Lecture 10:

The Link Layer

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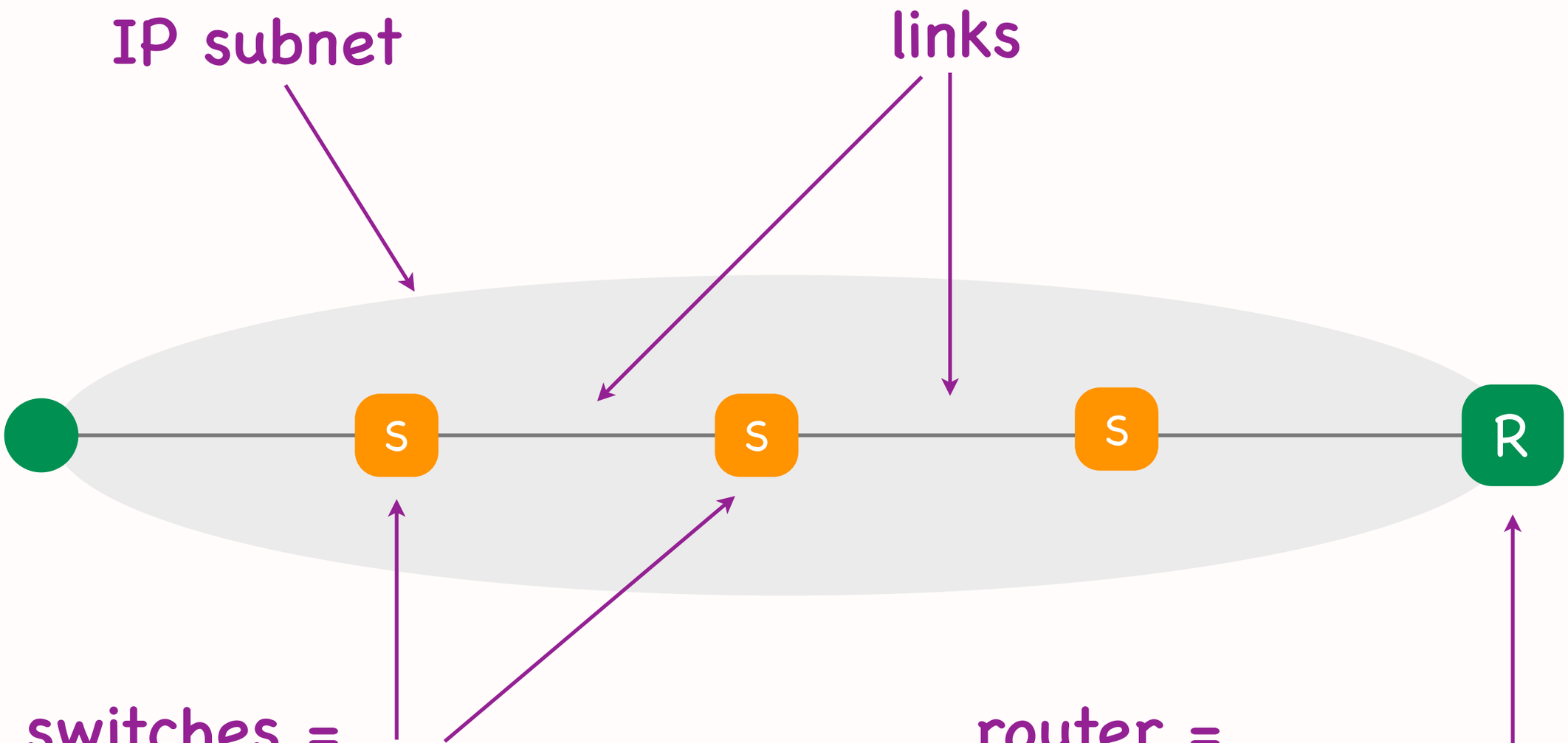
Link vs. network layer

- Link layer: takes each packet from one end of one link to the other end
- Network layer: takes each packet from one end of the network to the other end

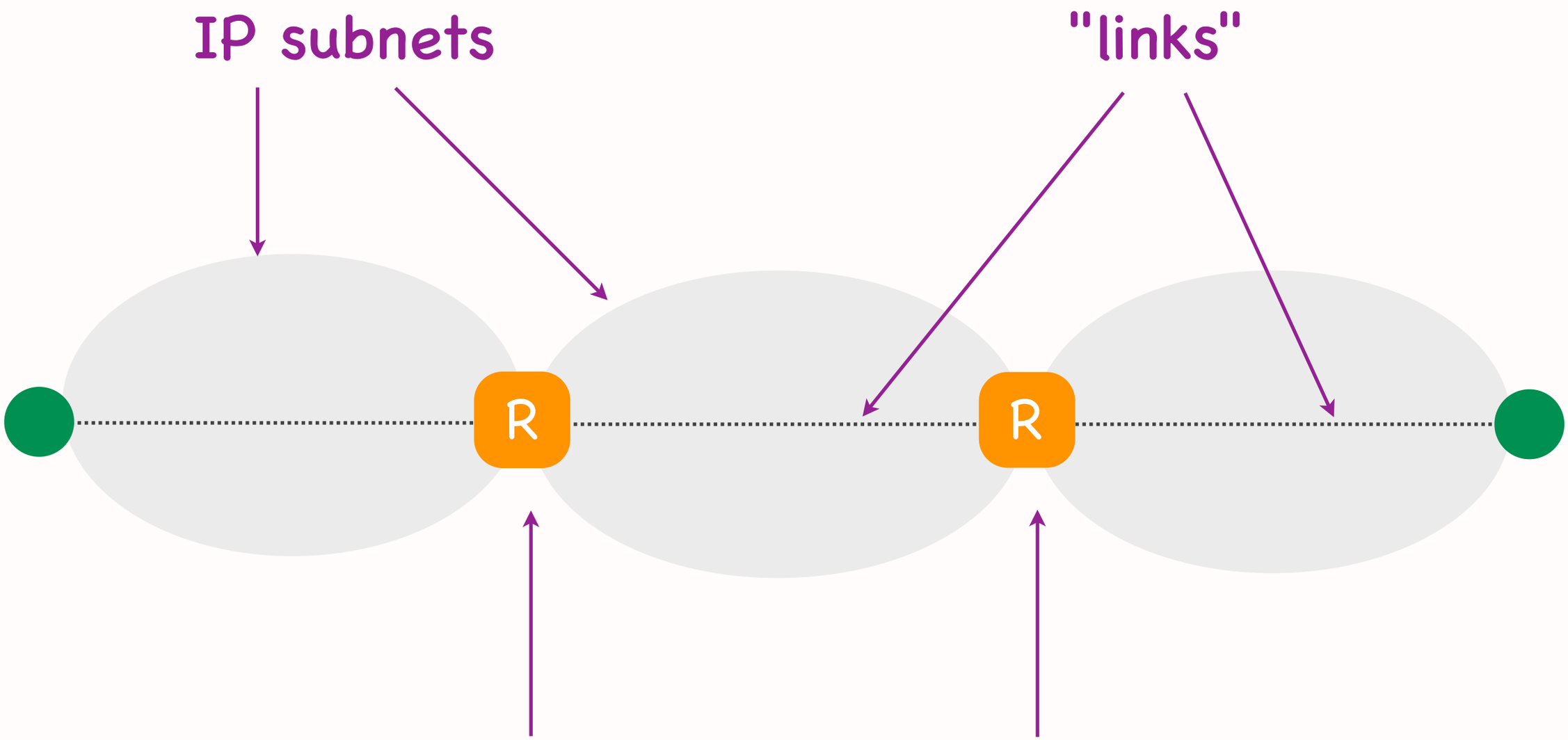


switches =
link-layer switches

router =
network-layer switch

IP subnet point of view

- Link layer: takes packet from
  one end of one physical link to the other end
- Network layer: takes packet from
  one end of the IP subnet to the other end



IP routers = network-layer switches

Internet point of view

- Link layer: takes packet from
  one end of one IP subnet to the other end
- Network layer: takes packet from
  one end of the Internet to the other end

The “link layer”

- Link layer of an IP subnet: takes packet from one end of one physical link to the other end
- Link layer of the Internet: takes packet from one end of one IP subnet to the other end

The “link layer”

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Link-layer services

- Error detection
  - receiver detects and drops corrupted packets
  - relies on checksums
- Reliable data delivery
  - sender/receiver detect corruption and loss, and try to recover
  - relies on checksums, ACKs, retransmissions, …
  - only for error-prone links, typically wireless

Link-layer services

- Medium access control (MAC)
  - sender manages access to shared medium (typically wireless link)
  - listens for ongoing transmissions or "collisions"
  - backs off and retries later

Why reliable data delivery at the link layer?

The transport layer does that anyway.

The “link layer”

- Link layer of an IP subnet: takes packet from one end of one physical link to the other end
- Link layer of the Internet: takes packet from one end of one IP subnet to the other end

Outline

- Addressing
- Forwarding
- Learning
- Address resolution

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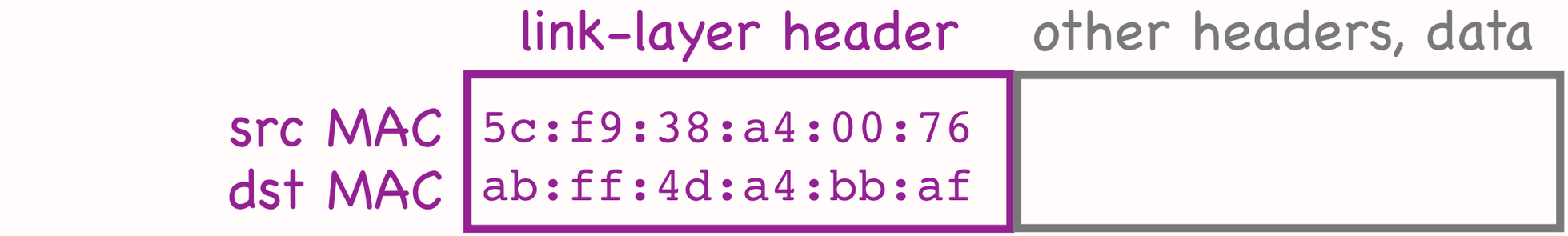
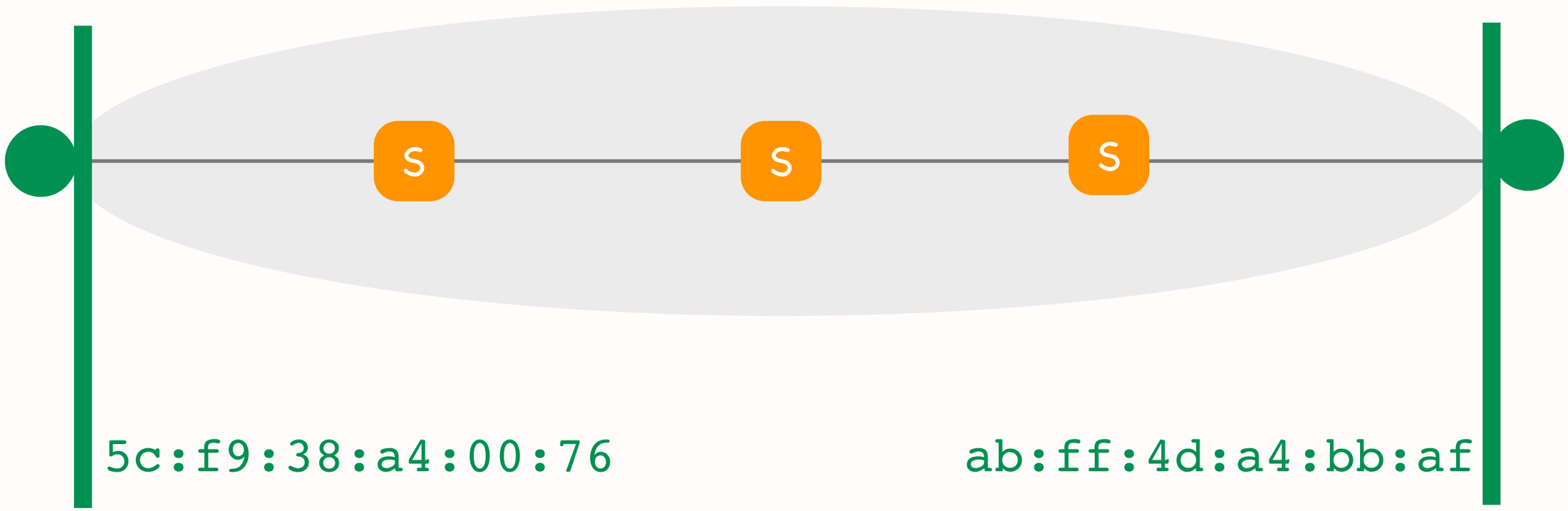

link-layer header
other headers, data
src MAC
dst MAC
5c:f9:38:a4:00:76
ab:ff:4d:a4:bb:af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S
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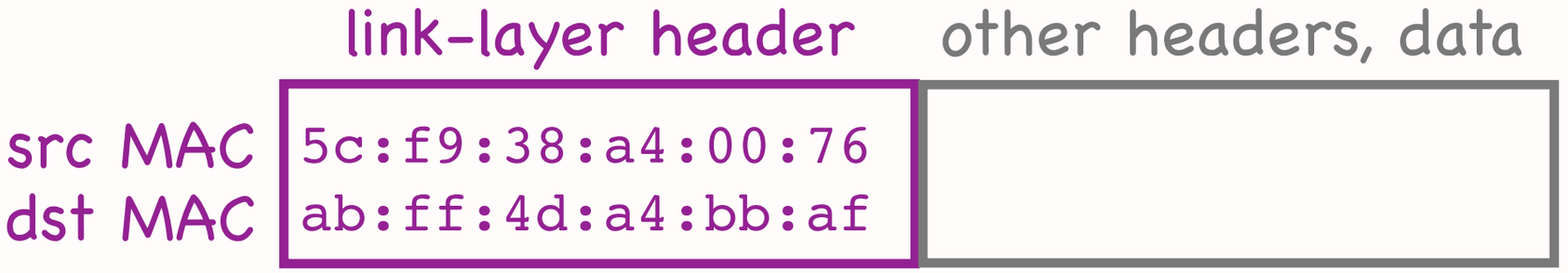
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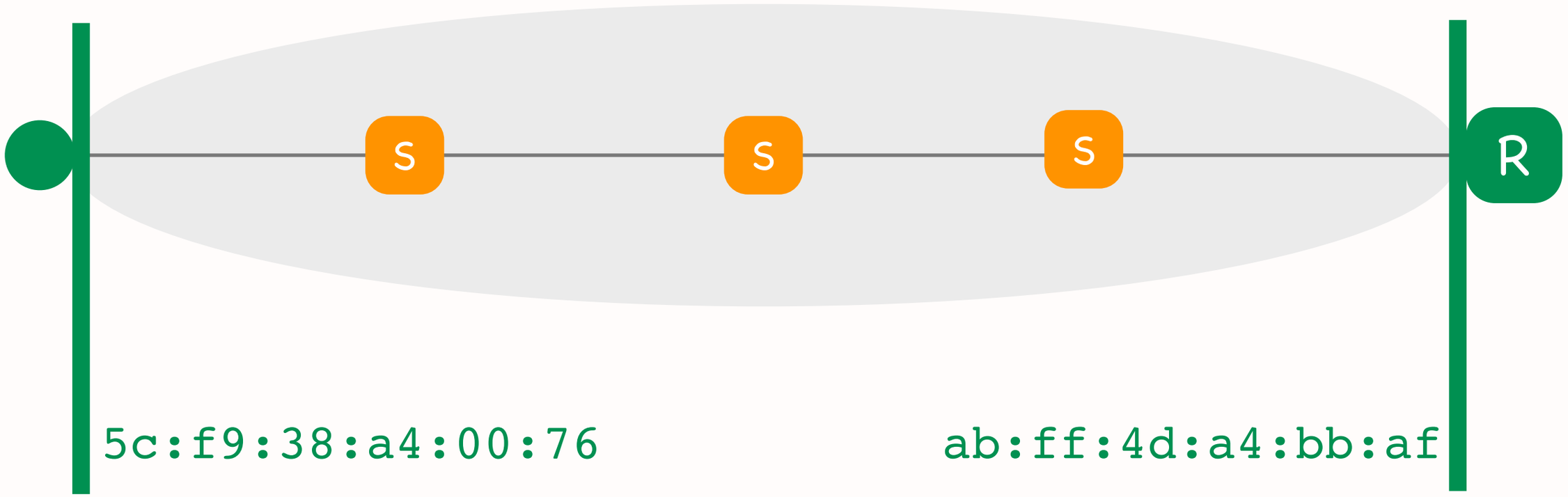
S
S
S
R
5c:f9:38:a4:00:76
ab:ff:4d:a4:bb:af

MAC address

- 48-bit number
  - typical format: 1A-2B-DD-78-CF-CC
  - the value of each byte as hexadecimal
- Flat
  - not hierarchical like IP address
  - not location dependent

Outline

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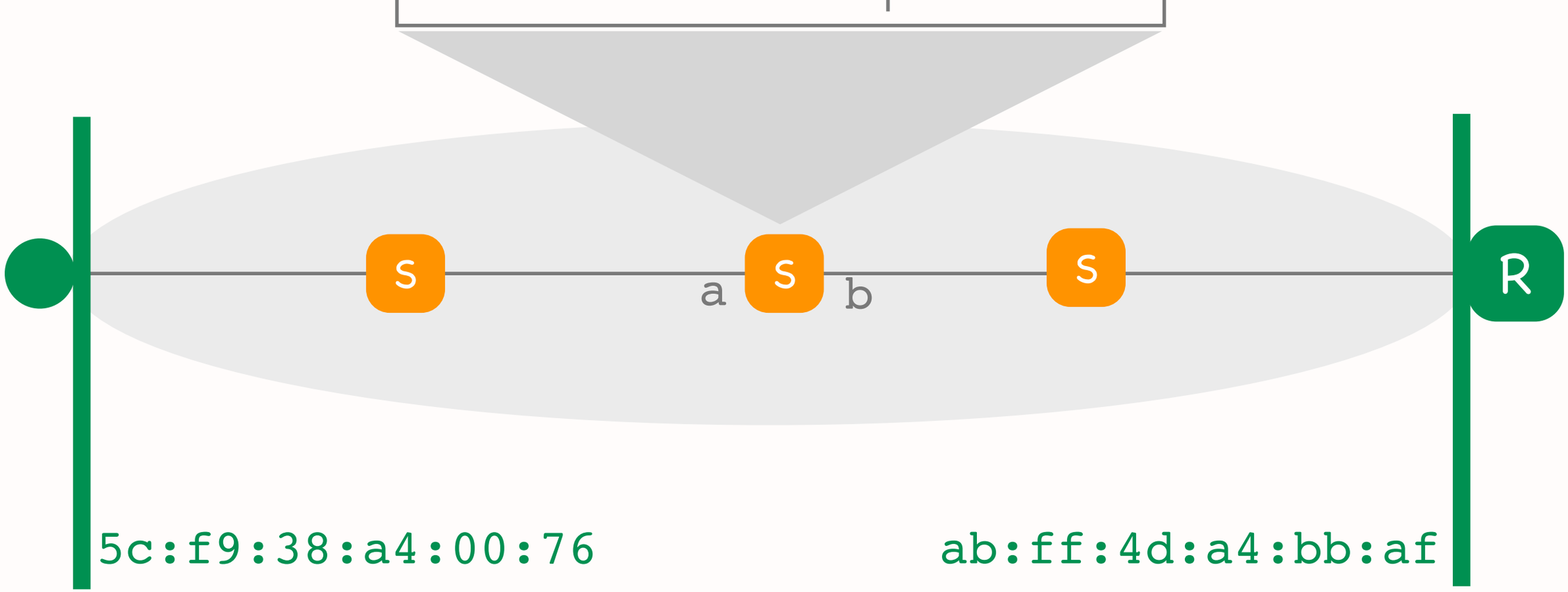
MAC address	link
5c:f9:38:a4:00:76	a
ab:ff:4d:a4:bb:af	b
...	...



L2 forwarding

- Local switch process that determines output link for each packet
- Relies on forwarding table
  - maps destination MAC addresses to output links
- Similar to IP (L3) forwarding, except...

MAC address

- Flat
  - not hierarchical like IP addresses
  - not location dependent

L2 vs. IP forwarding

- L2: relies on flat addresses
  - no way to group MAC addresses in prefixes
  - forwarding table size = # of active destination MAC addresses in the IP subnet

- IP (L3): relies on hierarchical addresses
  - IP addresses grouped in IP prefixes
  - forwarding table size = # of IP prefixes in the world

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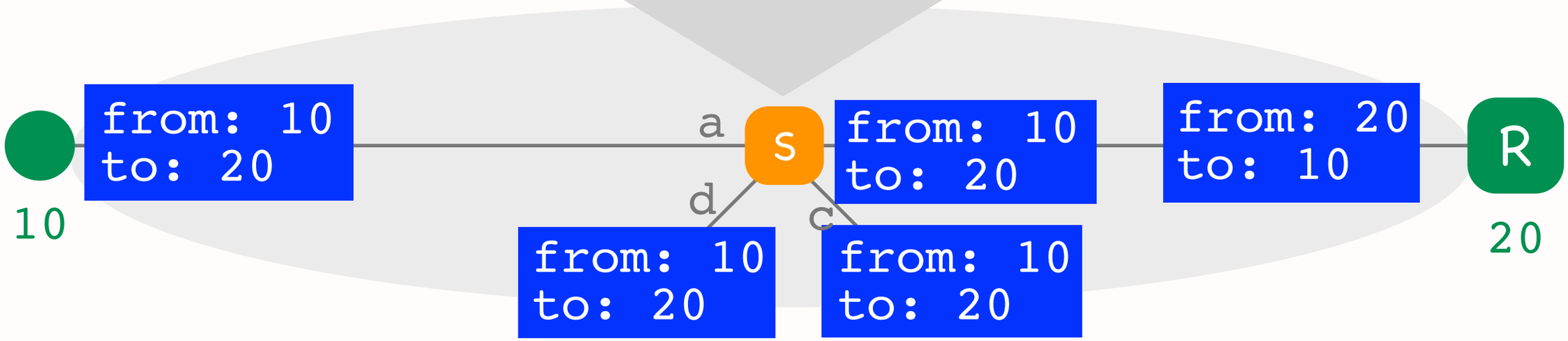
MAC address	link
10	a
20	b



L2 learning

- Switch learns from traffic
  - when packet with src MAC x arrives at link y, switch adds MAC x --> link y mapping to forwarding table

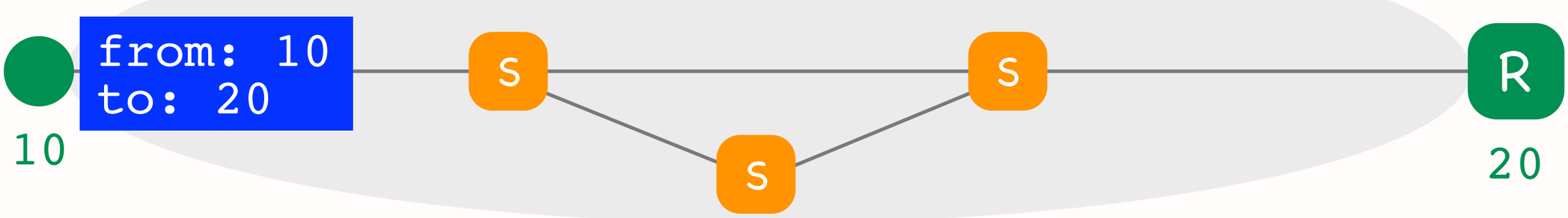
- Broadcasts when it does not know
  - when packet with unknown dst MAC arrives, switch broadcasts the packet

- Serves similar role as IP routing, but…

L2 learning vs. IP routing

- L2 learning: relies on actual traffic
  - switches do not exchange explicit routing information
- IP routing: relies on routing protocol
  - routers exchange explicit routing messages

naïve broadcasting = forwarding loops!



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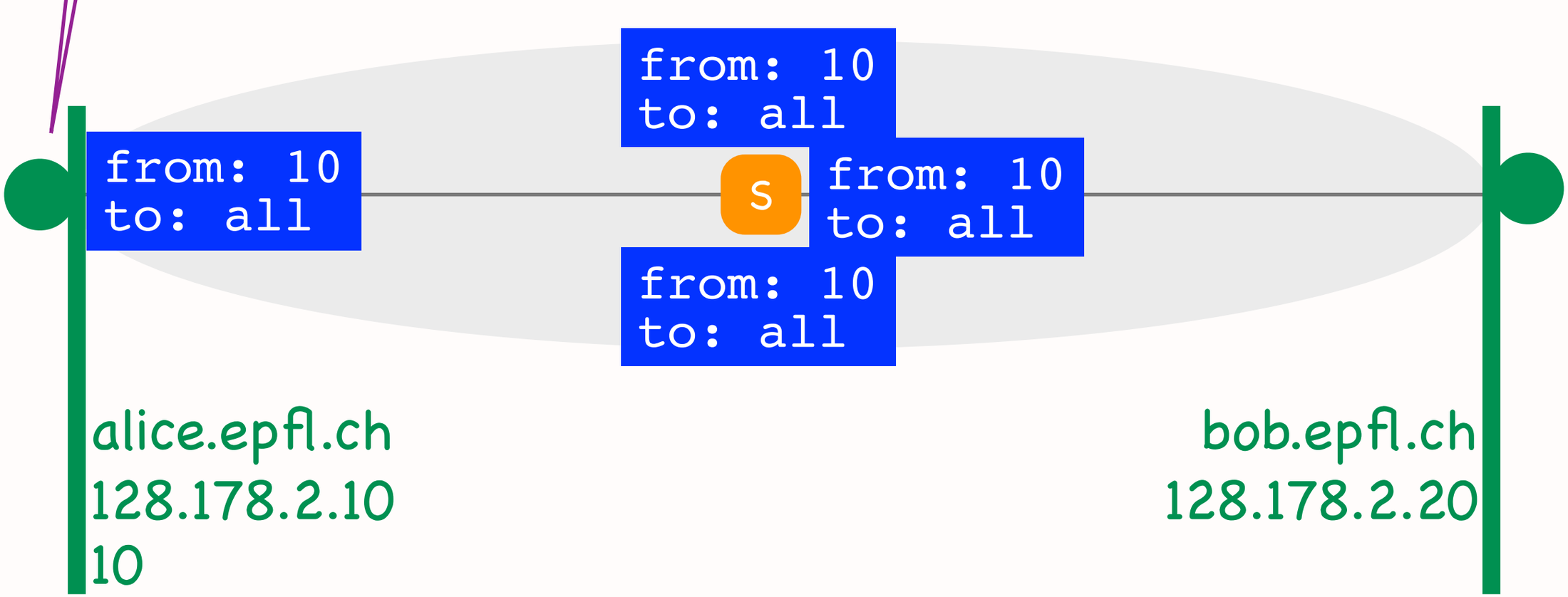
I want to send a packet to IP address 128.178.2.20.
Which destination MAC address should I use?



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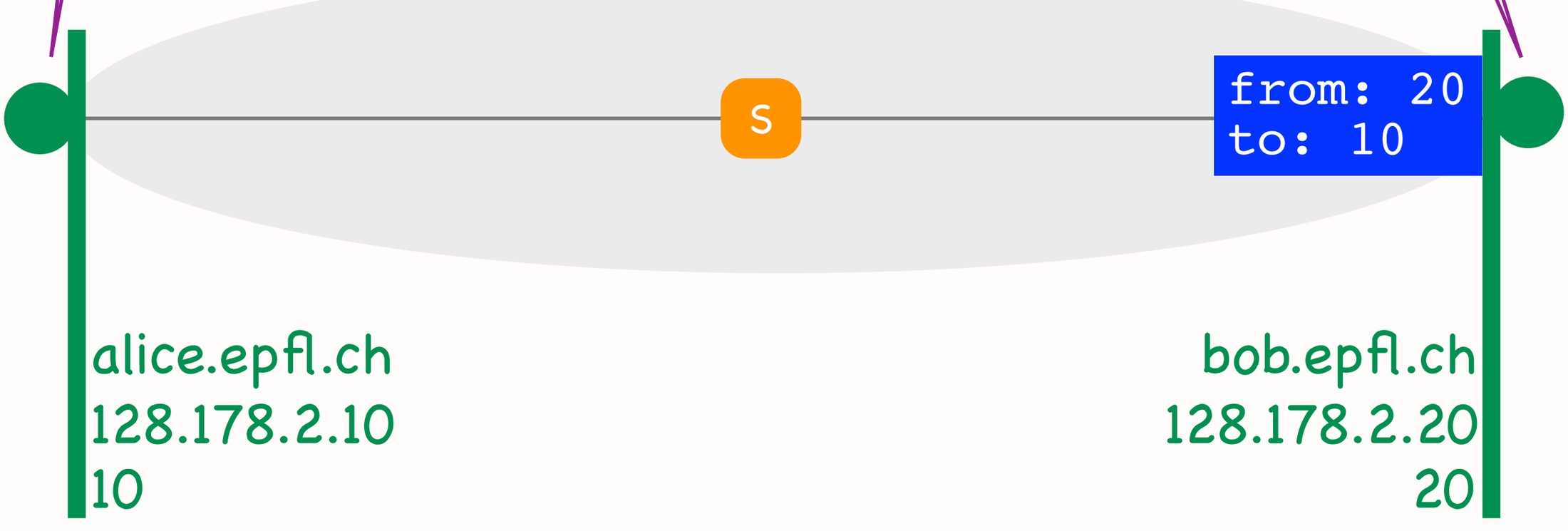
Use my MAC address! It is 20.



I want to send a packet to IP address 104.20.228.42.
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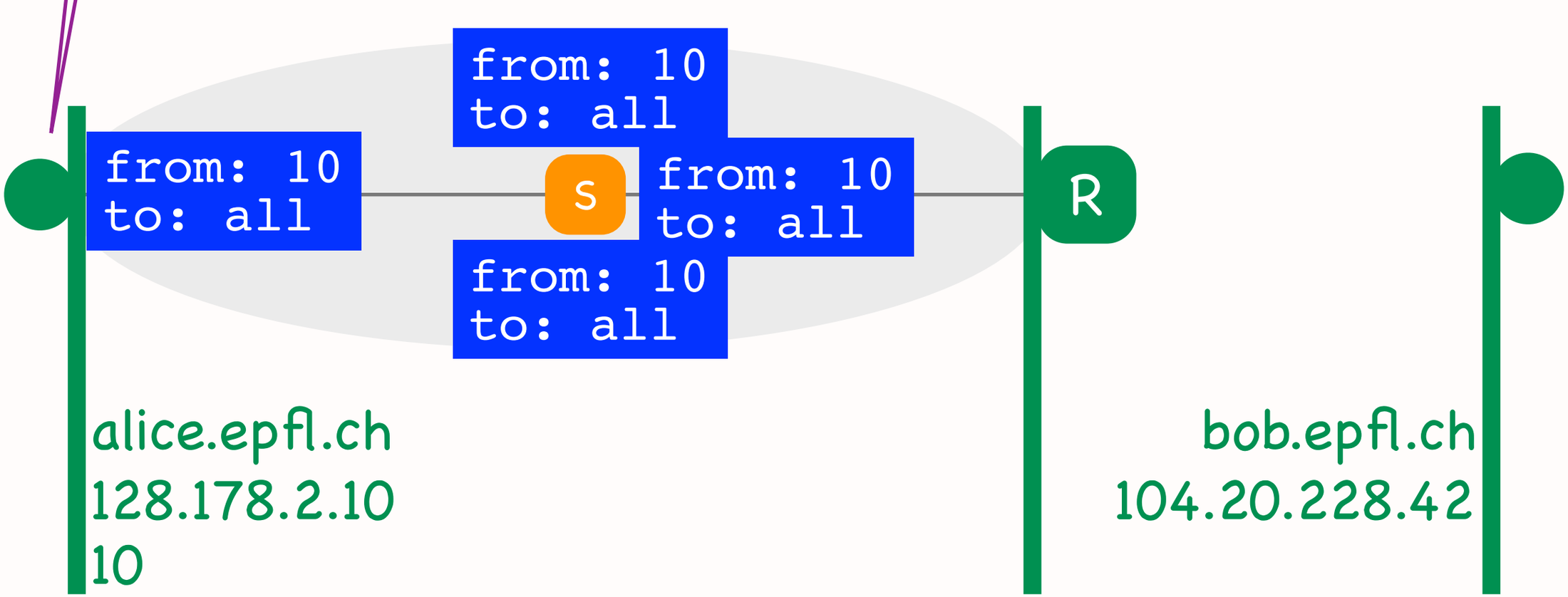

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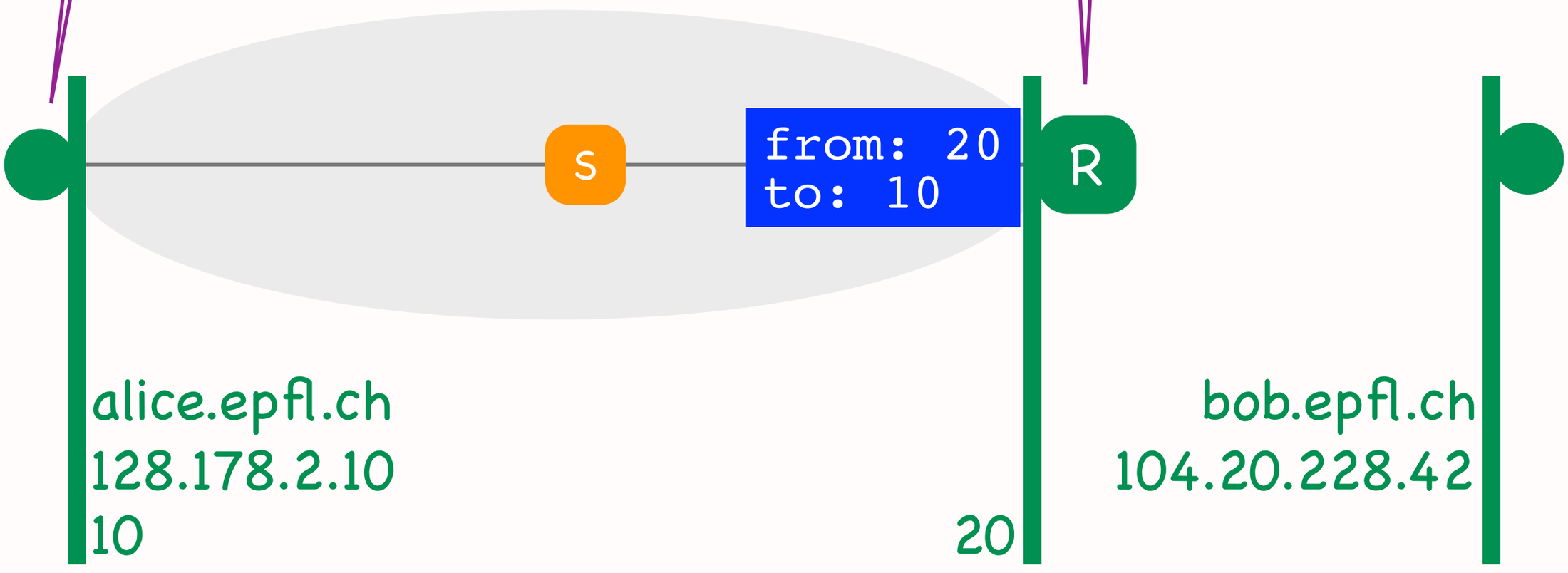
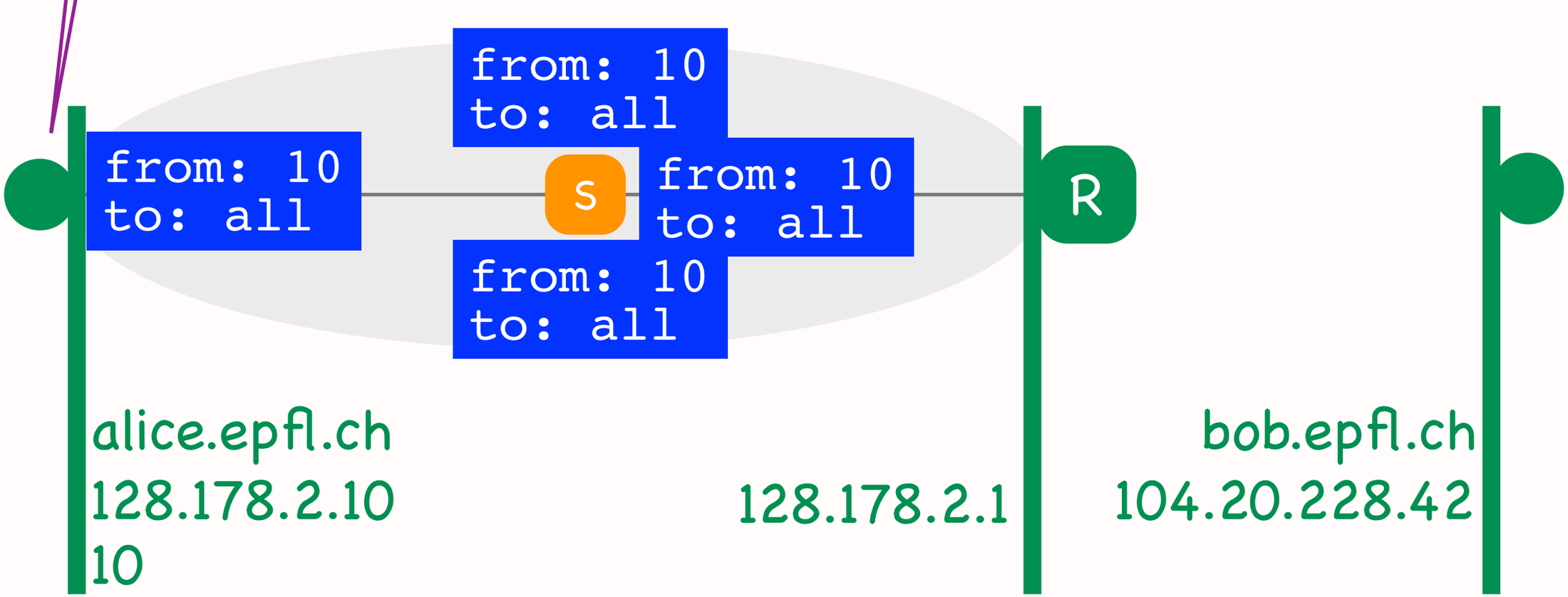


My default gateway has IP address 128.178.2.1.
Which is its MAC address?



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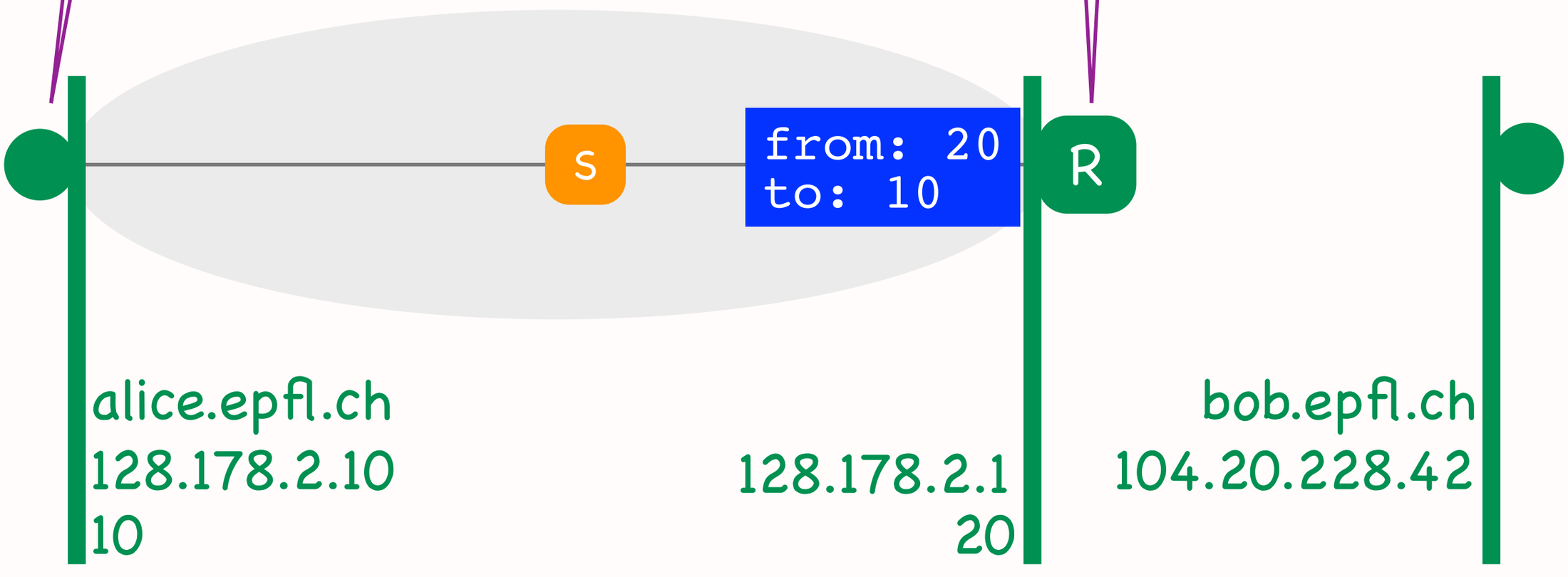

Address Resolution Protocol (ARP)

- Goal: map IP address to MAC address
  - Alice knows destination IP address
  - which destination MAC address to use?

- How: broadcast request, targeted response
  - Alice broadcasts her request
  - the right entity responds to Alice

- Serves similar role as DNS, but…

Broadcasting

- Alice sends request to special, broadcast destination MAC address
  - `FF-FF-FF-FF-FF-FF`
- Reaches every end-system and router in the local IP subnet

ARP vs. DNS

- ARP: relies on broadcasting
  - no logically centralized map
  - each entity knows its own MAC address and knows which requests to respond to

- DNS: relies on DNS infrastructure
  - logically centralized map
  - stored in DNS servers

Basic Ethernet elements

- Address Resolution Protocol
  - resolves IP address to MAC address
- L2 forwarding
  - based on MAC addresses (which are flat)
- L2 learning
  - populates switch forwarding table

Basic Ethernet elements

- Address Resolution Protocol [rel. to DNS]
  - resolves IP address to MAC address
- L2 forwarding [rel. to IP forwarding]
  - based on MAC addresses (which are flat)
- L2 learning [rel. to IP routing]
  - populates switch forwarding table

Get rid of IP addresses and IP forwarding?

Get rid of MAC addresses and L2 forwarding?