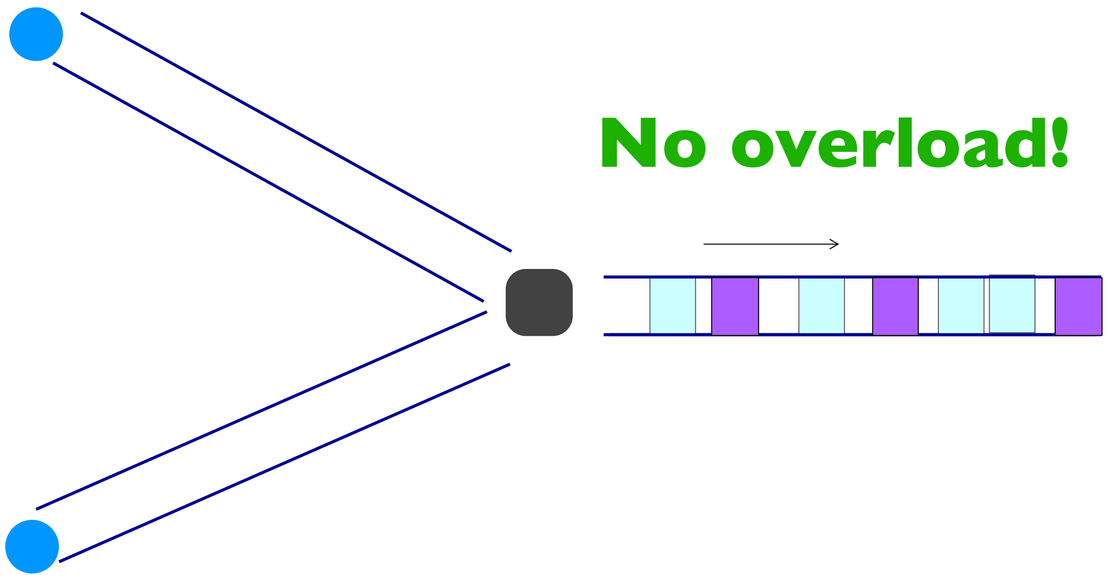

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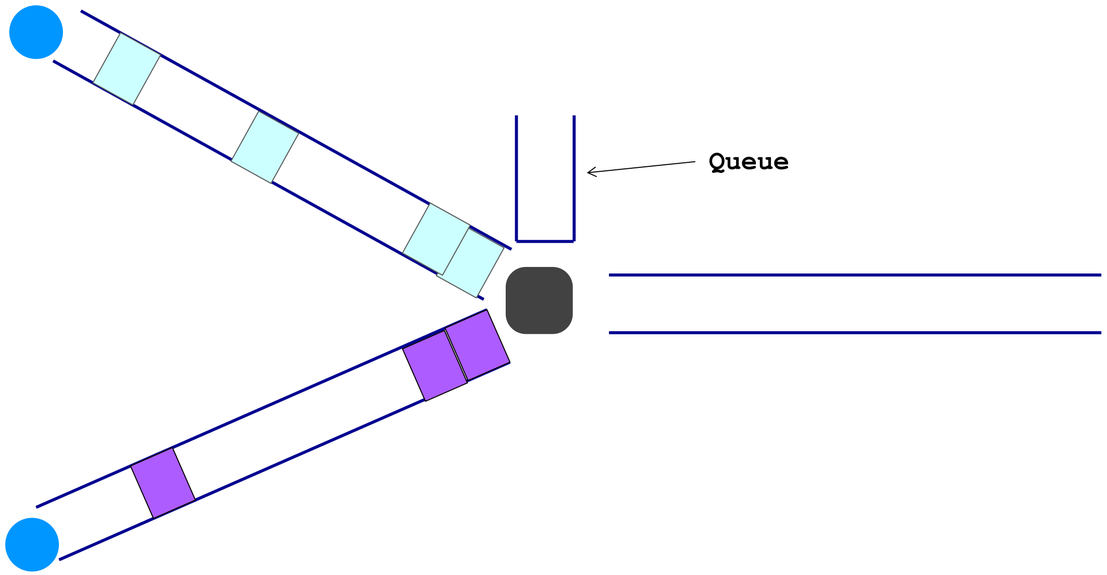

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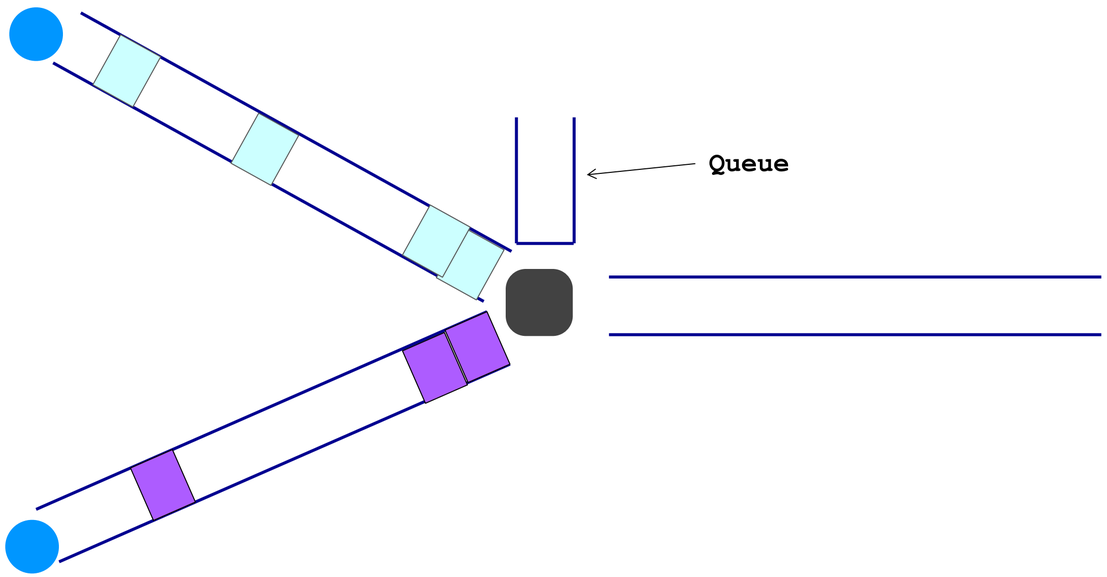

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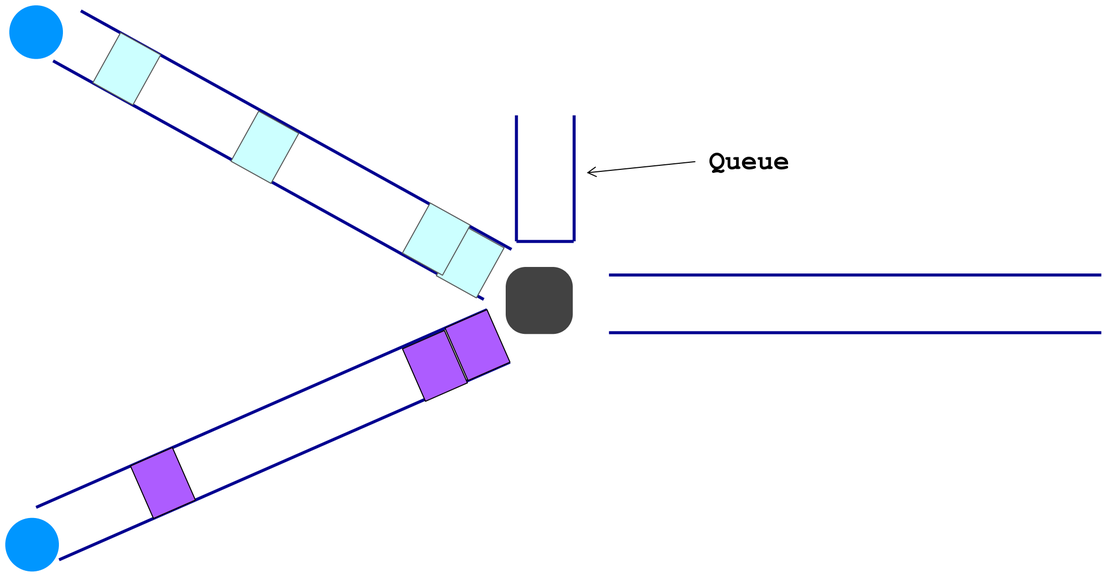

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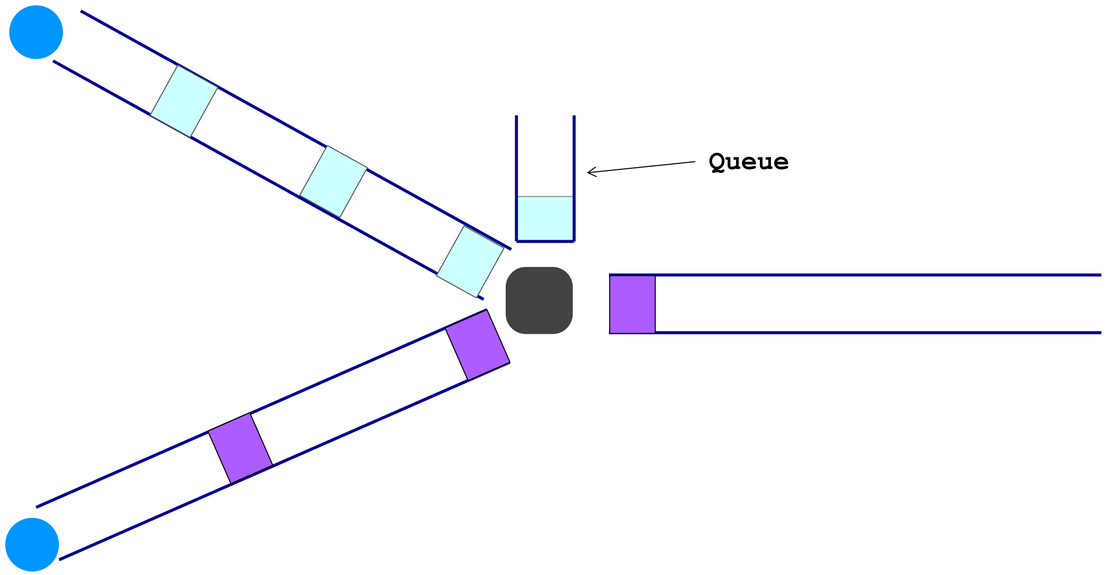

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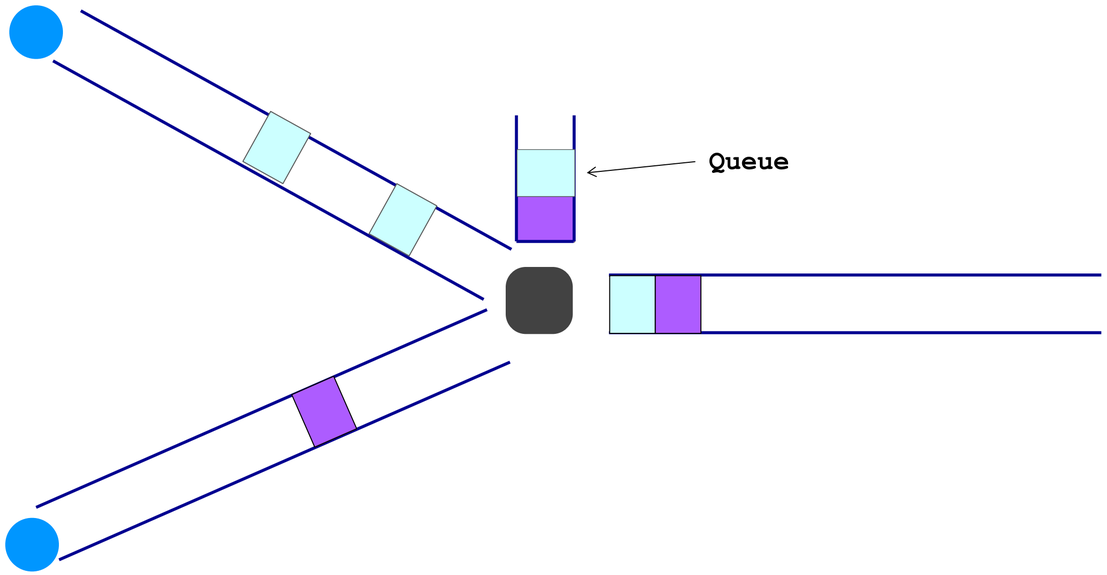

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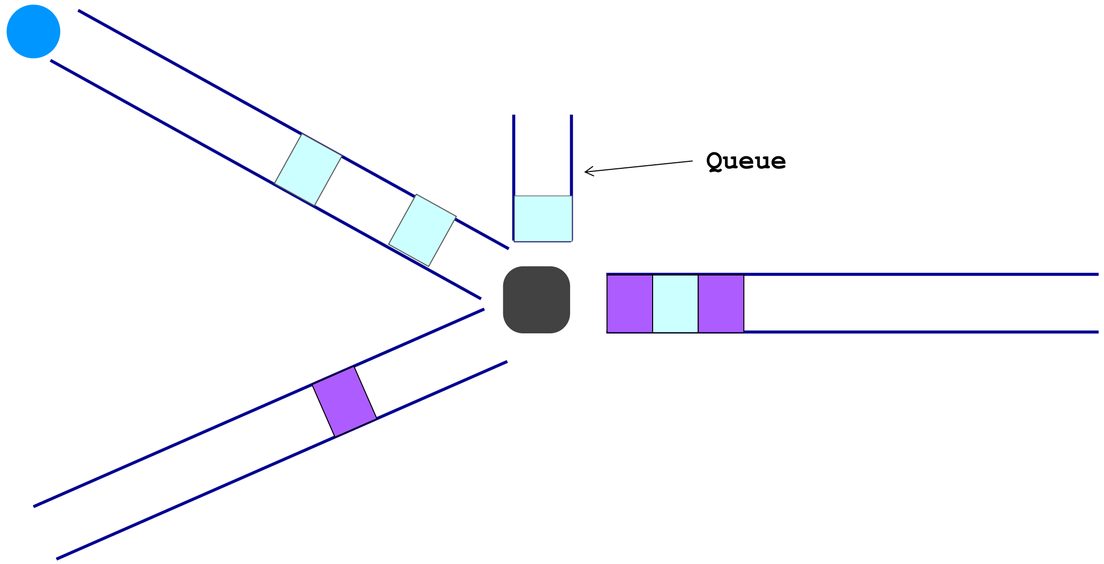

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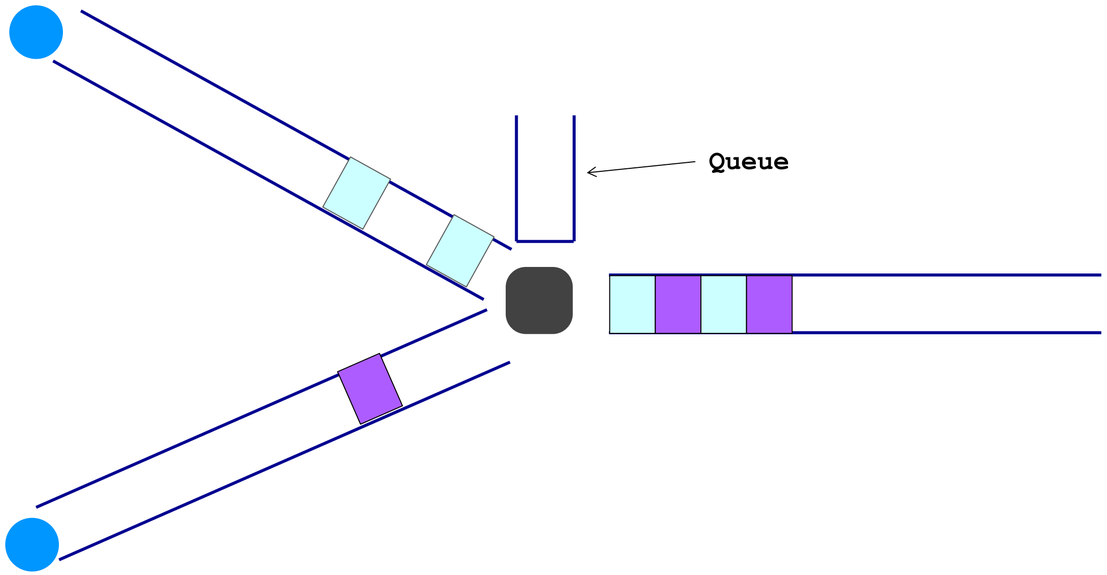

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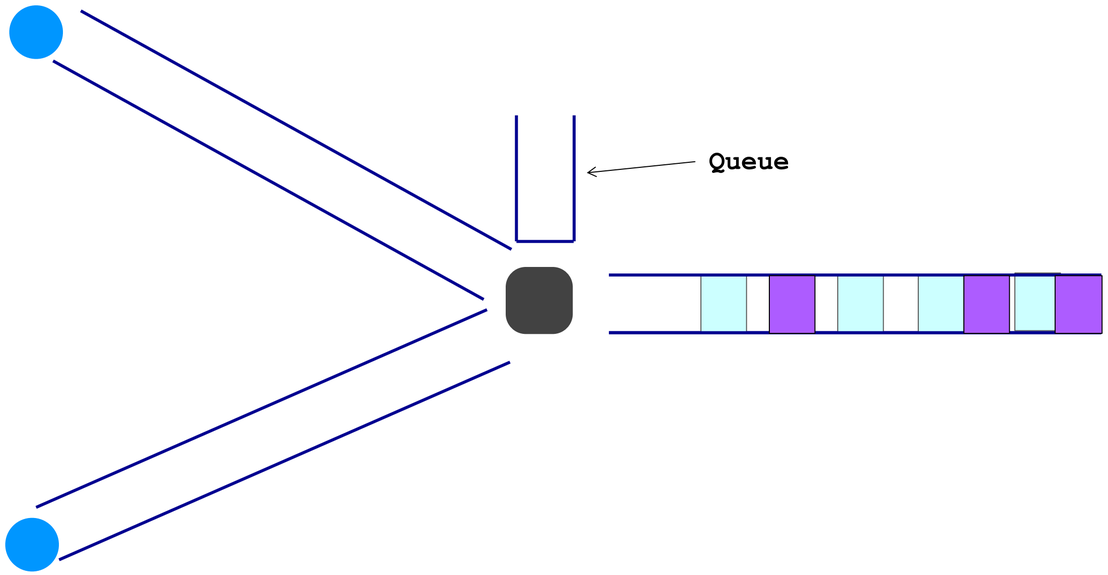

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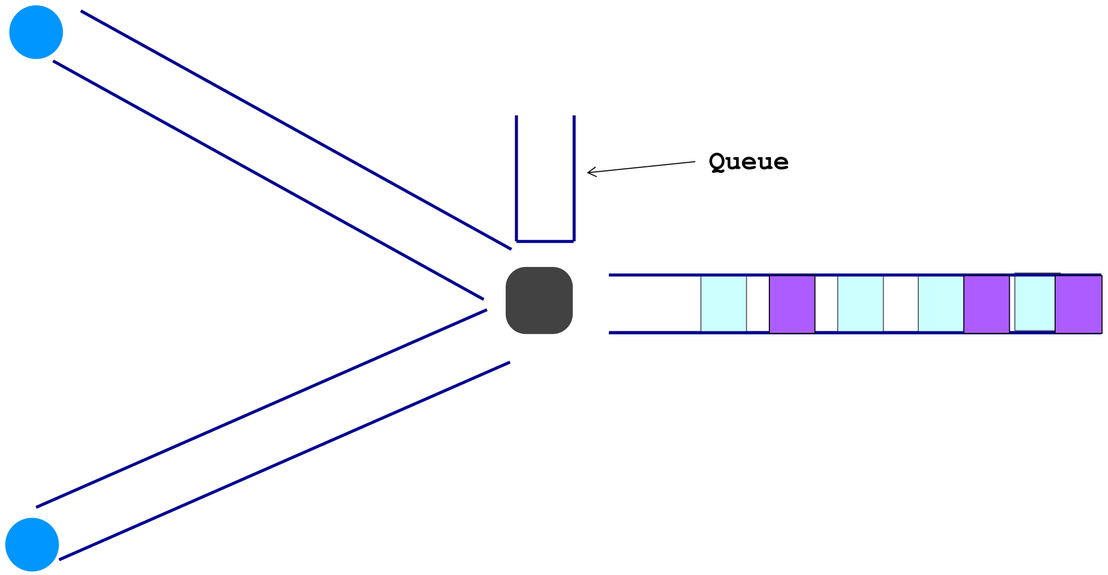

Queues absorb transient bursts but introduce queueing delay

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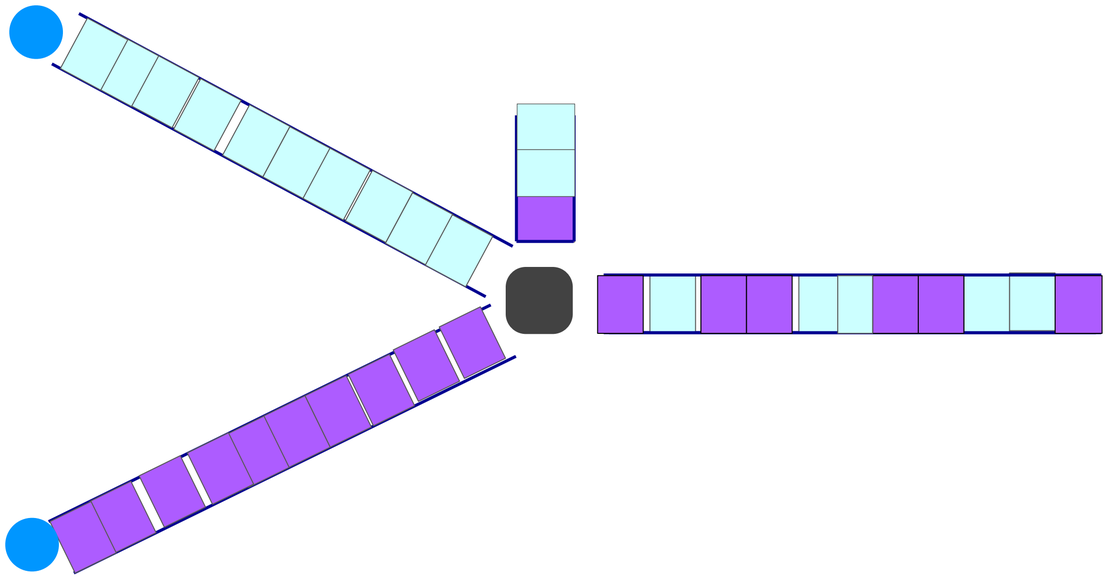

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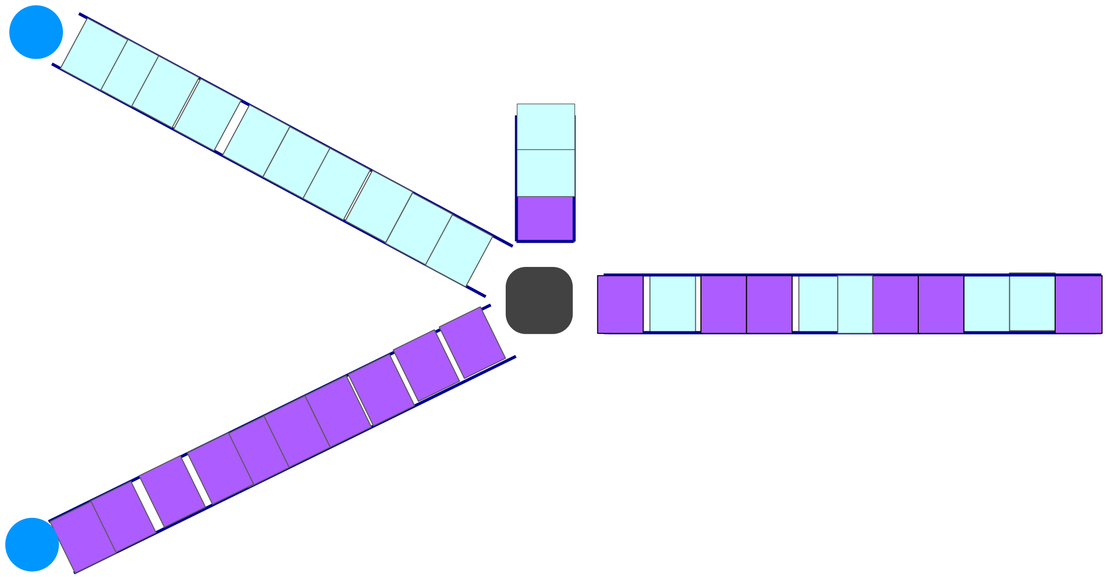

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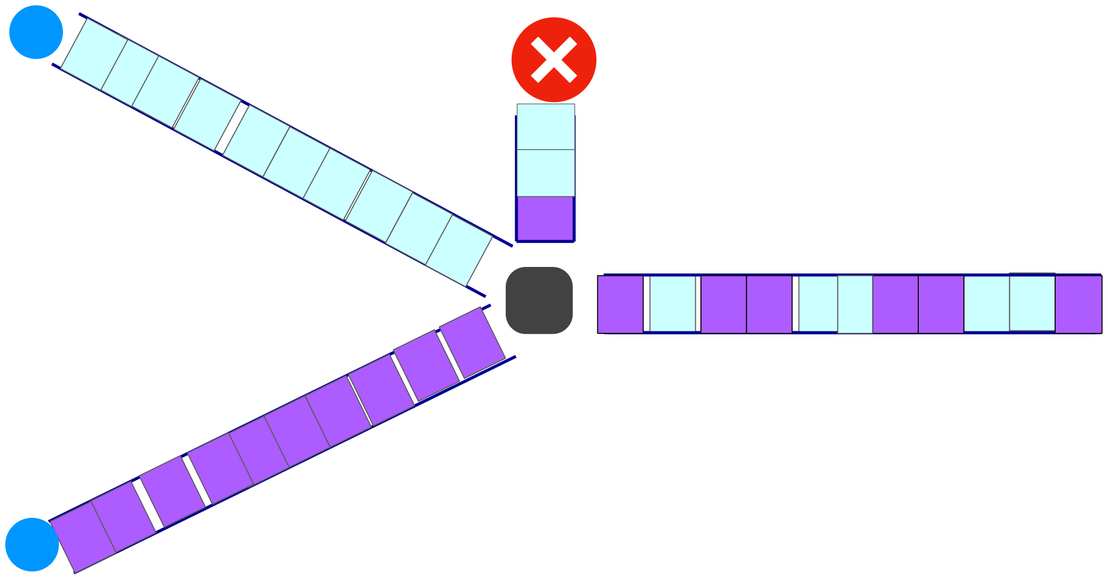

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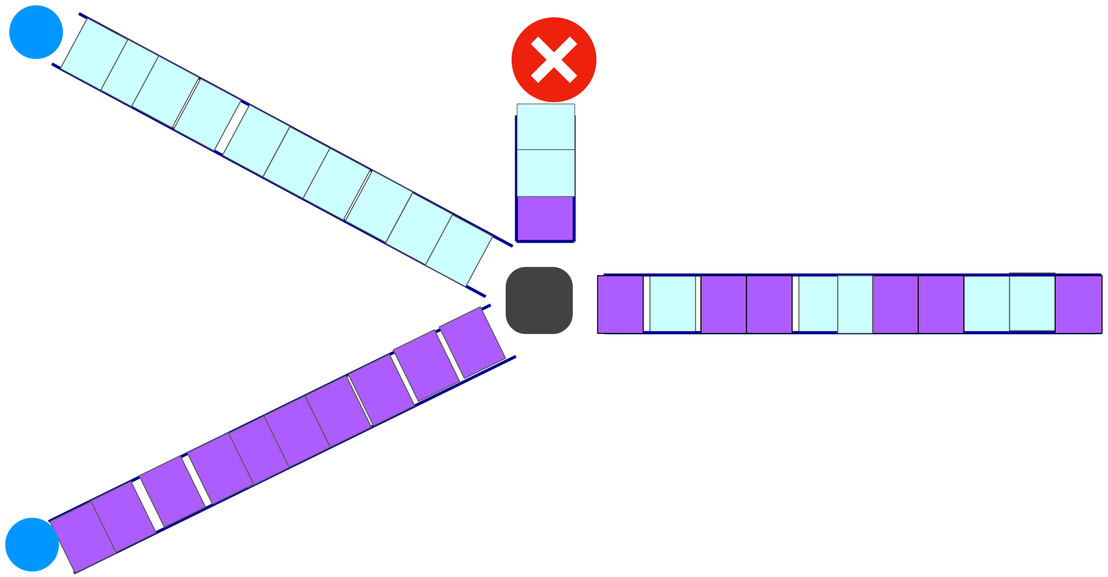

What about persistent overload?

Leads to packet loss

Queueing Delay

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- Depends on traffic pattern
- Characterized by statistical measures
  - Average queueing delay
  - Average arrival rate
  - Average departure rate

Basic Queueing Theory Terminology

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  - L for "length of the queue"

Little's Law (1969)

A: avg. packet arrival rate (/s)

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L = A x W

or,

W = L / A

Processing Delay

Processing Delay

- How long does a switch take to process this packet?
  - Typically assume this is negligible

Delay

- Consists of four components
  - Transmission Delay
  - Propagation Delay
  - Queueing Delay
  - Processing Delay

Transmission Delay, Propagation Delay: Due to link properties

Queueing Delay, Processing Delay: Due to traffic matrix and switch internals

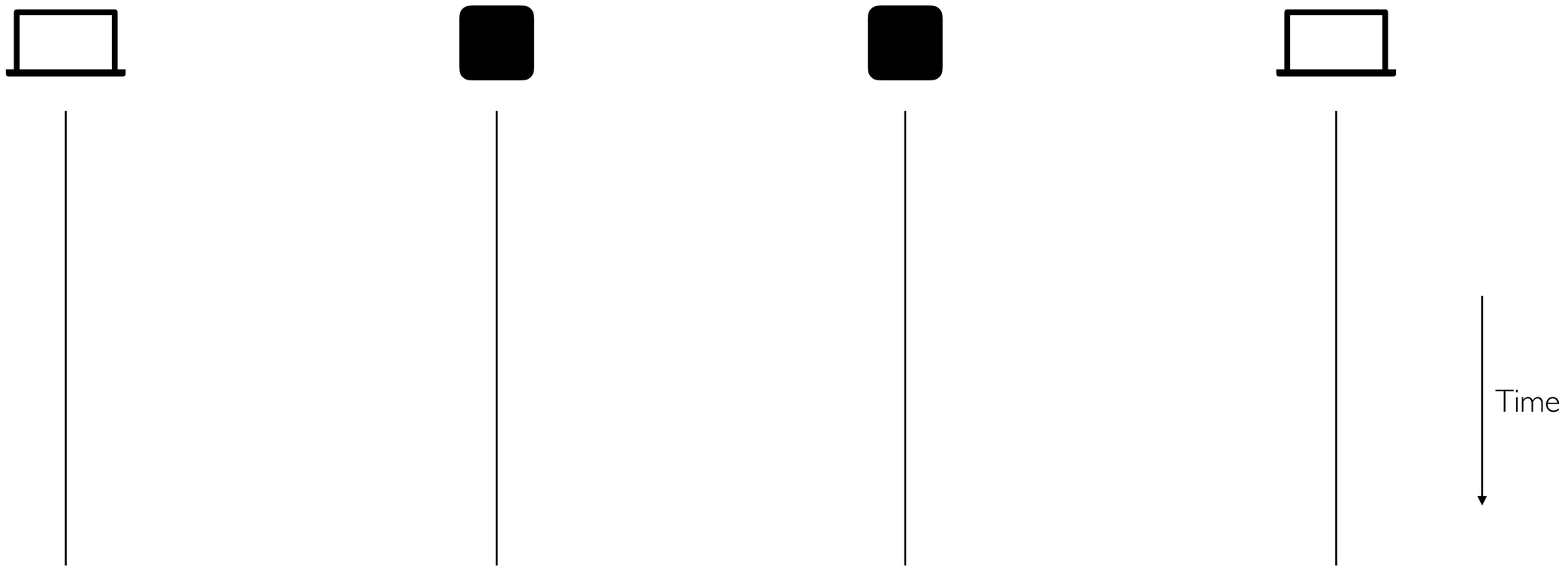
End-to-end Delay

T Transmission Delay

Q Queuing Delay

P Propagation Delay

Pr Processing Delay



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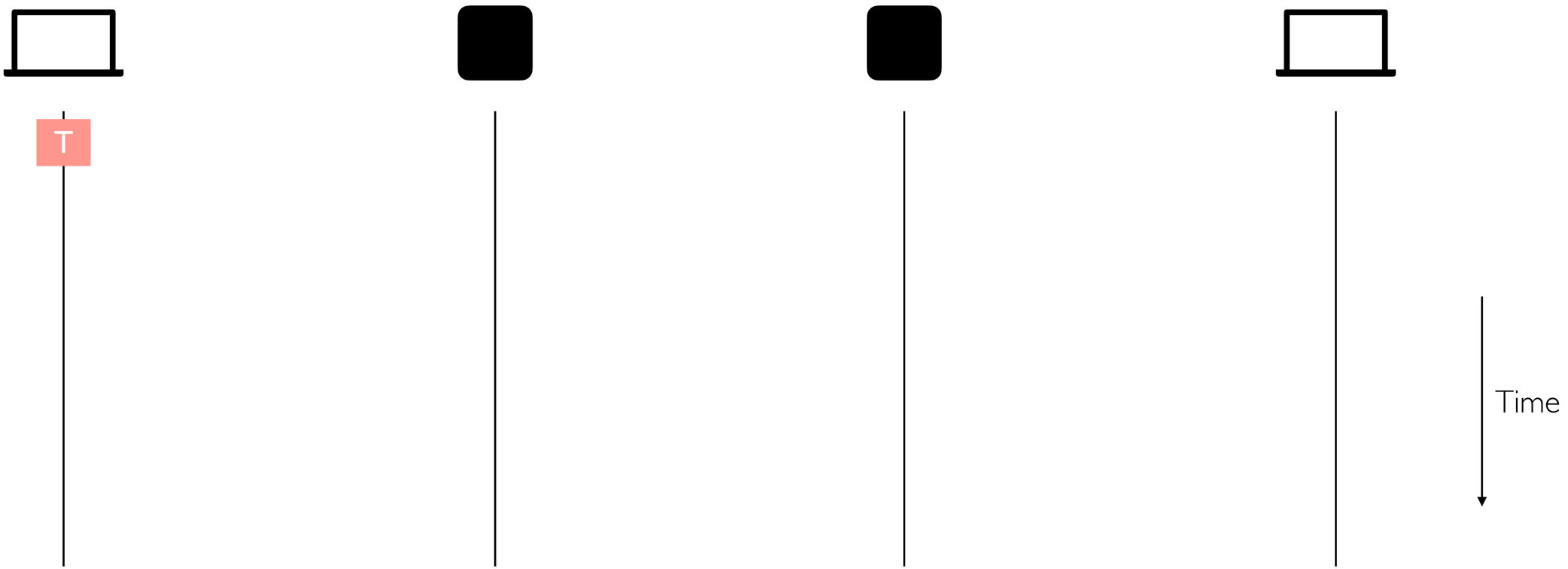

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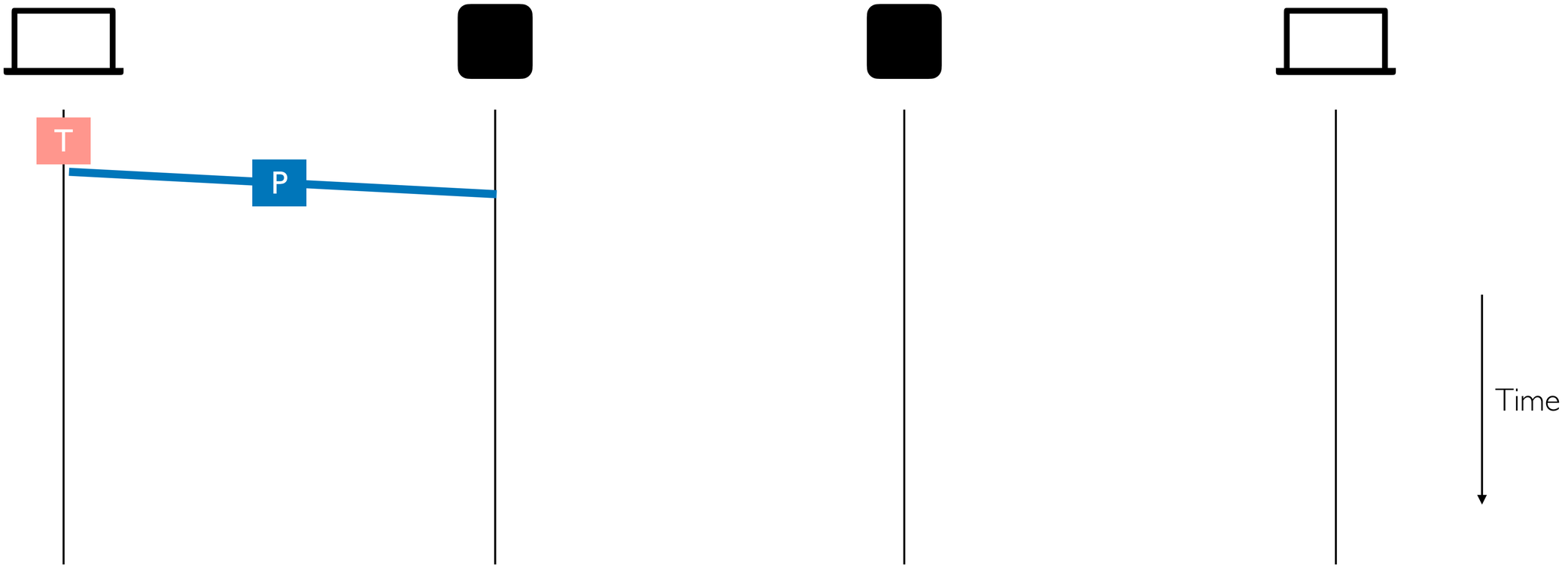

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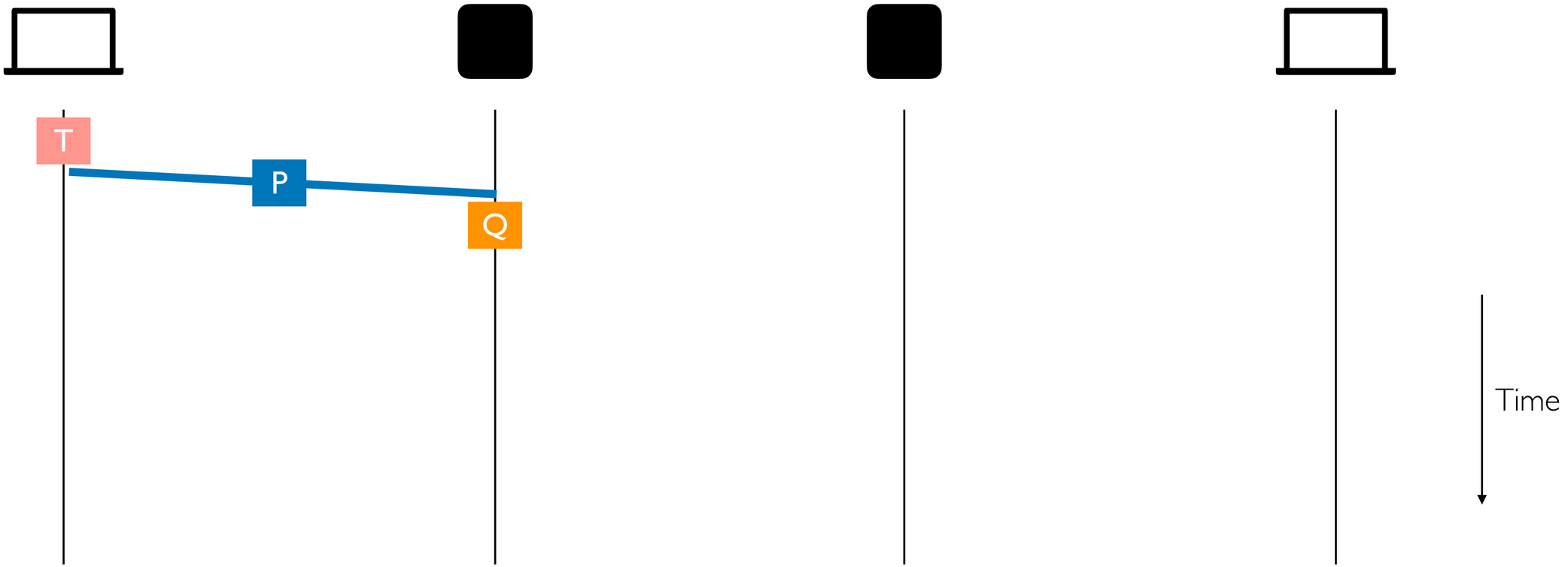

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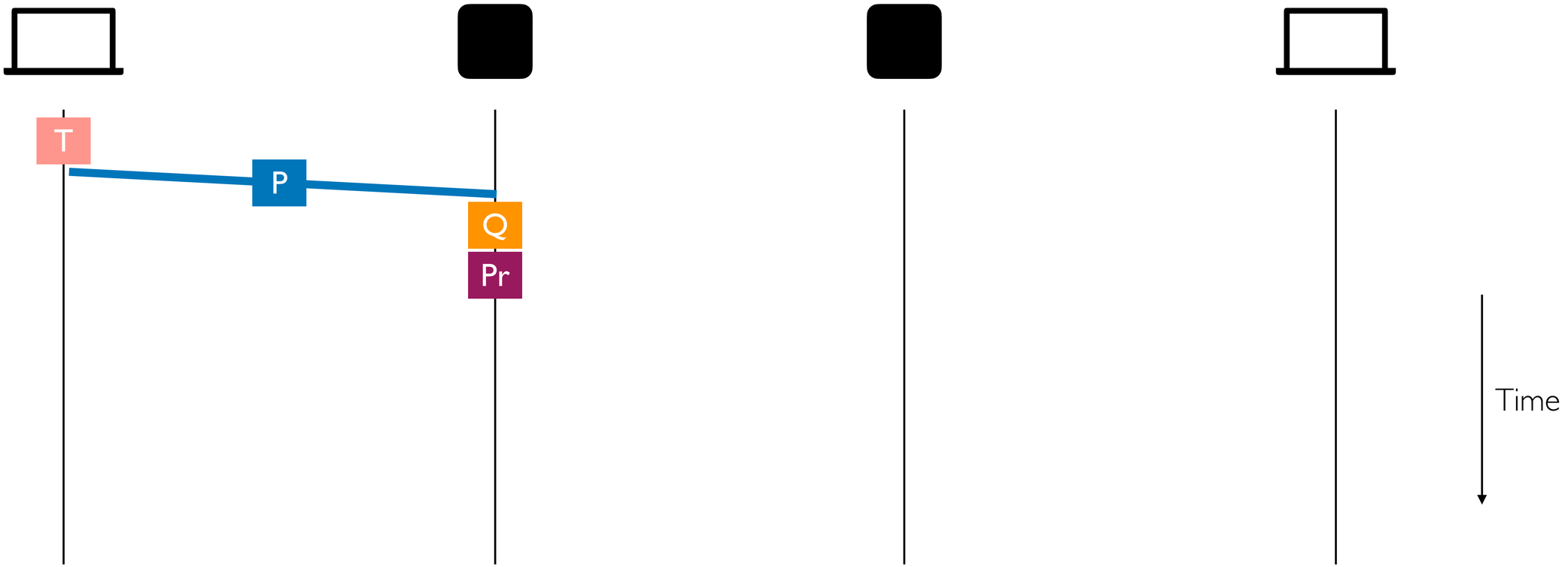

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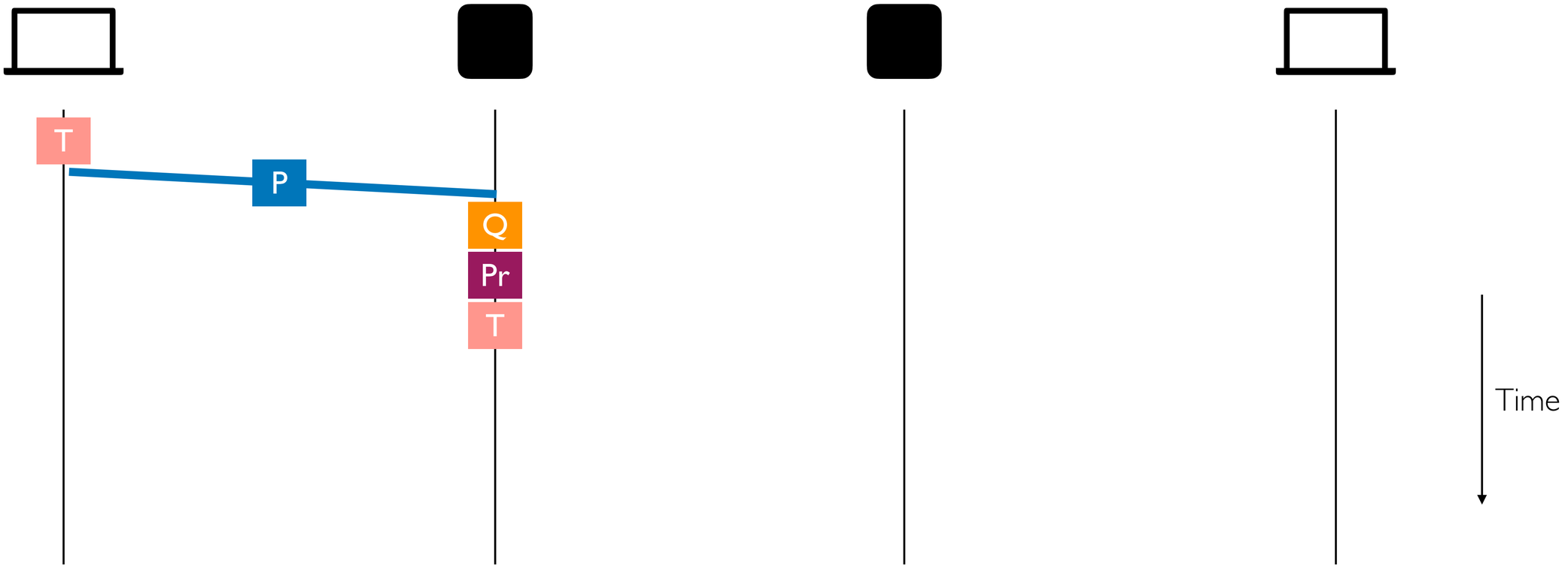

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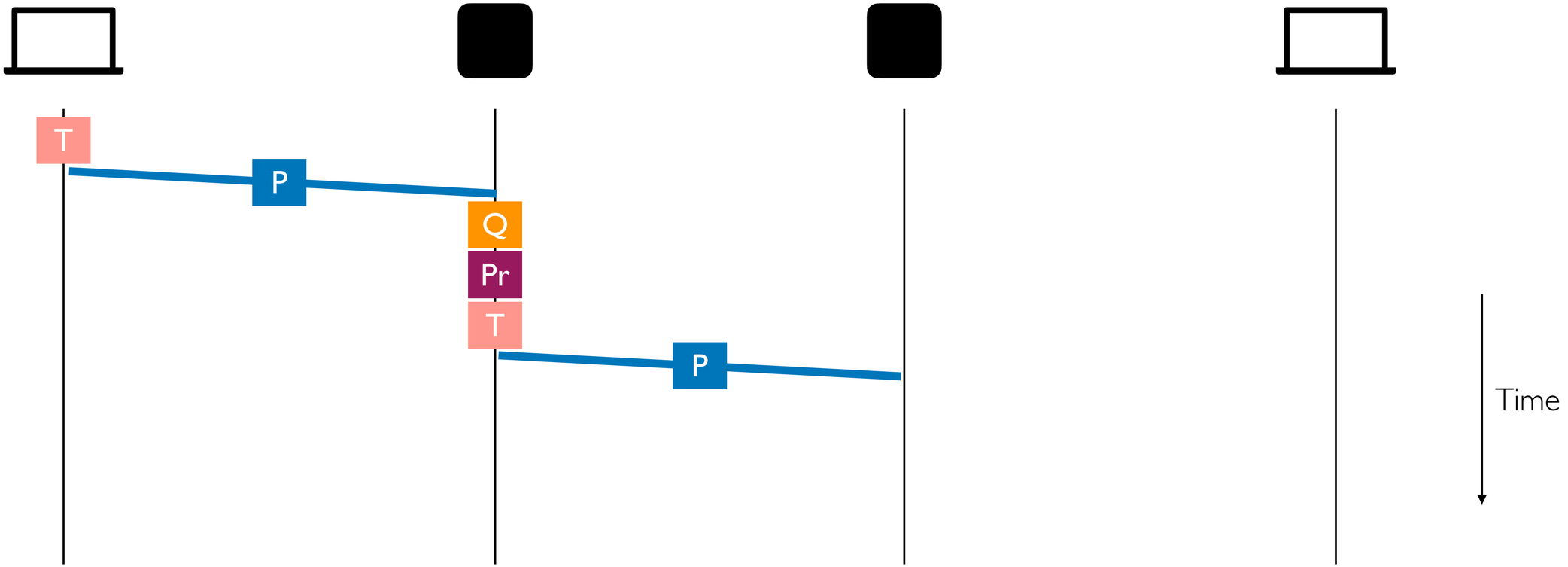

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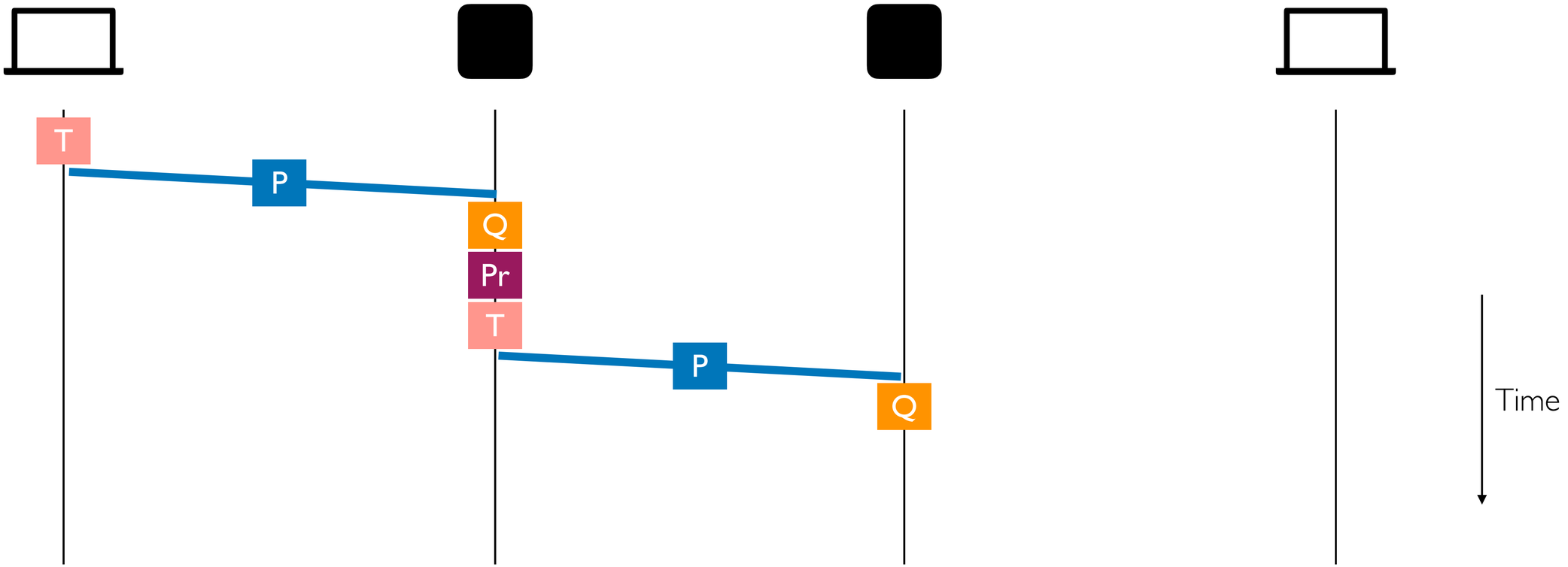

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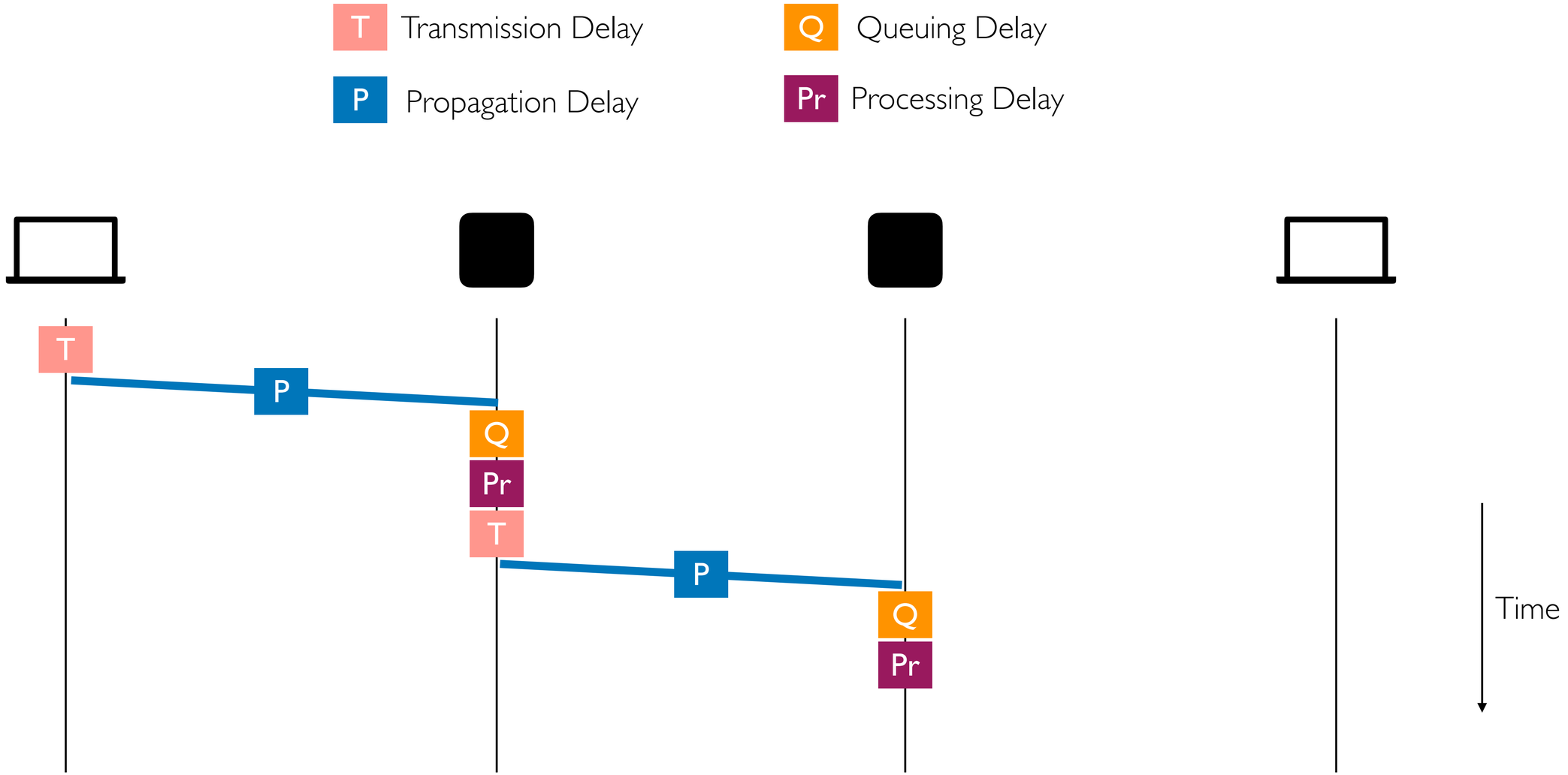

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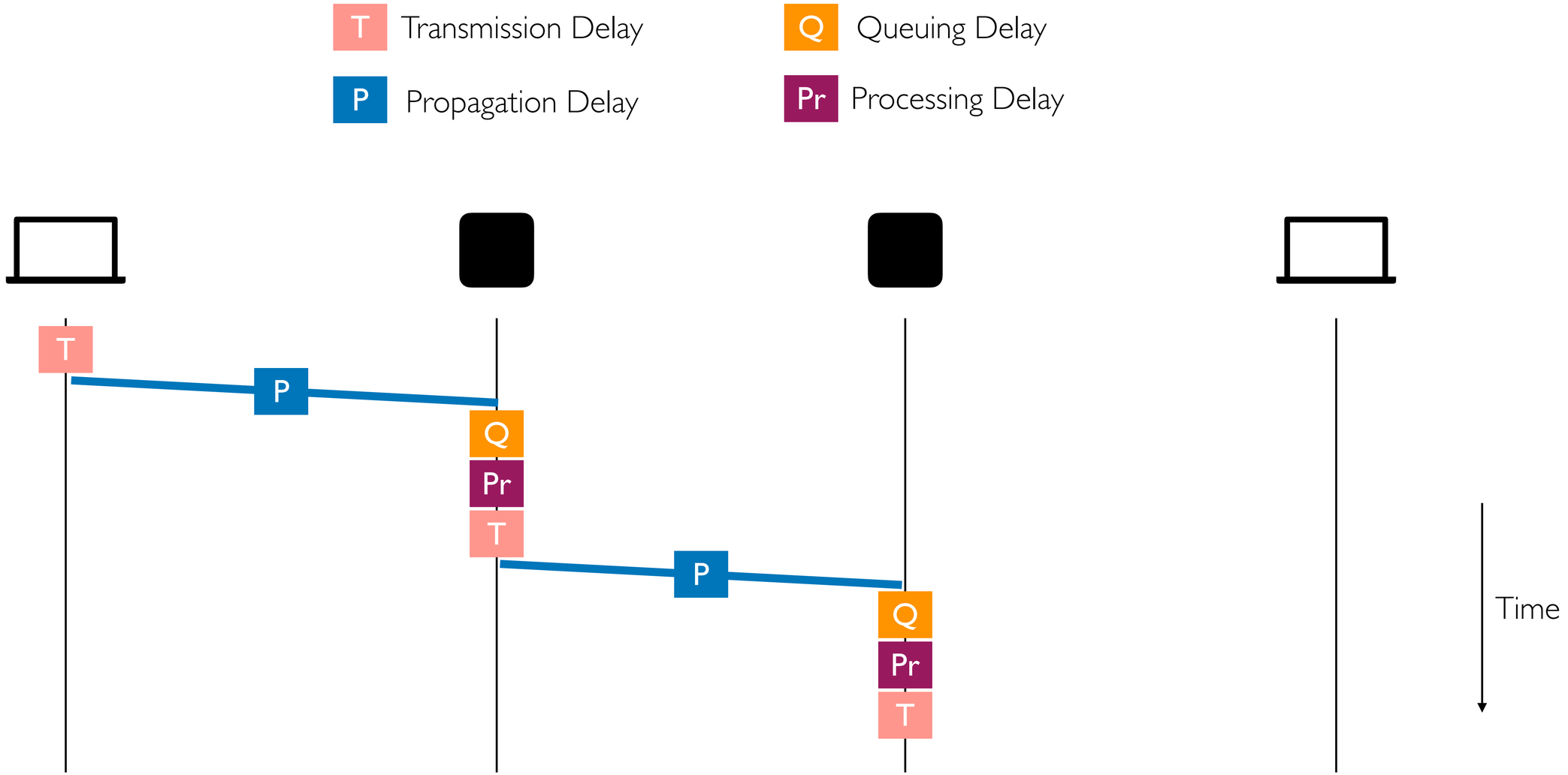

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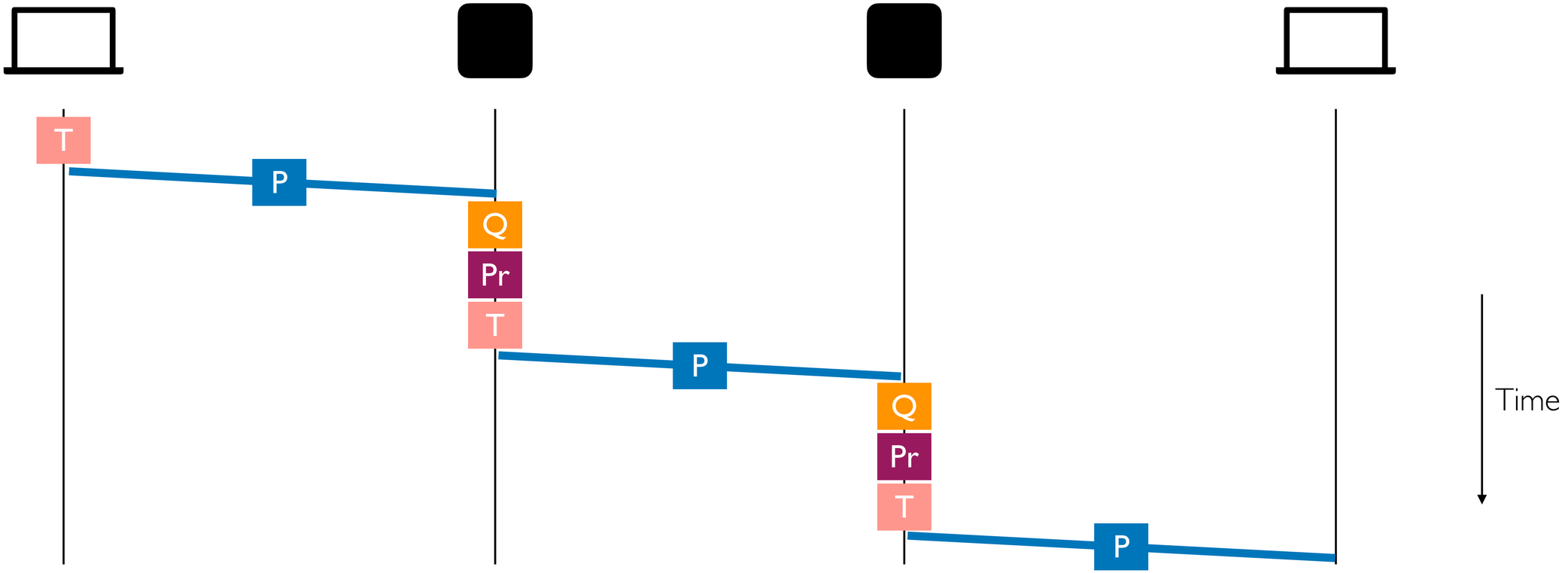


Questions?

Loss

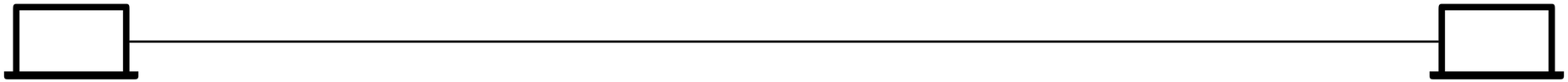
Loss

- What fraction of the packets sent to a destination are dropped?

Throughput

- At what rate is the destination receiving data from the source?
  - **Data size / transfer time**

Throughput



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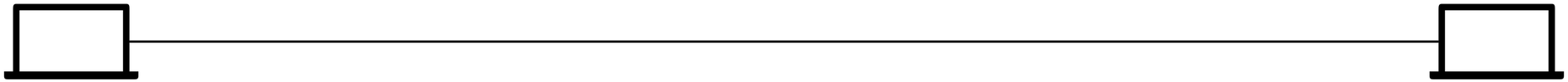

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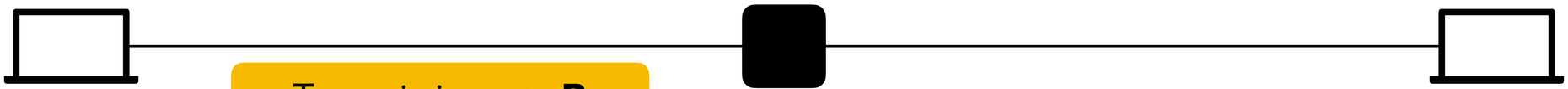

Transmission rate **R**

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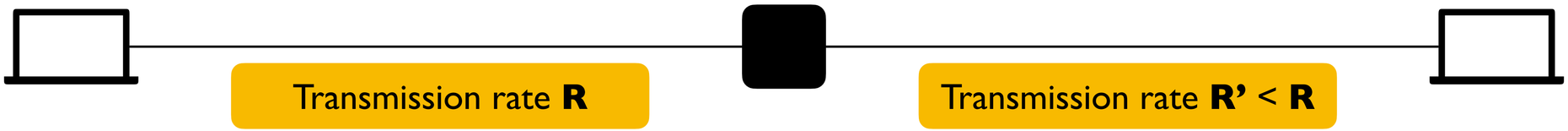

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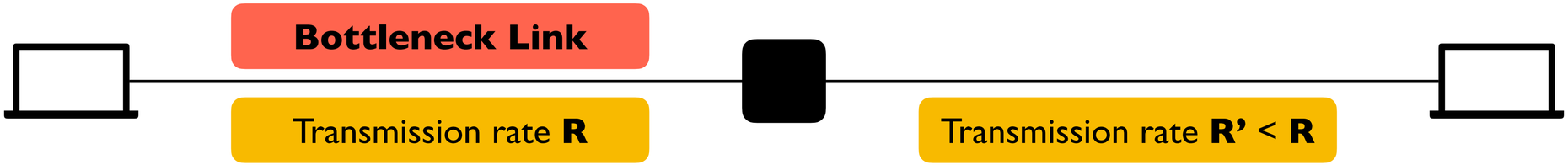

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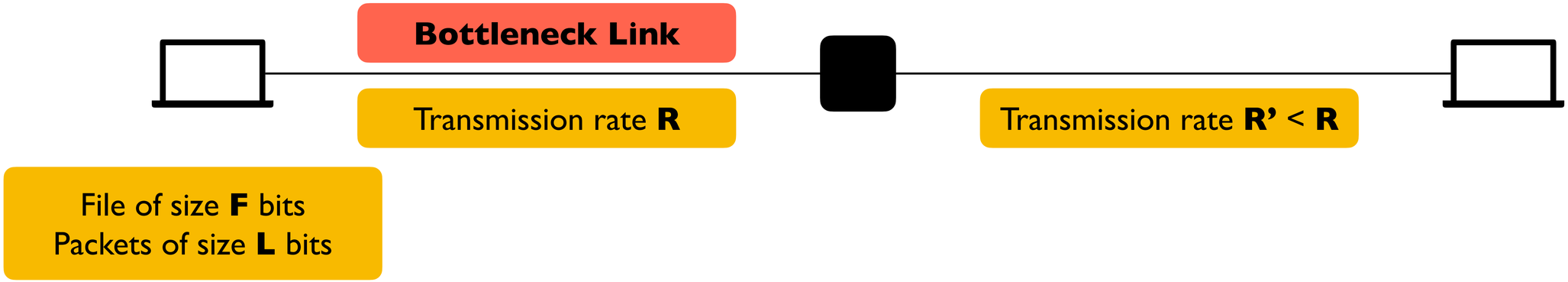

- Average throughput = min {**R, R'**} = **R**

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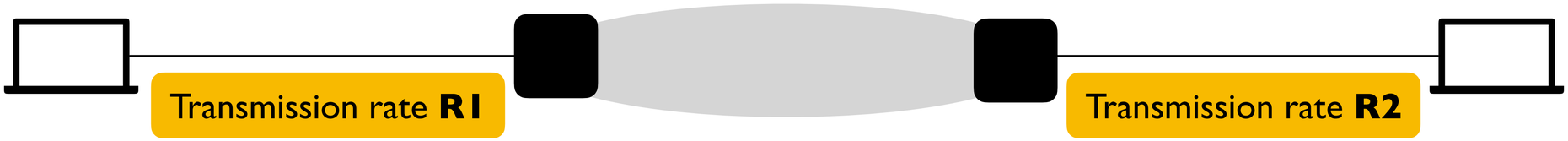

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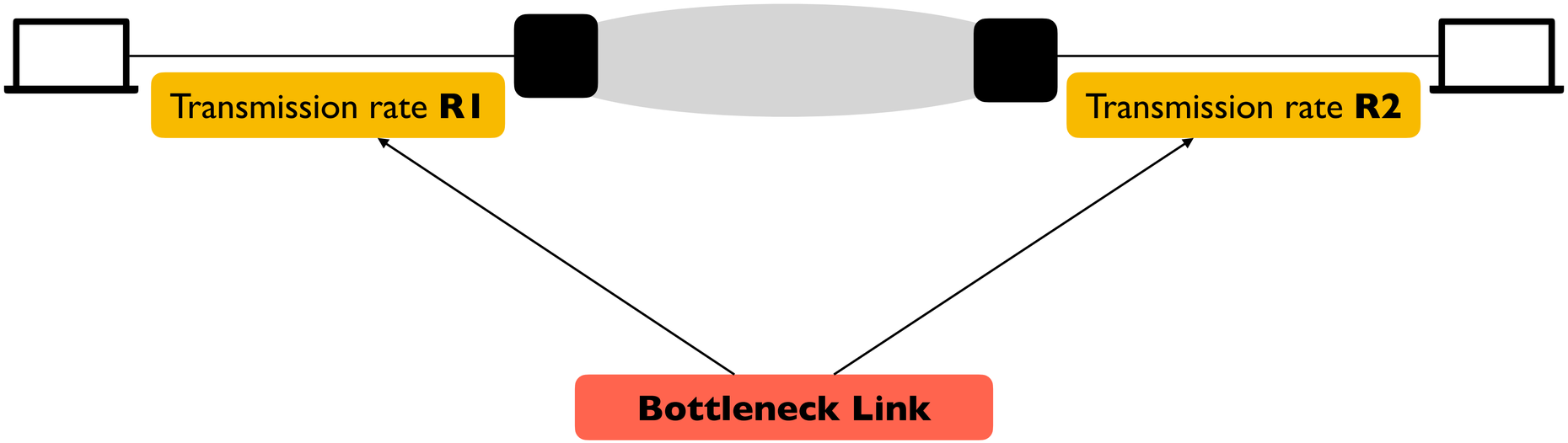
Transmission rate **R1**
Transmission rate **R2**
Bottleneck Link

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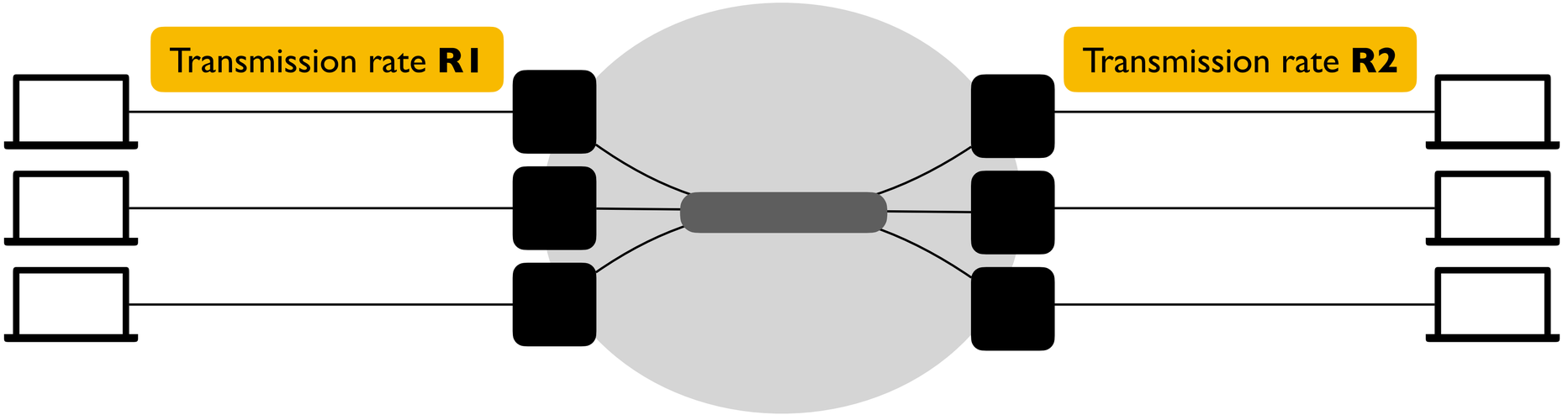

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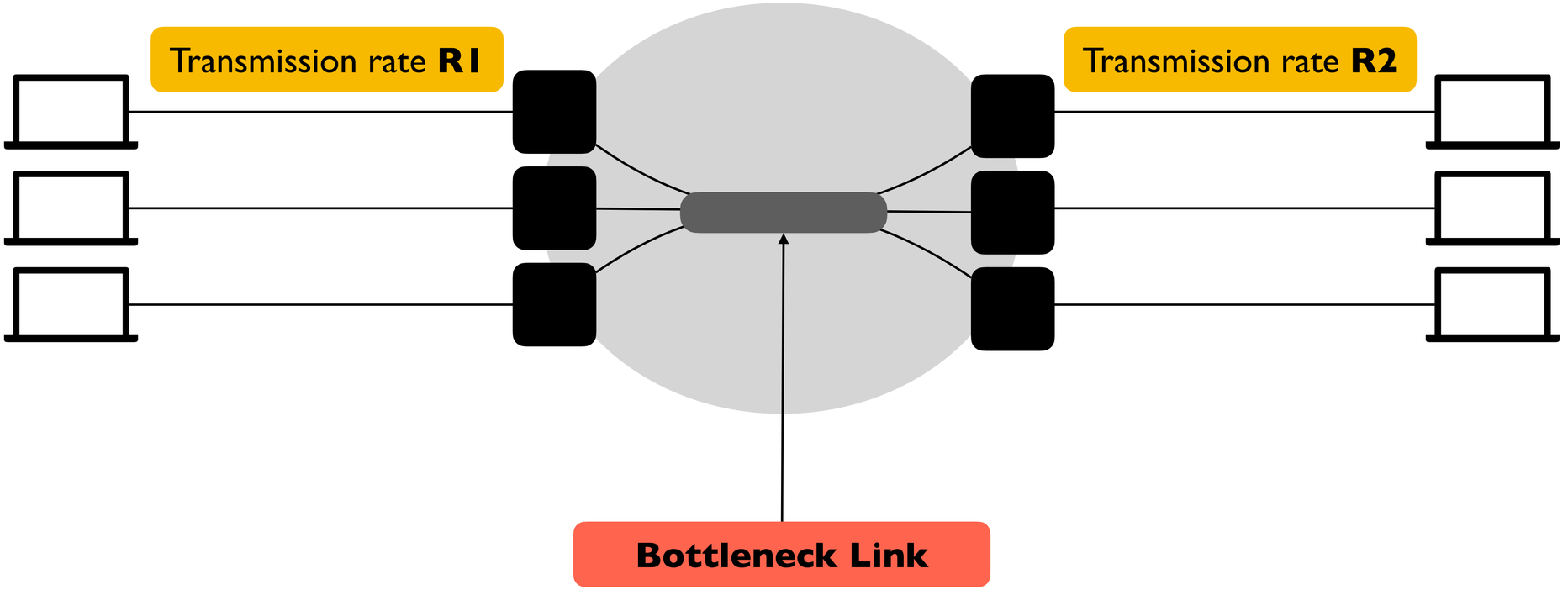
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