

CS 725/825 & IT 725

Lecture 7

Networking Fundamentals

September 28, 2026

Host routing table

```
rbartos@agate ~$ route
Kernel IP routing table
Destination        Gateway            Genmask           Flags  Metric  Ref    Use  Iface
default            _gateway          0.0.0.0           UG     100     0      0   eno1np0
unh-cs             0.0.0.0           255.255.252.0     U       100     0      0   eno1np0

rbartos@agate ~$ route -n
Kernel IP routing table
Destination        Gateway            Genmask           Flags  Metric  Ref    Use  Iface
0.0.0.0            132.177.4.4        0.0.0.0           UG     100     0      0   eno1np0
132.177.4.0        0.0.0.0           255.255.252.0     U       100     0      0   eno1np0
```

“-n” = do not resolve IP addresses

132.177.4.0/22 → local delivery via interface **eno1np0**
(do ARP for the destination IP)

0.0.0.0/0 (everything else) → send to _gateway
132.177.4.4 via **eno1np0**
(do ARP for 132.177.4.4)

Host routing table

```
rbartos@agate ~$ route
```

```
Kernel IP routing table
```

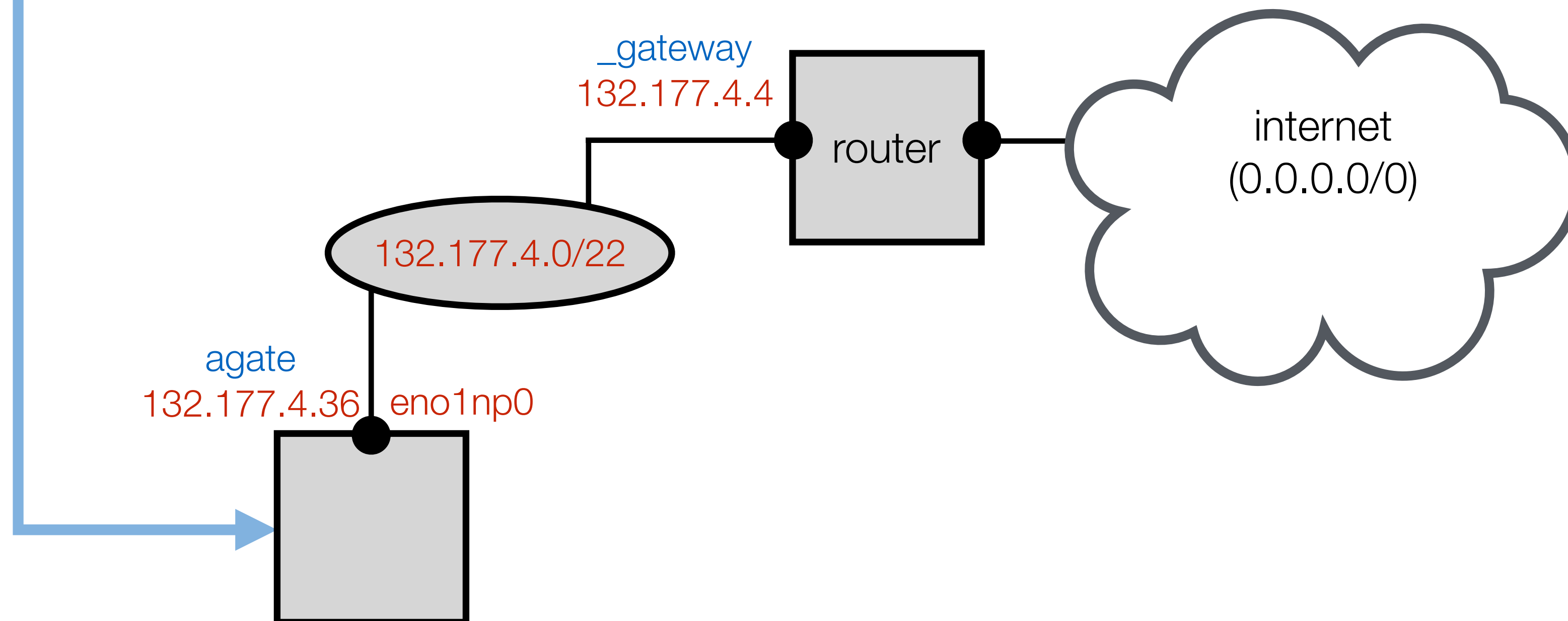
Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
default	_gateway	0.0.0.0	UG	100	0	0	eno1np0
unh-cs	0.0.0.0	255.255.252.0	U	100	0	0	eno1np0

```
rbartos@agate ~$ route -n
```

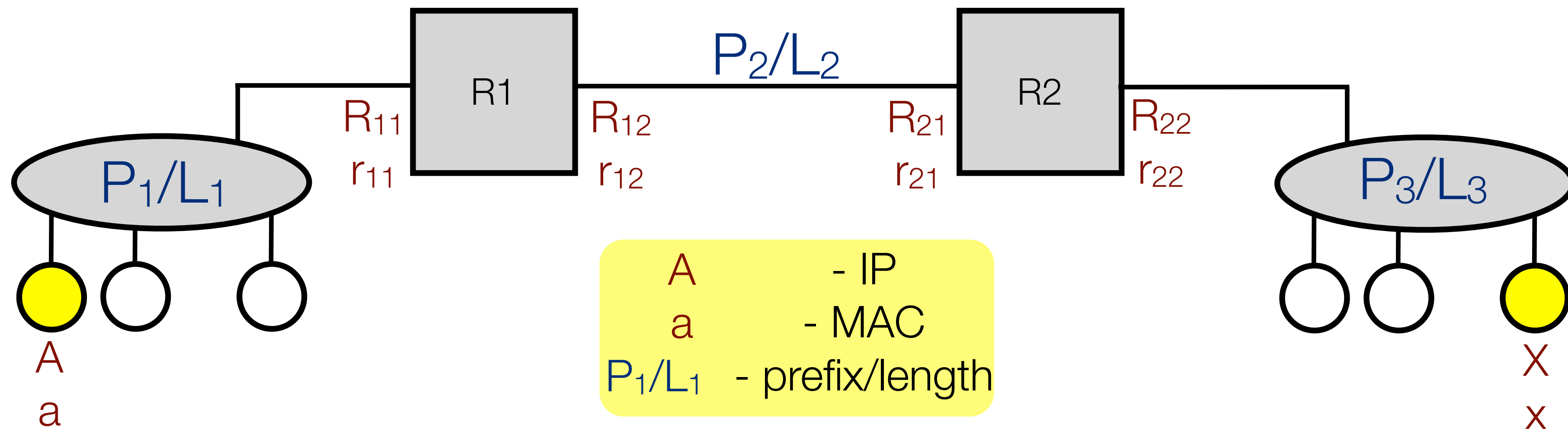
```
Kernel IP routing table
```

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
0.0.0.0	132.177.4.4	0.0.0.0	UG	100	0	0	eno1np0
132.177.4.0	0.0.0.0	255.255.252.0	U	100	0	0	eno1np0

“-n” = do not resolve IP addresses



Static IP Routing



For example:

P_1/L_1 10.0.1.0/24

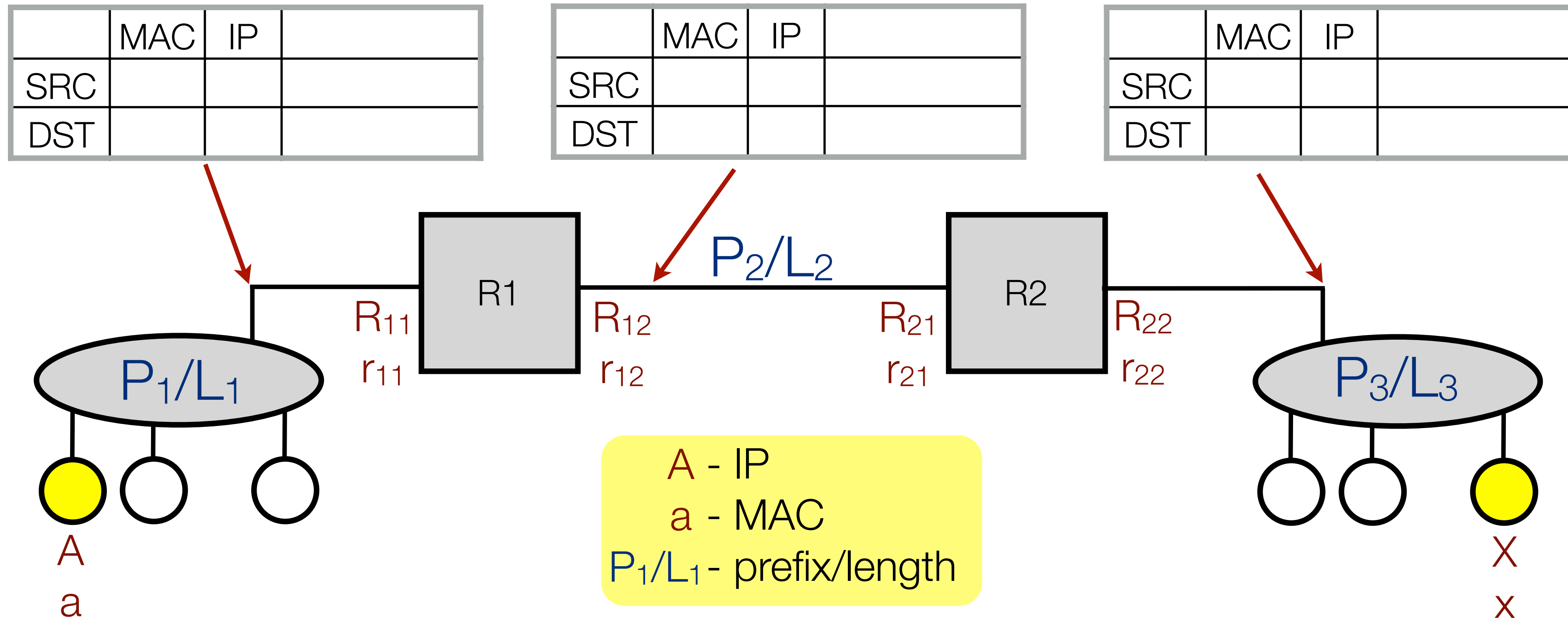
A 10.0.1.101

R_{11} 10.0.1.1

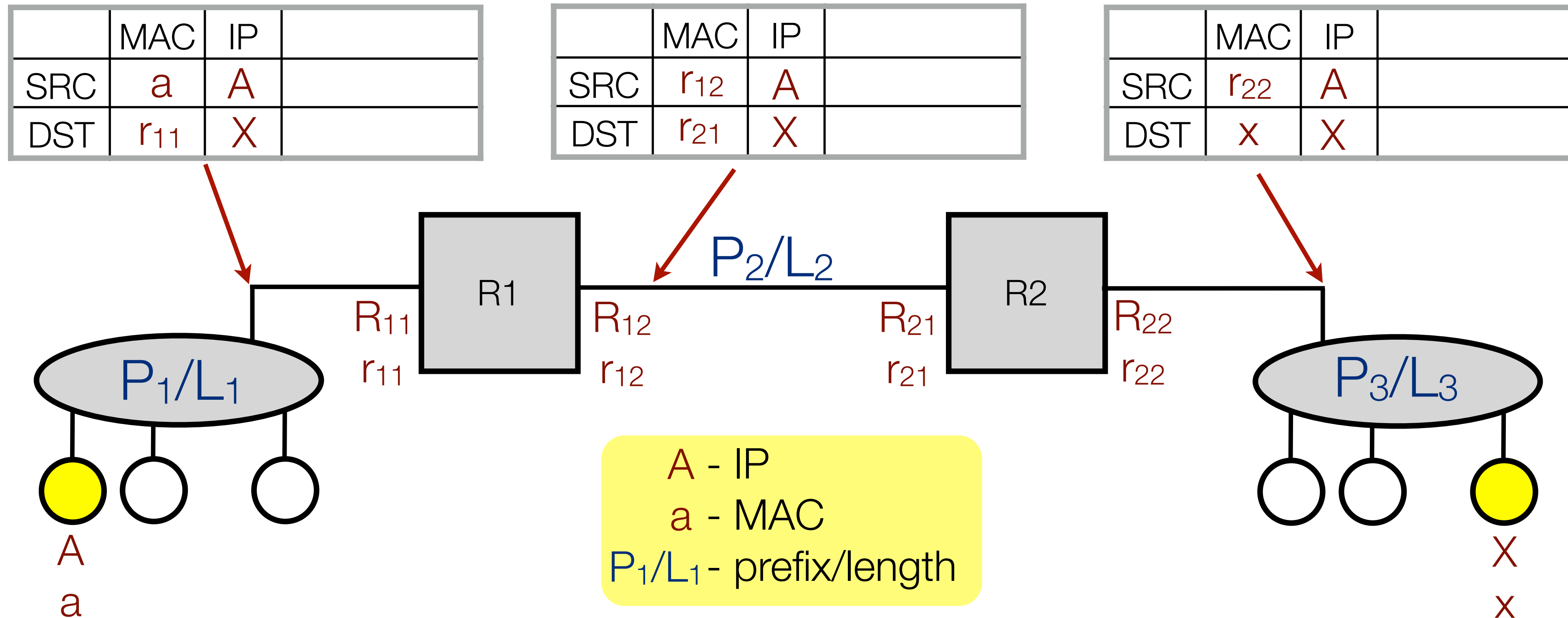
a f8:ff:c2:24:6a:0f

r_{11} aa:c2:74:08:cf:12

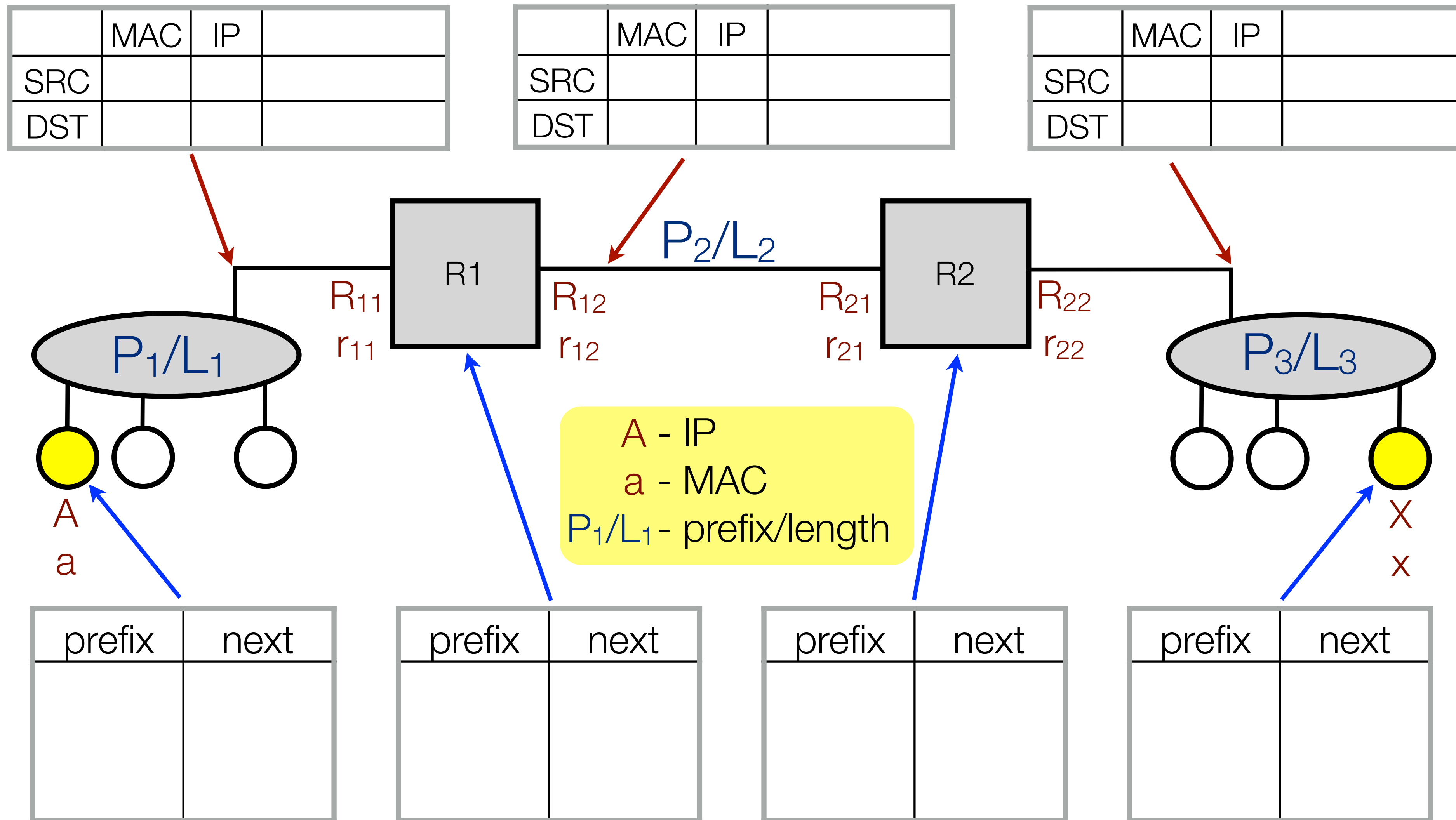
Static IP Routing



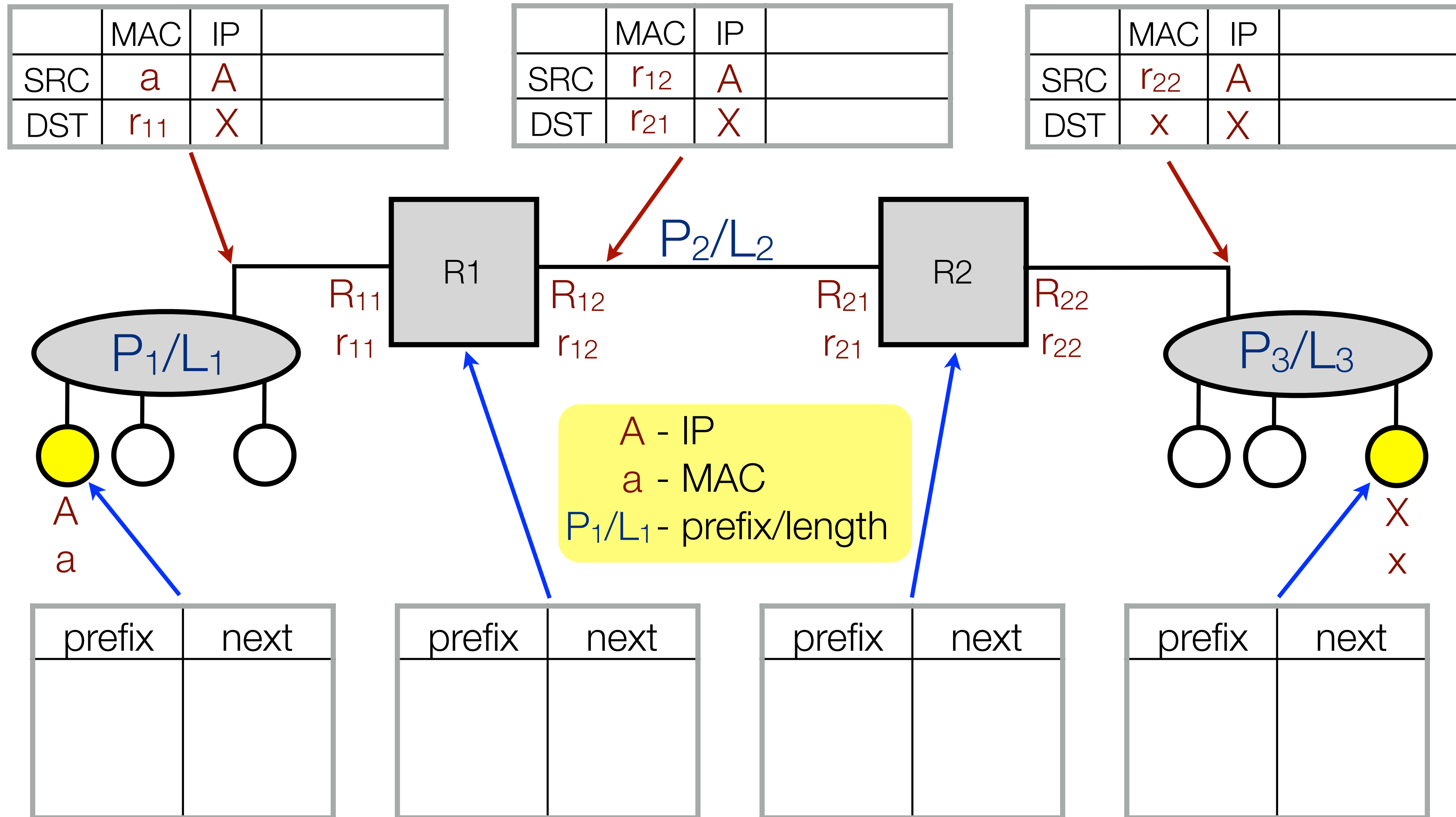
Static IP Routing



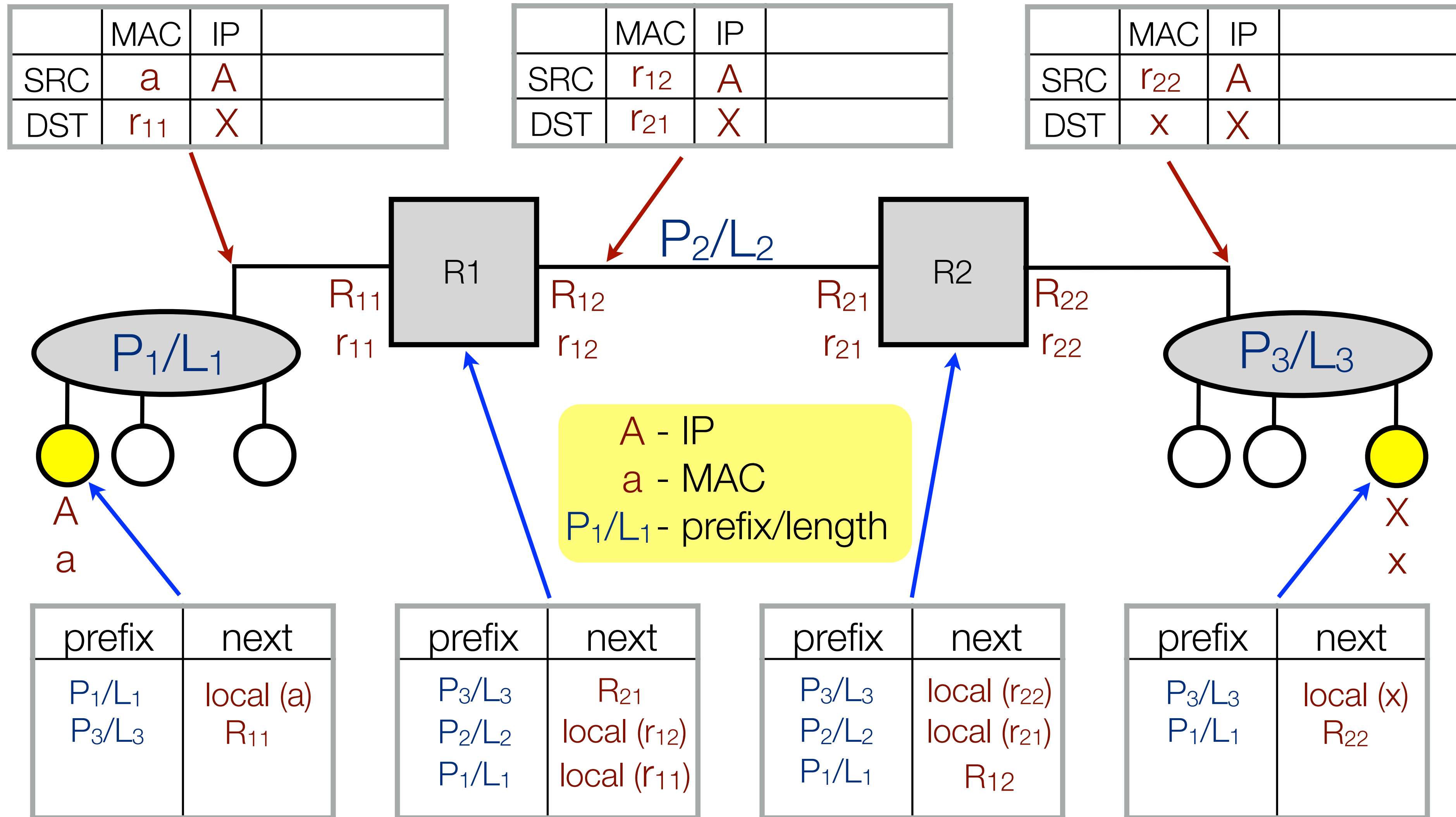
Static IP Routing



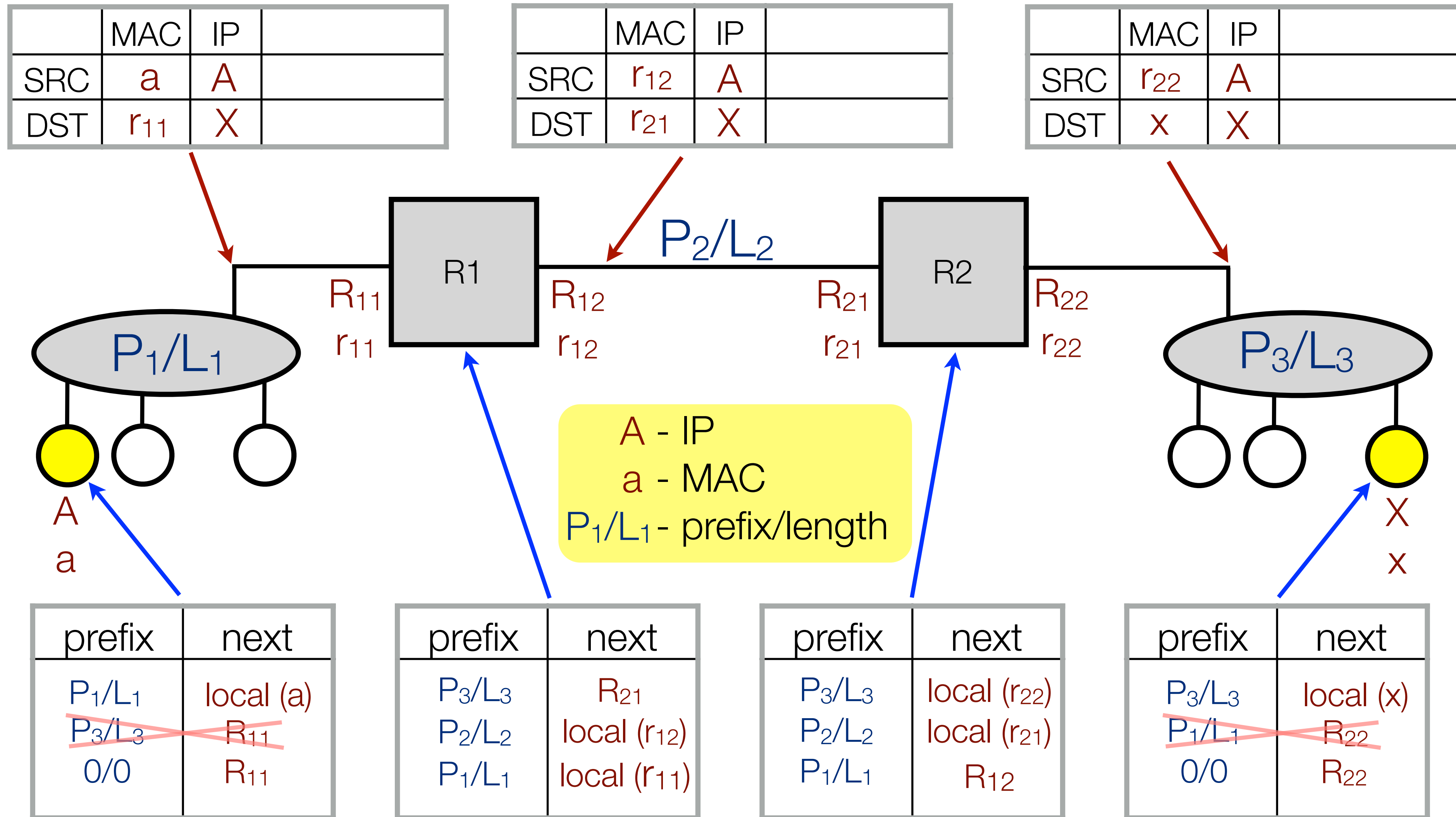
Static IP Routing



Static IP Routing



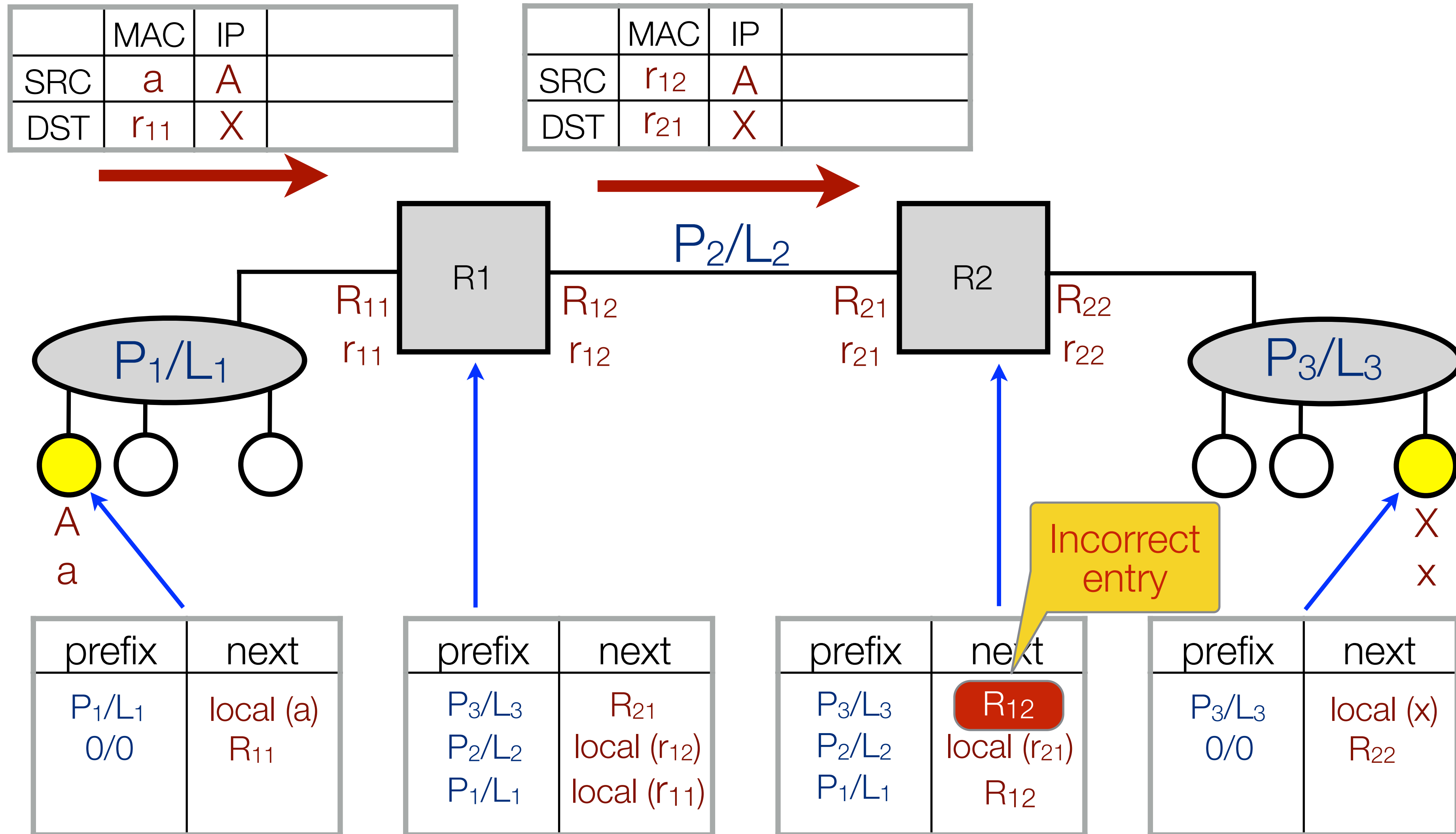
Static IP Routing



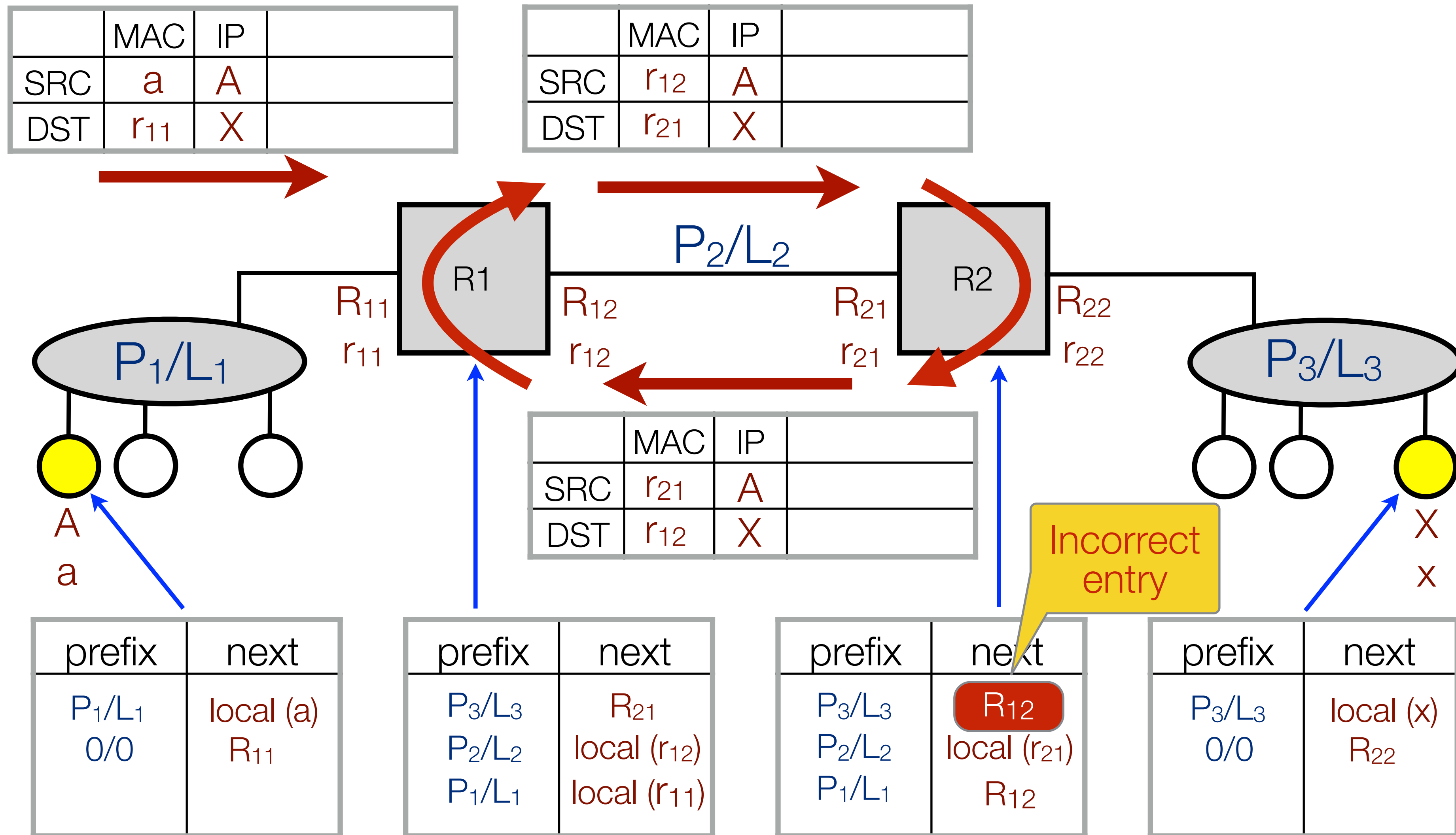
Routing loop



Routing loop



Routing loop

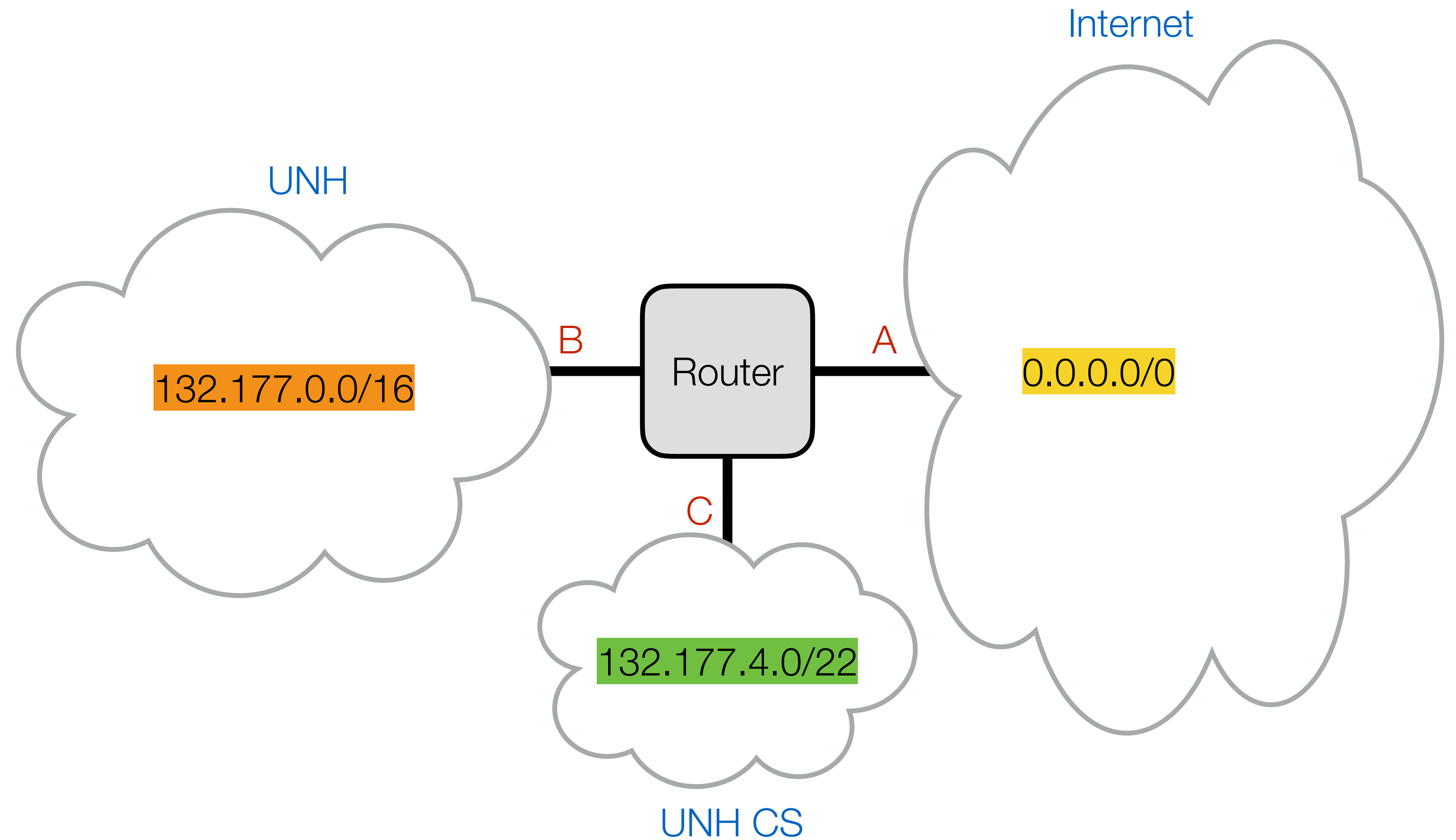


No route to host

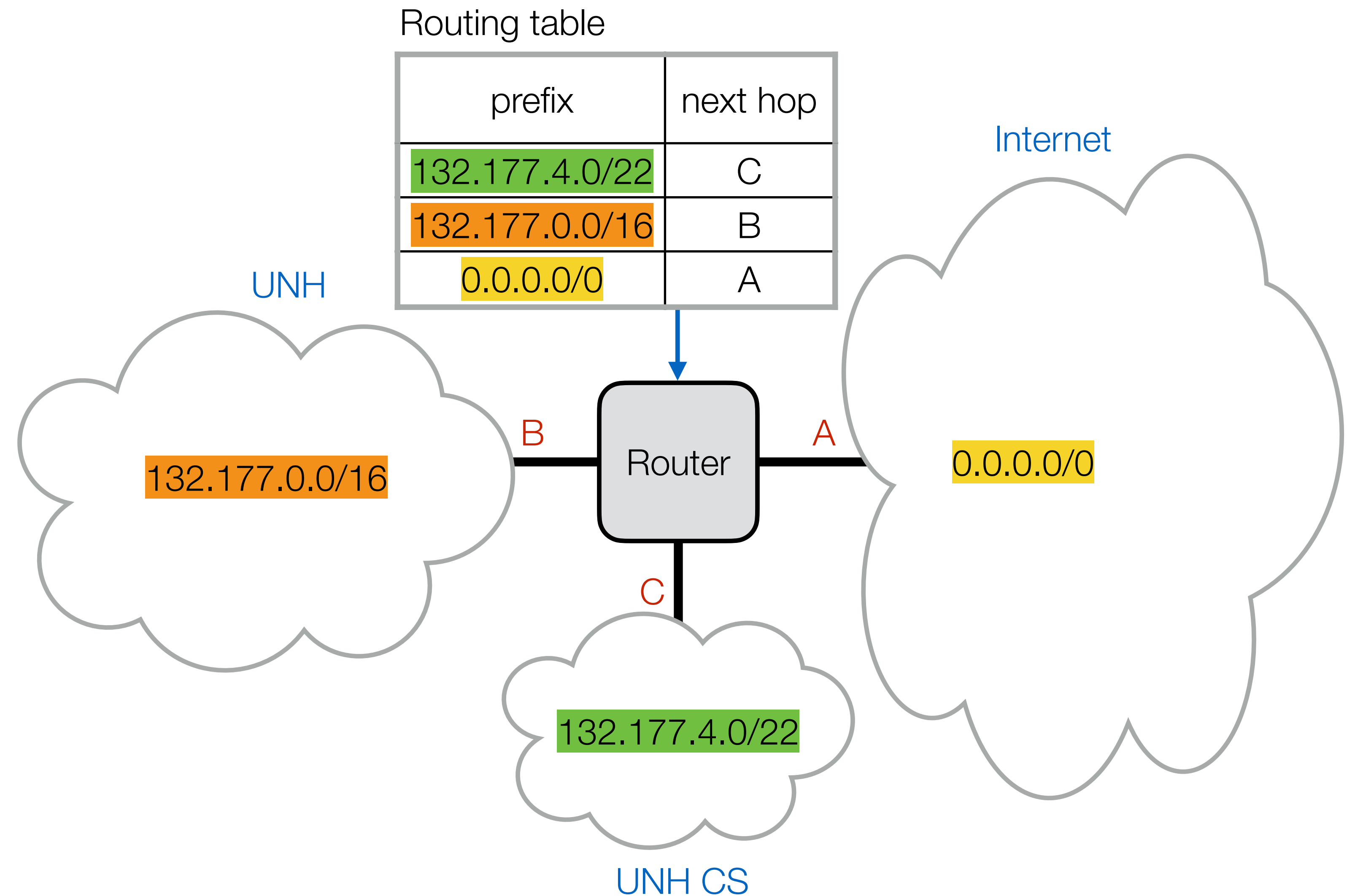


Photo courtesy of Chip McNaughton, UNH-CS

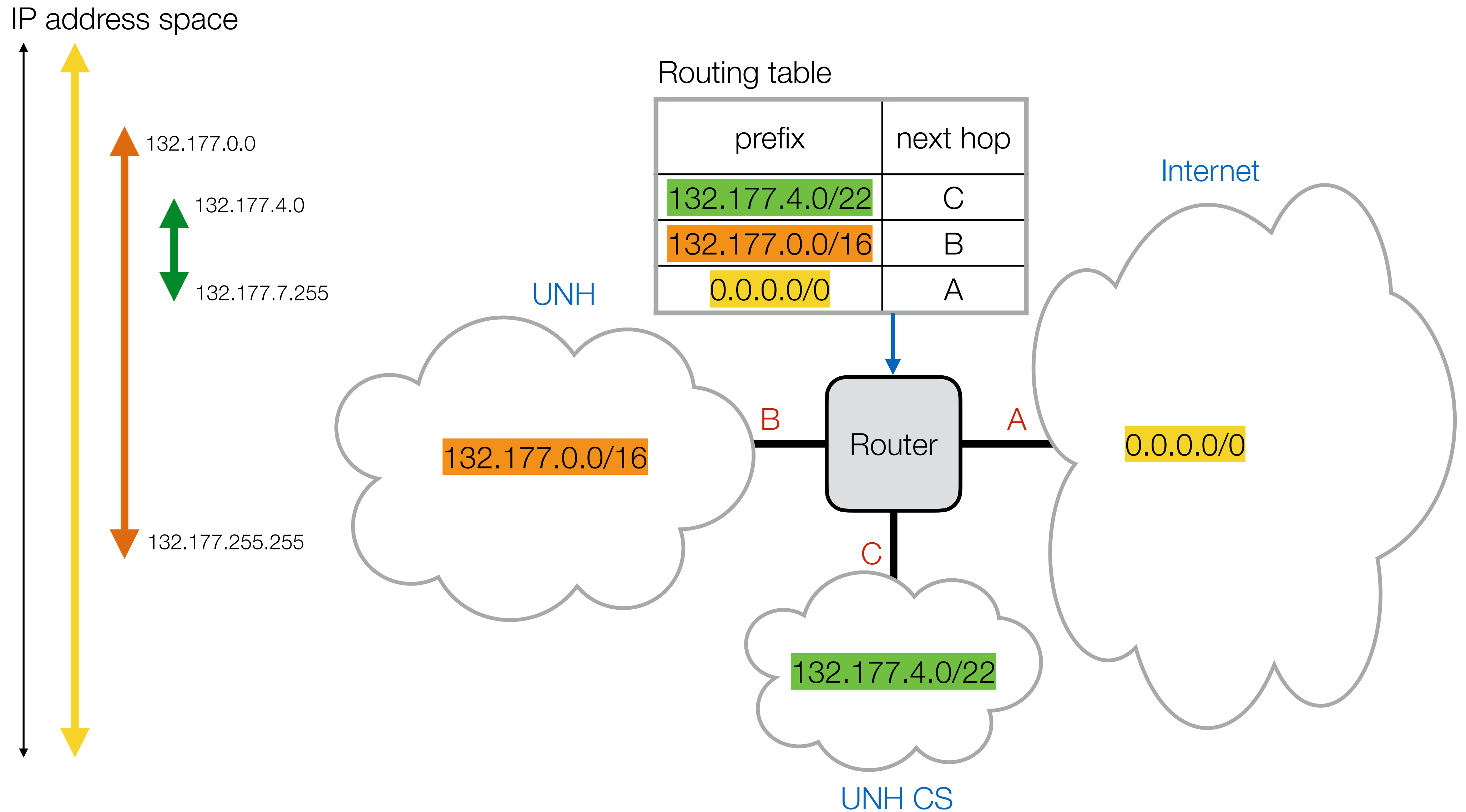
Routing example



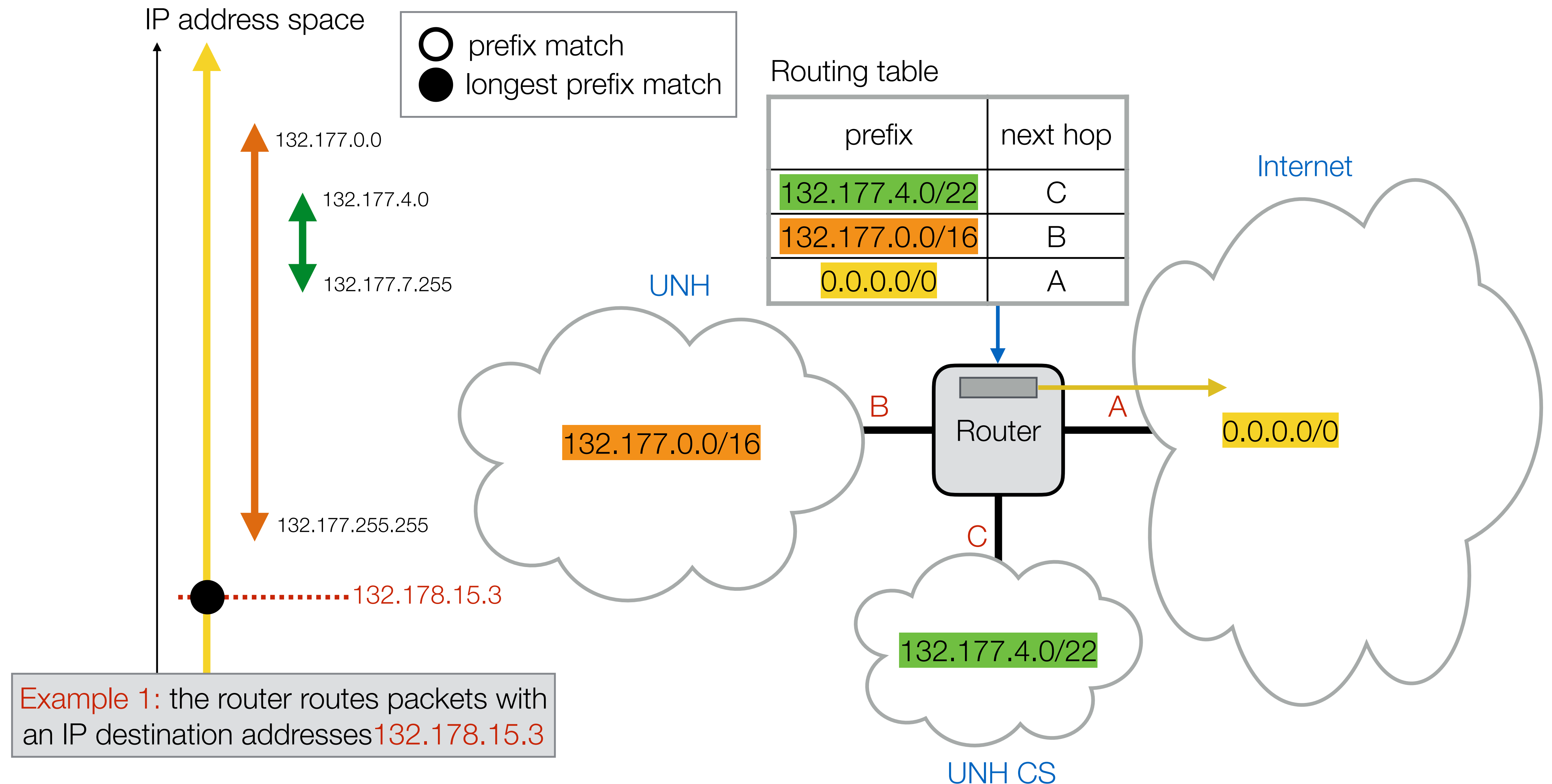
Routing example



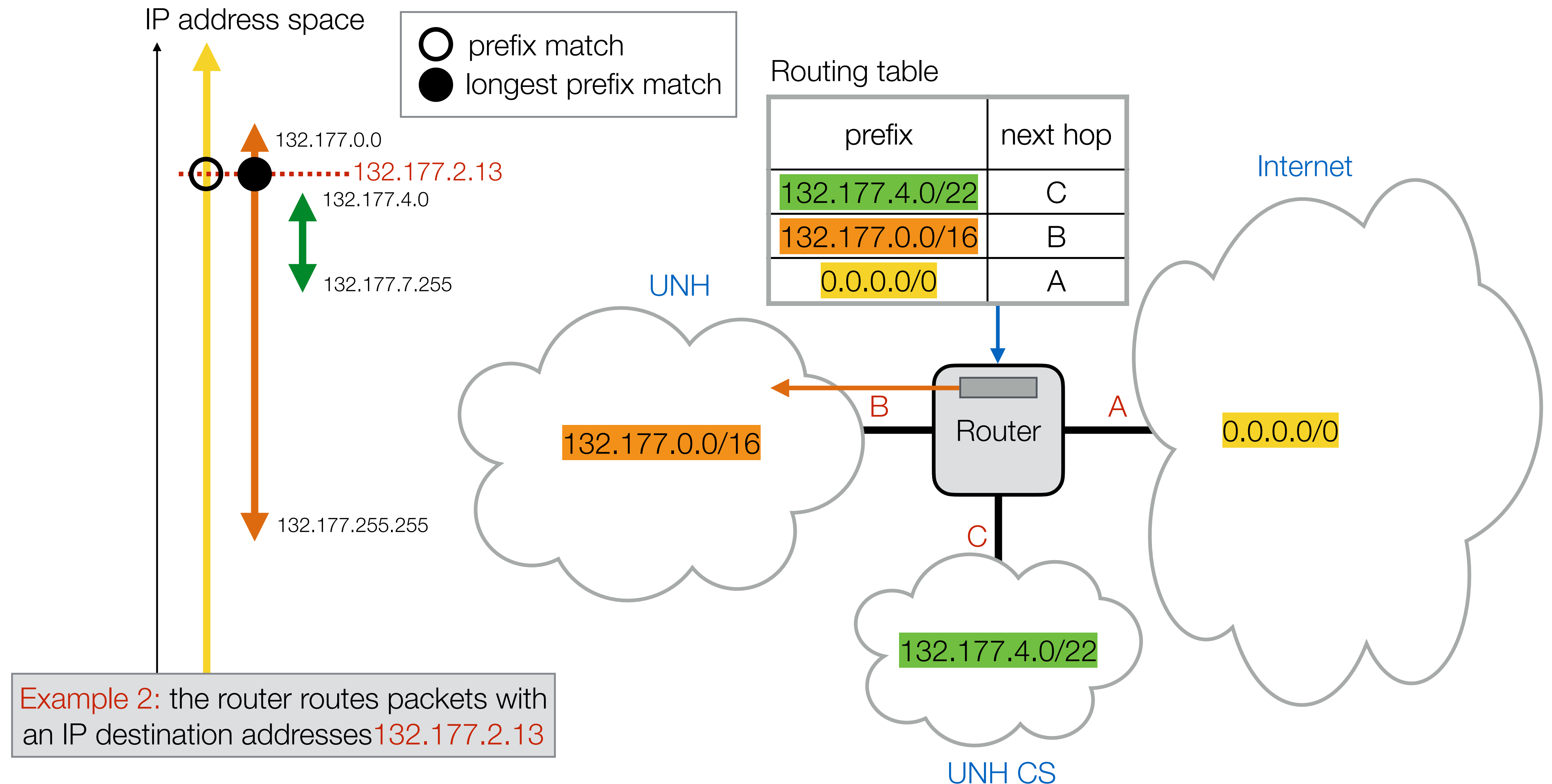
Routing example



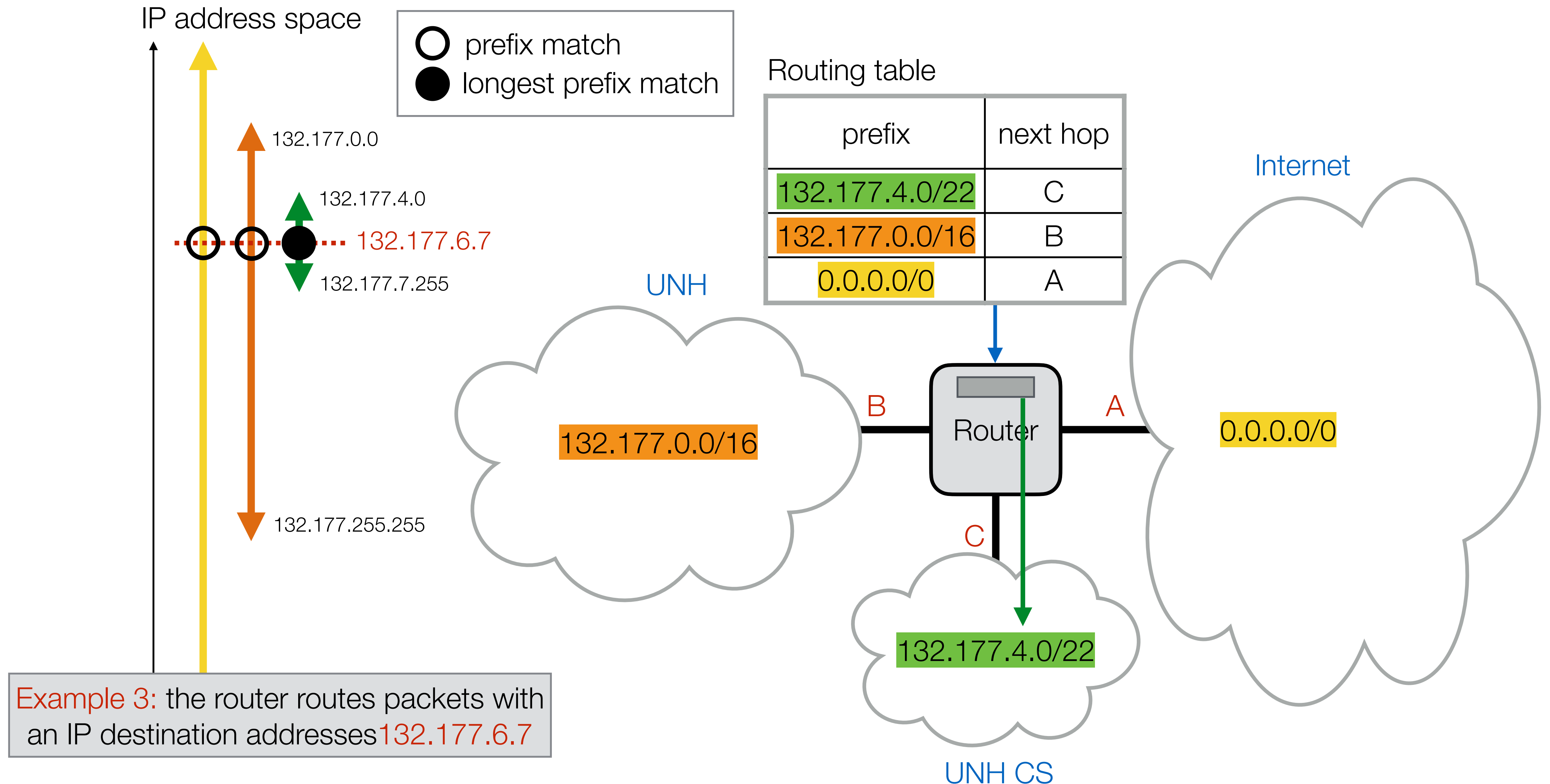
Routing example 1



Routing example 2



Routing example 3

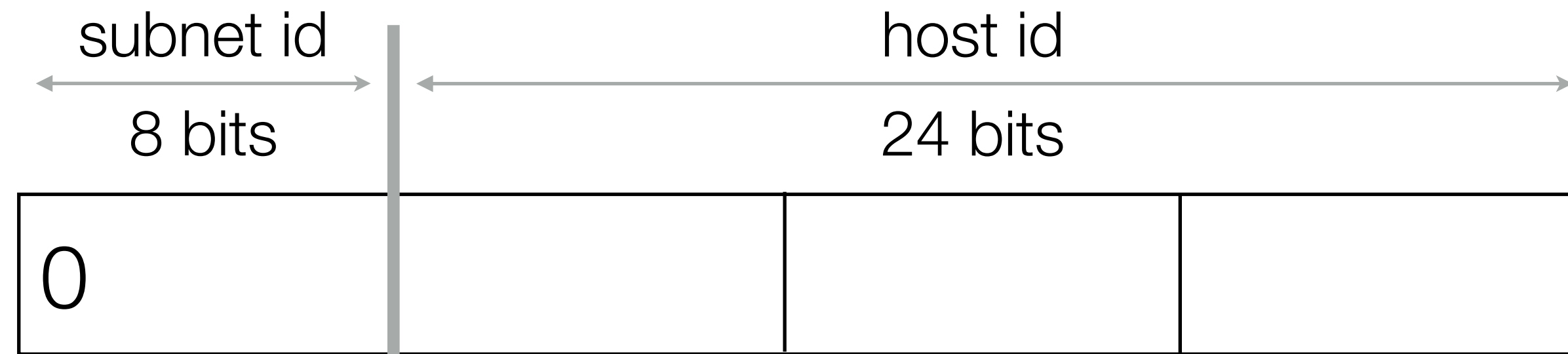


Special Use IPv4 Addresses

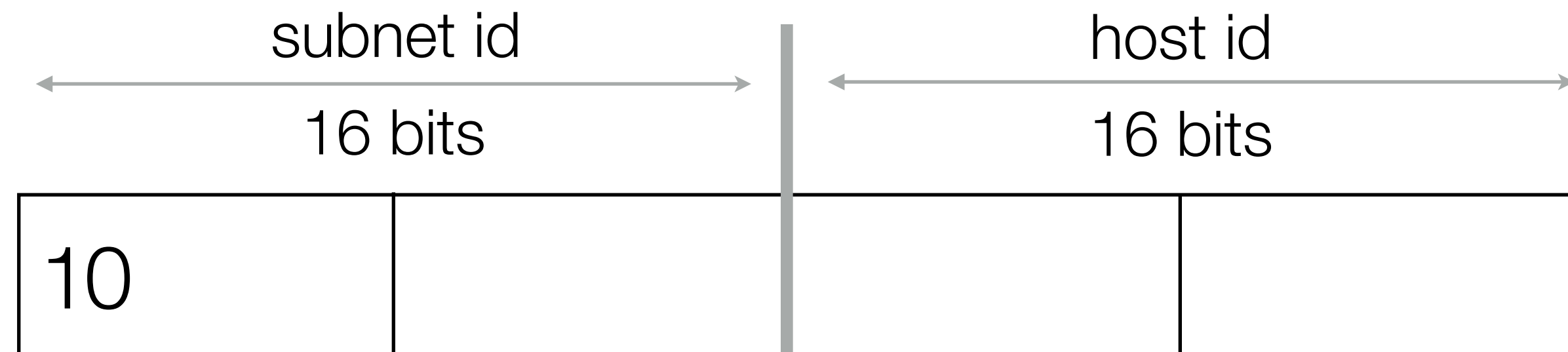
- ▶ 0.0.0.0/8 - "This" network
- ▶ 127.0.0.0/8 - Loopback
- ▶ 10.0.0.0/8,
172.16.0.0/12,
192.168.0.0/16 - Private networks
- ▶ 255.255.255.255/32 - Limited broadcast
- ▶ 169.254.0.0/16 - Link local
- ▶ (first and last IP address of a prefix: subnet broadcast)
 - i.e., host id consisting of all zeros or all ones

Class-based Routing

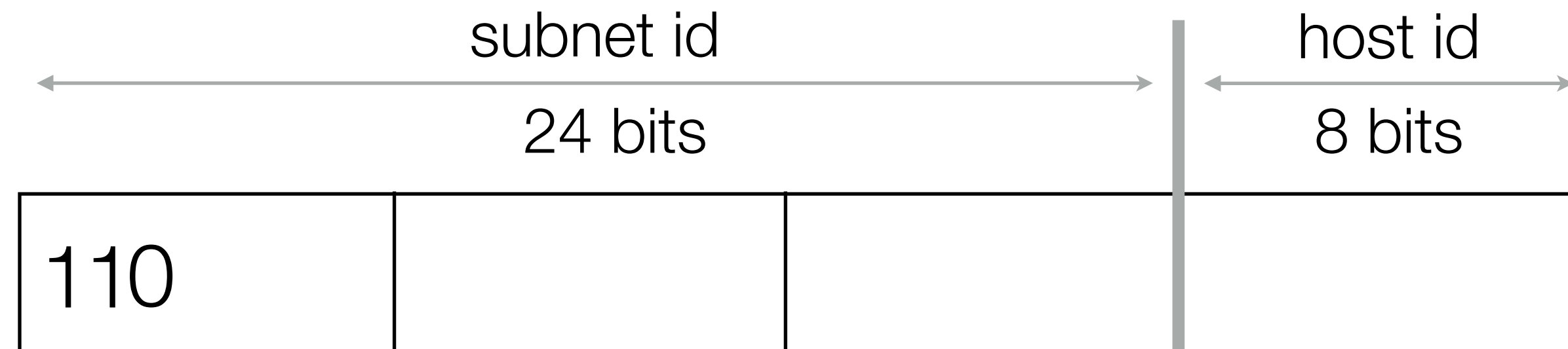
Class A



Class B



Class C

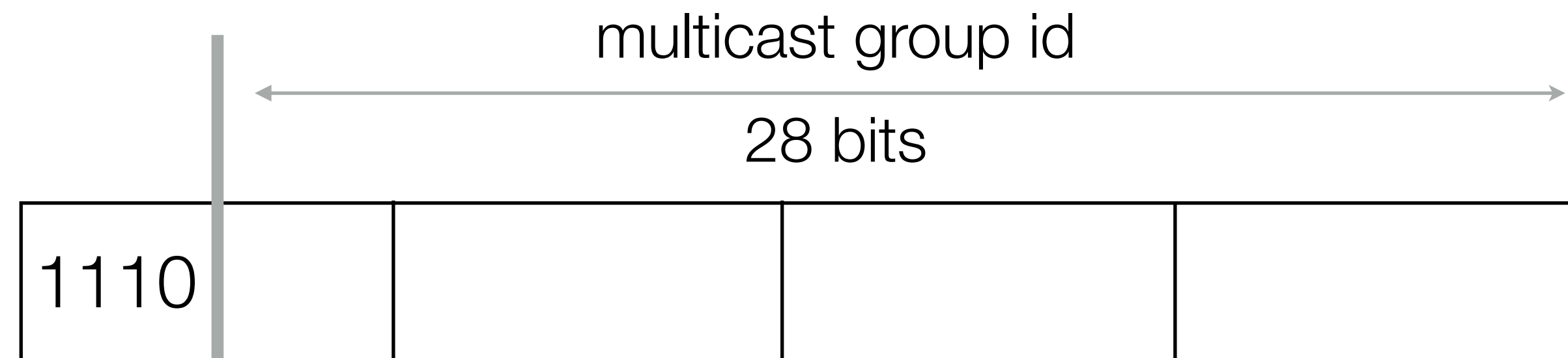


only for historical reference...

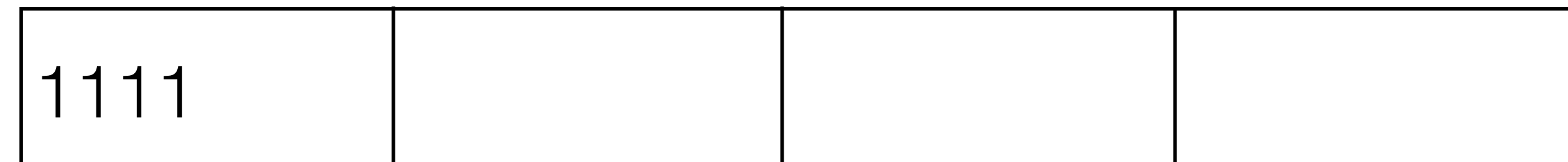
Class-based Routing

(continued...)

Multicast IP



Reserved



CIDR Addresses

notation	addrs/block	# blocks	
-----	-----	-----	
n.n.n.n/32	1	4294967296	"host route"
n.n.n.x/31	2	2147483648	"p2p link"
n.n.n.x/30	4	1073741824	
n.n.n.x/29	8	536870912	
n.n.n.x/28	16	268435456	
n.n.n.x/27	32	134217728	
n.n.n.x/26	64	67108864	
n.n.n.x/25	128	33554432	
n.n.n.0/24	256	16777216	legacy "Class C"
n.n.x.0/23	512	8388608	
n.n.x.0/22	1024	4194304	
n.n.x.0/21	2048	2097152	
n.n.x.0/20	4096	1048576	
n.n.x.0/19	8192	524288	
n.n.x.0/18	16384	262144	
n.n.x.0/17	32768	131072	
n.n.0.0/16	65536	65536	legacy "Class B"
n.x.0.0/15	131072	32768	
n.x.0.0/14	262144	16384	
n.x.0.0/13	524288	8192	
n.x.0.0/12	1048576	4096	
n.x.0.0/11	2097152	2048	
n.x.0.0/10	4194304	1024	
n.x.0.0/9	8388608	512	
n.0.0.0/8	16777216	256	legacy "Class A"
x.0.0.0/7	33554432	128	
x.0.0.0/6	67108864	64	
x.0.0.0/5	134217728	32	
x.0.0.0/4	268435456	16	
x.0.0.0/3	536870912	8	
x.0.0.0/2	1073741824	4	
x.0.0.0/1	2147483648	2	
0.0.0.0/0	4294967296	1	"default route"

Classless Inter-Domain Routing

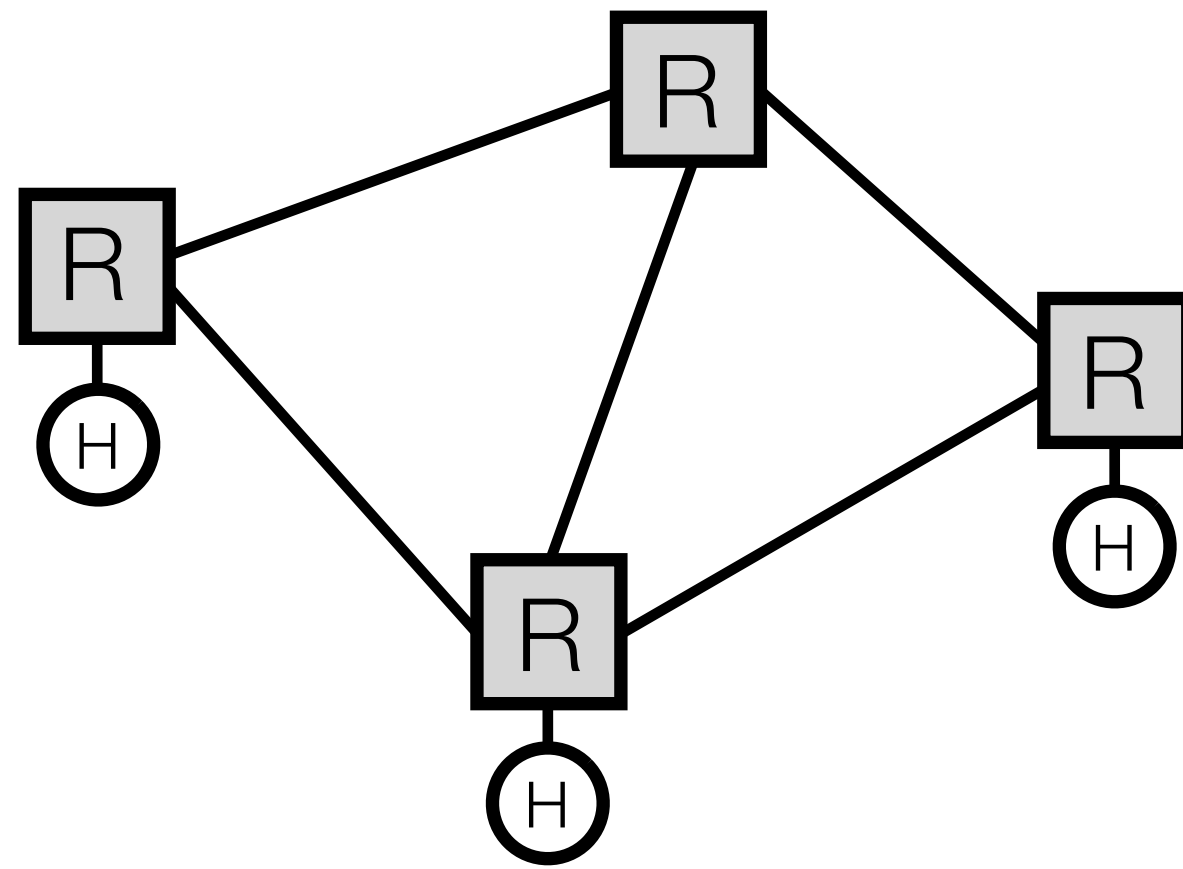
From **RFC 4632**:

n is an 8-bit decimal octet value.

x is a 1- to 7-bit value, based on the prefix length, shifted into the most significant bits of the octet and converted into decimal form; the least significant bits of the octet are zero.

Recall...

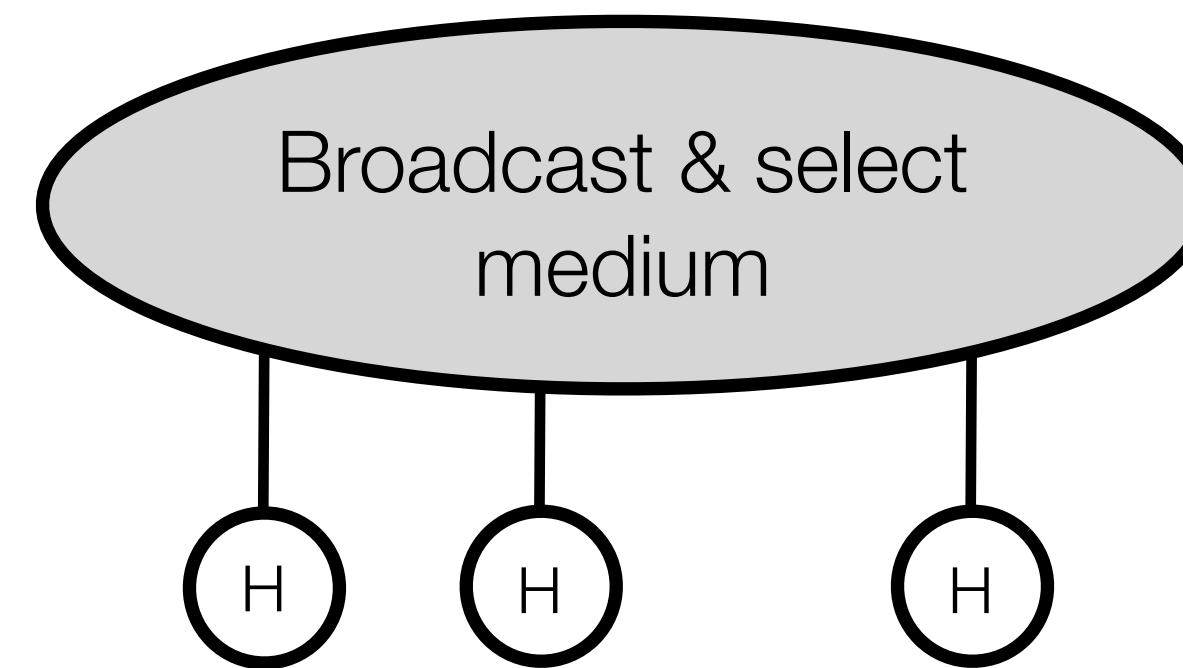
► Routed networks



- topology driven by geography
- long distances (high latency)
- need for scalability
- location-related addresses
- routing

➡ **Network Layer (L3)**

► Broadcast & select



- everyone connected to everyone
- short distances (low latency)
- lesser need for scalability
- arbitrary addresses
- address discovery

➡ **Link Layer (L2)**

Routing Alternative: Bridging

► Motivation

- L2 networks do not scale due to the broadcast nature of the underlying medium
- Routers are expensive and require configuration

► Approach - extend the reach of L2

► Solution - limit the scope of packet delivery (bridging)

Motivation (personal)

John Green Hall, the former home of the *Department of Mathematics and Computer Science*, University of Denver

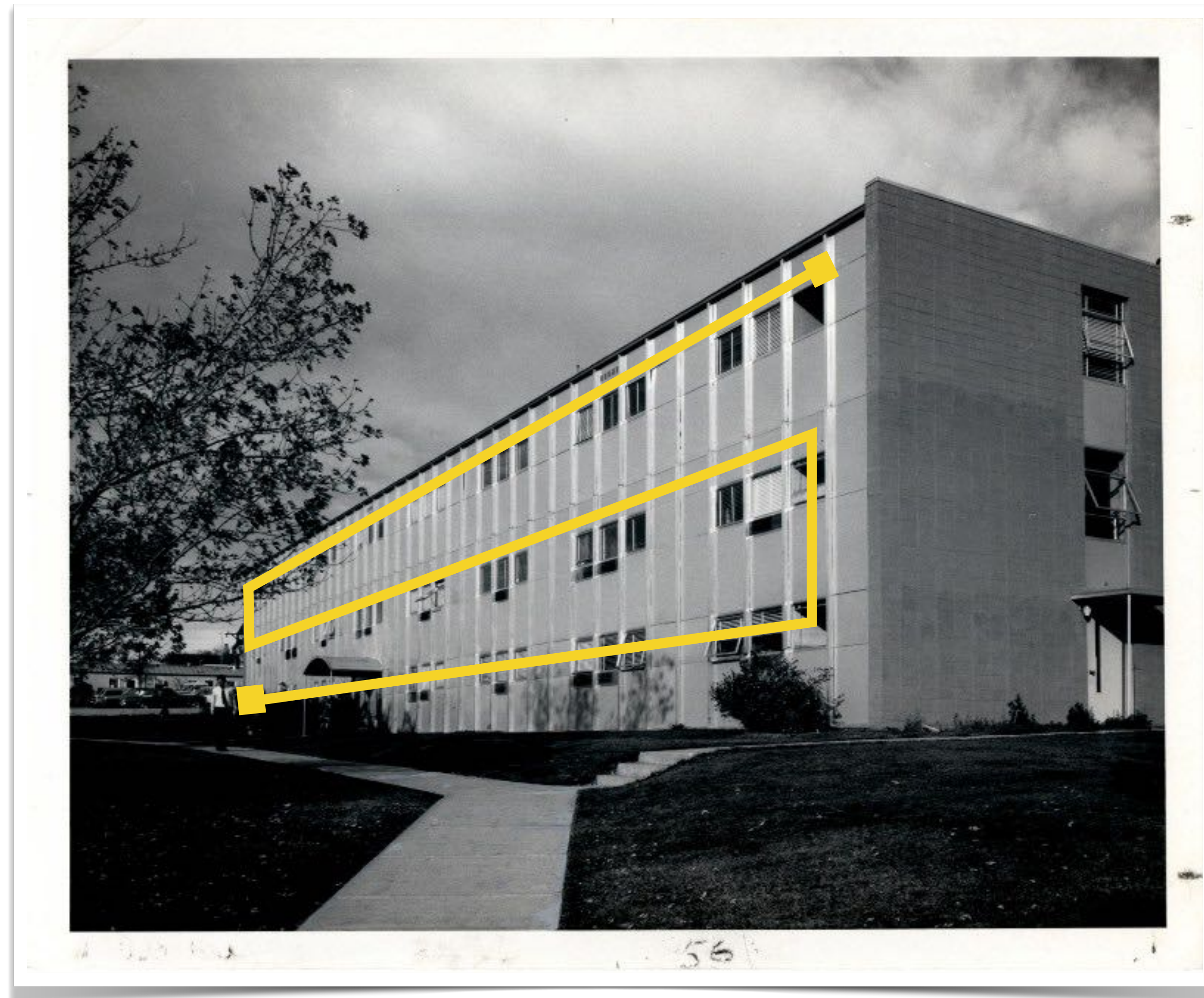
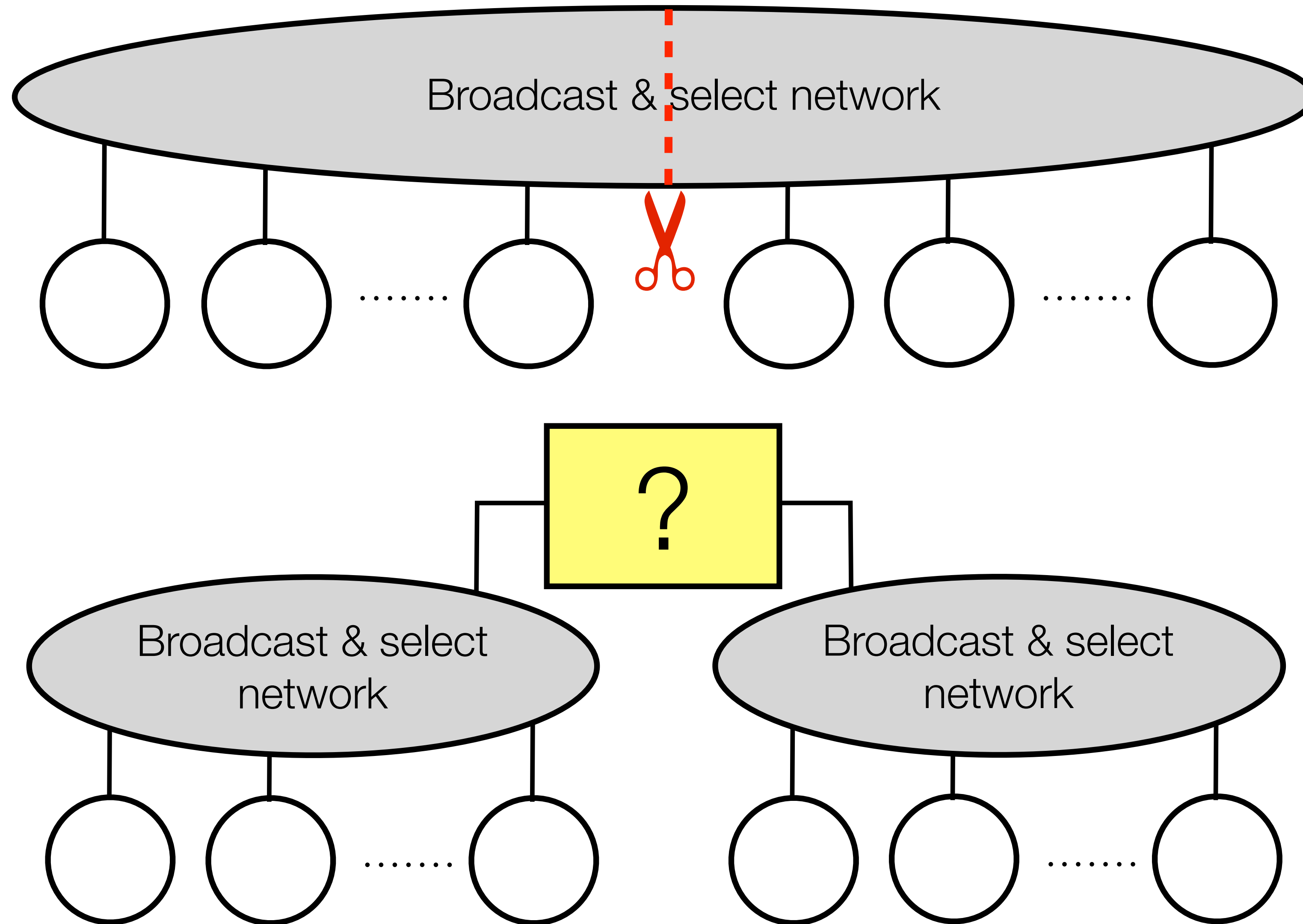


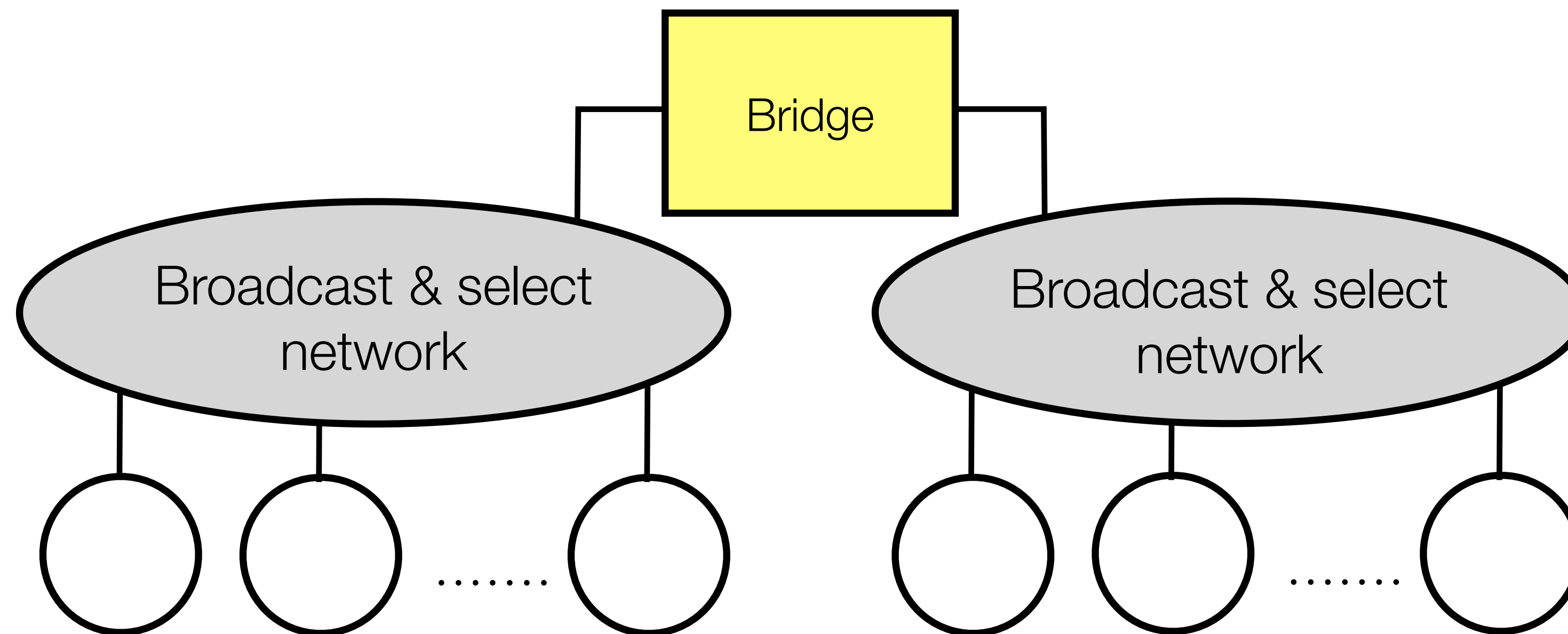
Image source: University of Denver

Historical Evolution



Link Layer Bridging

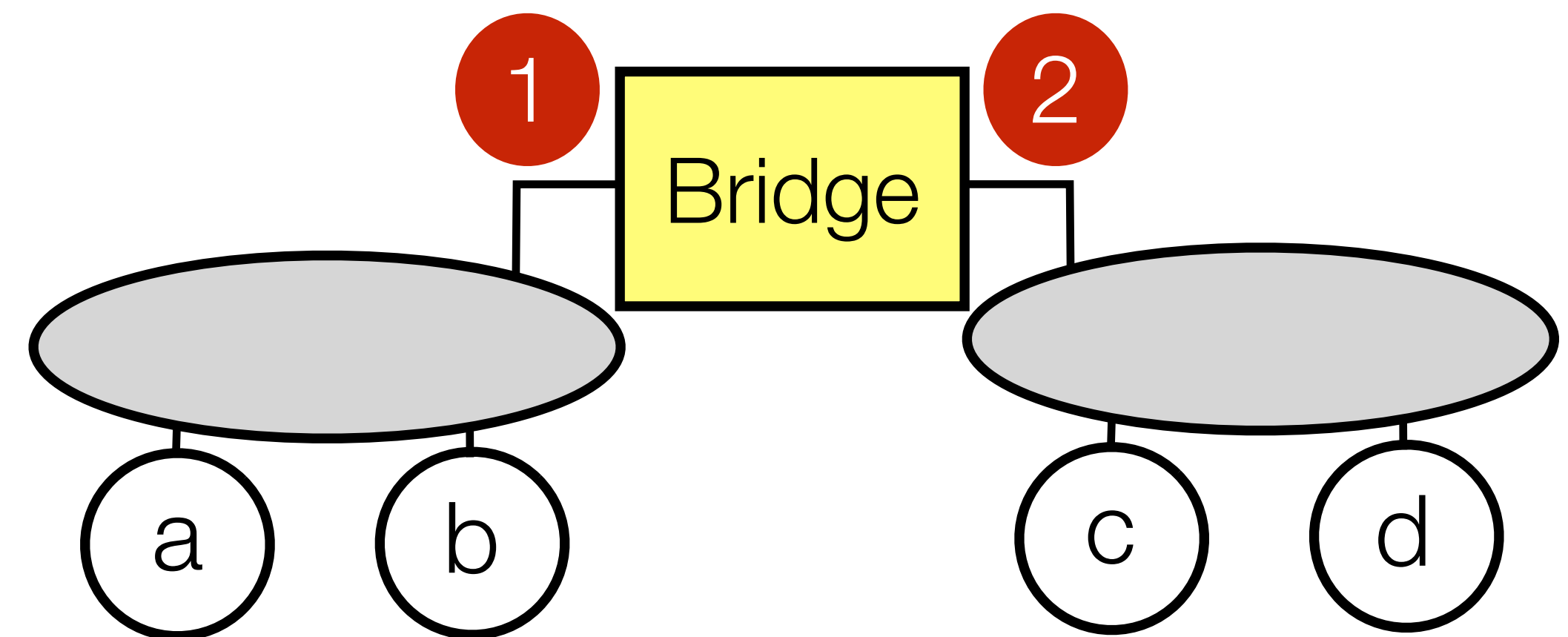
- ▶ Bridge “opens” for non-local traffic and broadcasts
- ▶ Bridge **learns** node locations from passing traffic and stores them in its **Forwarding Database (FDB)** (a.k.a. bridge, bridging, or switching table)



Transparent Bridging

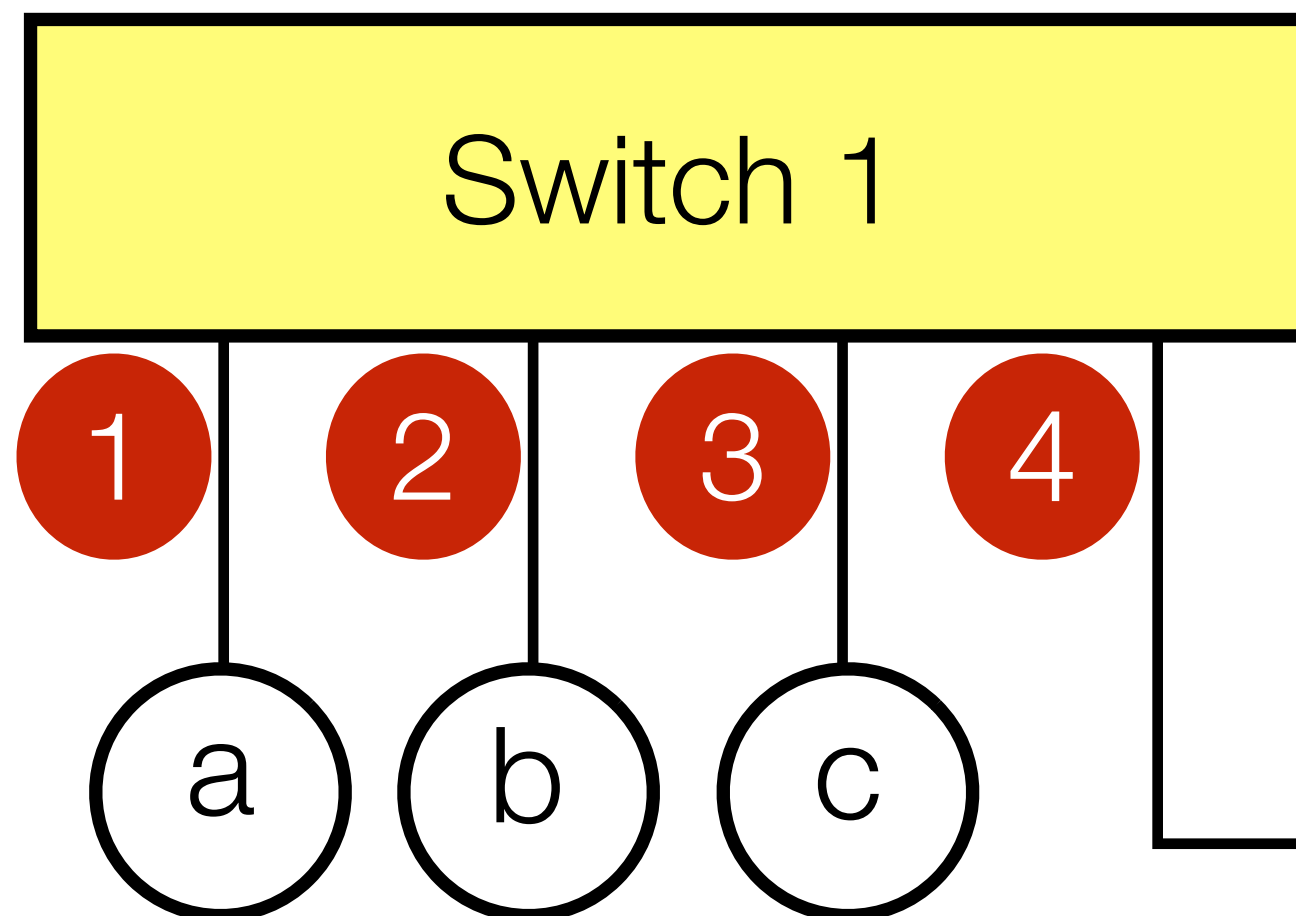
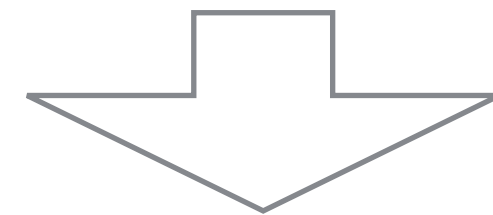
- ▶ Initially, the bridging table (FDB) is empty
- ▶ Broadcast traffic is let to pass, source address recorded in the FDB
- ▶ Traffic to an unknown destination is let to pass through the bridge, source address is recorded in the FDB
- ▶ Non-local traffic (to a known destination that is associated with different interface, e.g., *a* to *d*) is let to pass, “local” traffic (e.g., *a* to *b*) is blocked

MAC	Interface
a	1
b	1
c	2
d	2

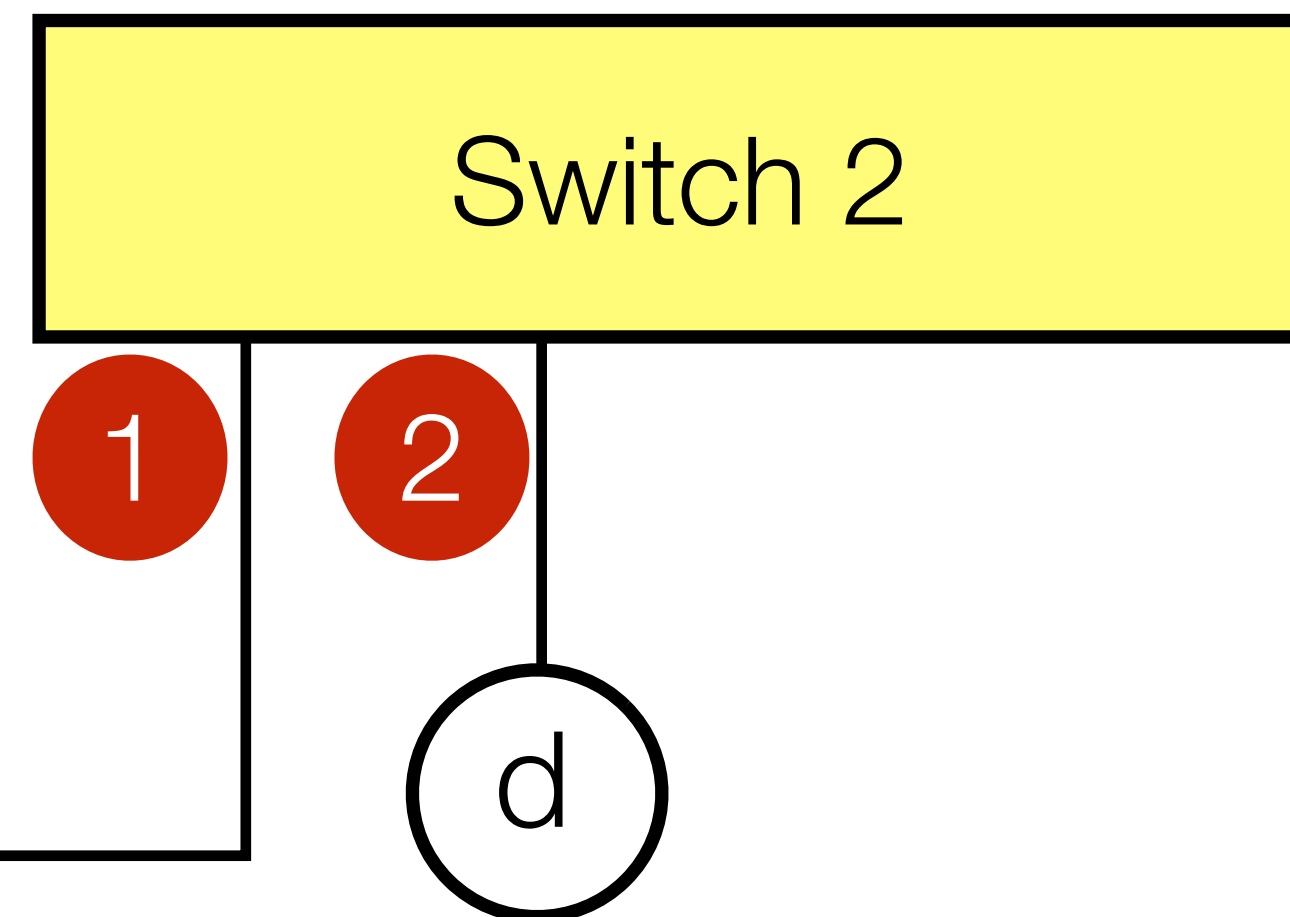
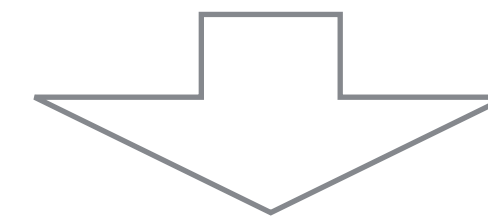


L2 (Ethernet) Switching

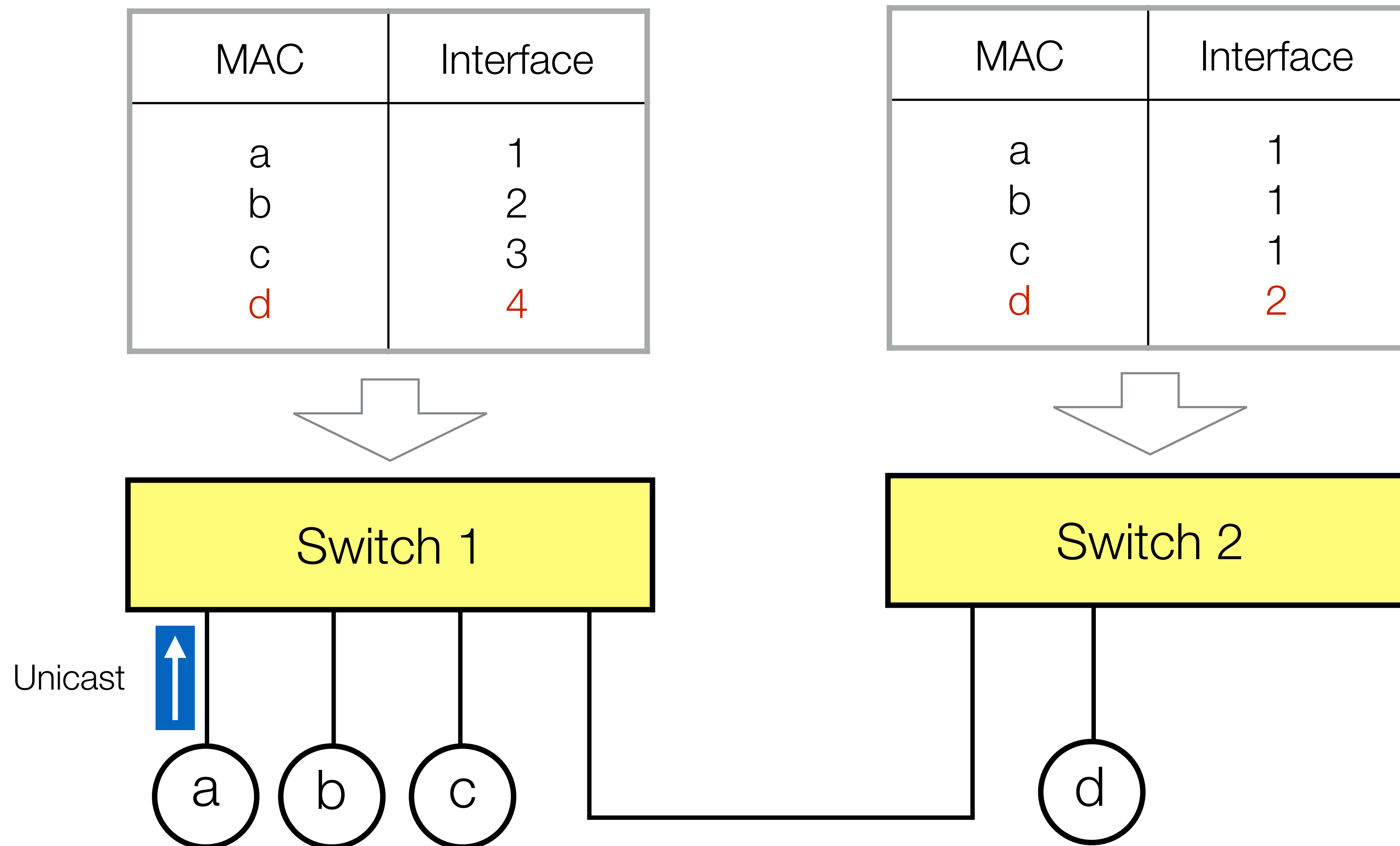
MAC	Interface
a	1
b	2
c	3
d	4



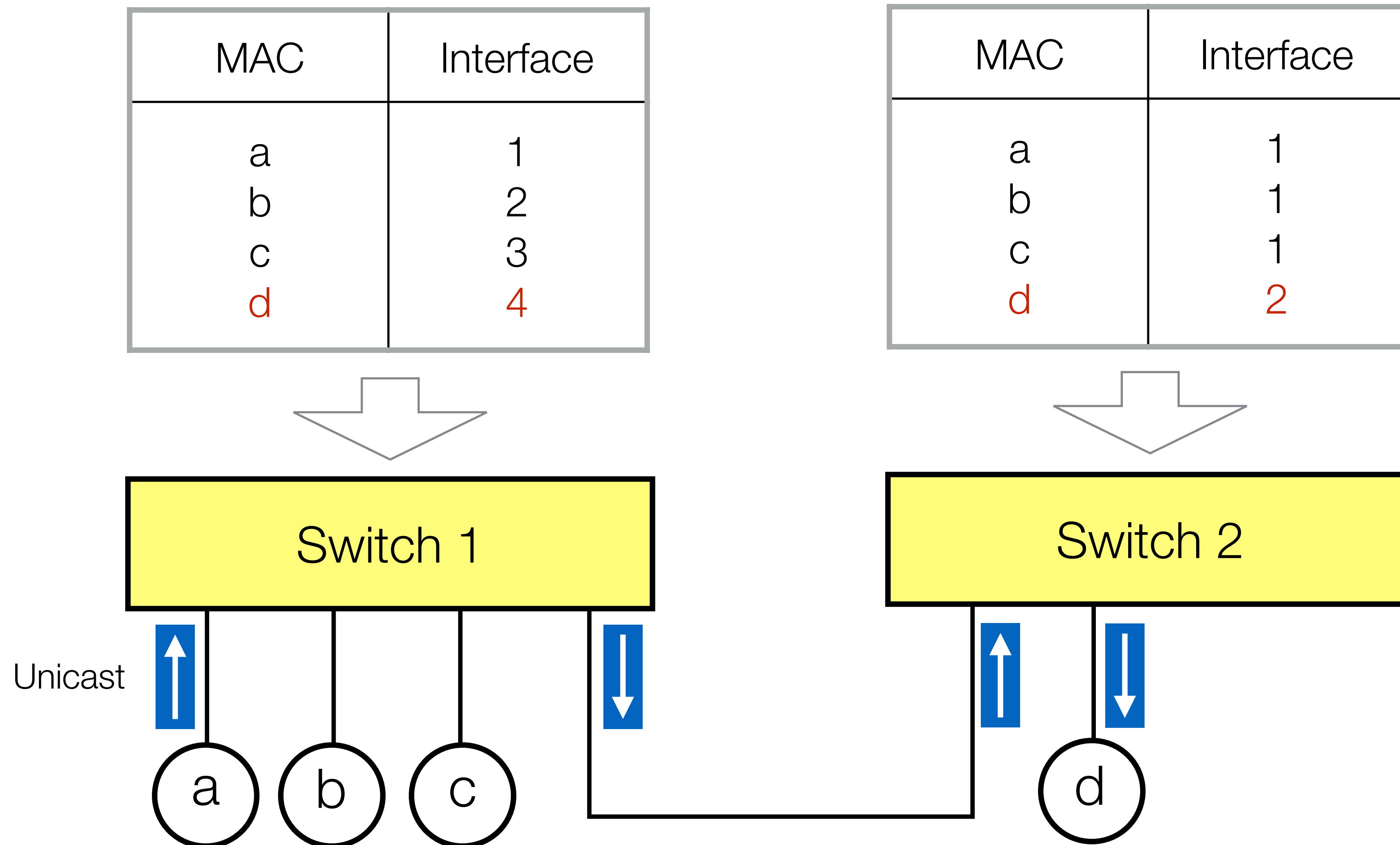
MAC	Interface
a	1
b	1
c	1
d	2



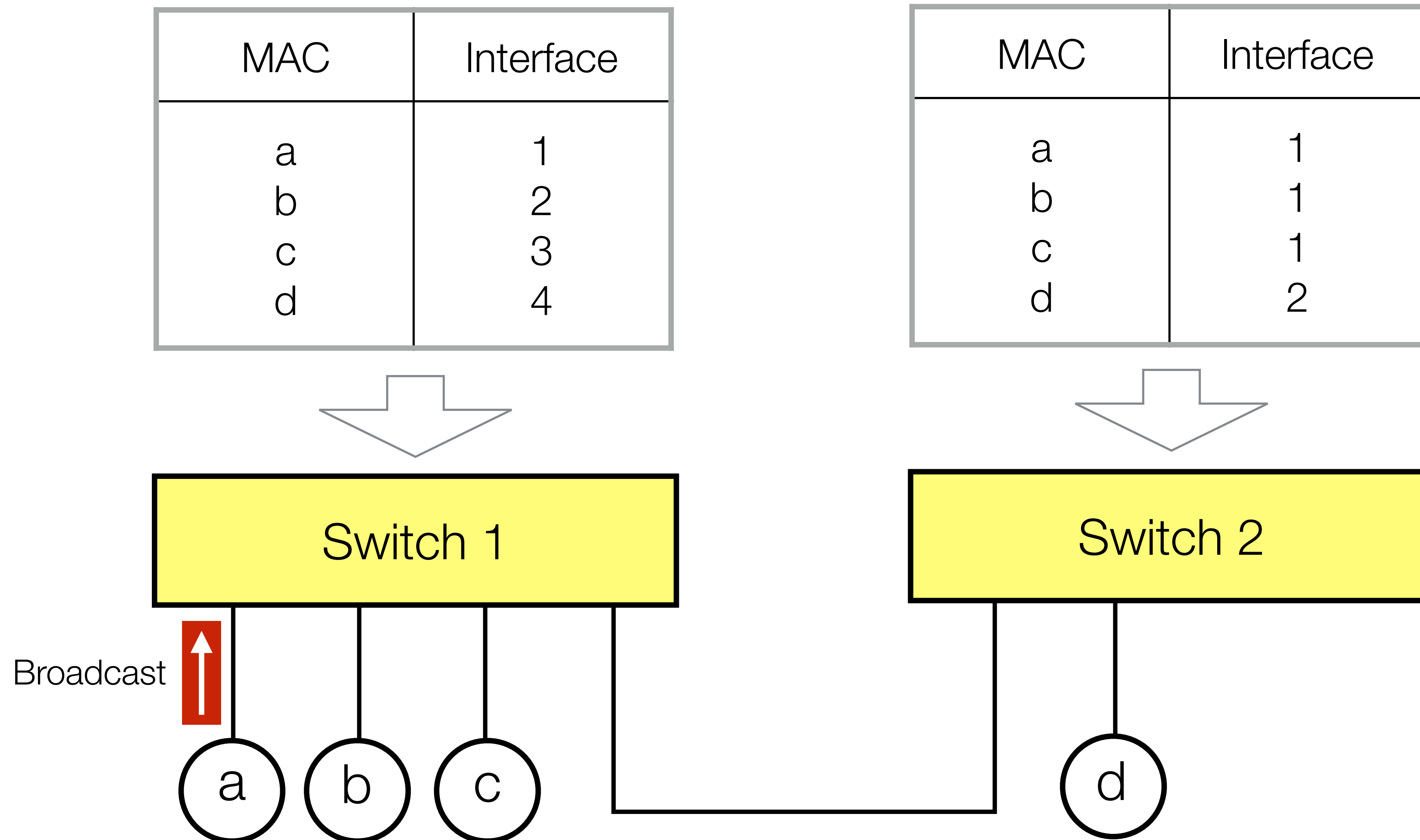
Unicast packet from *a* to *d*



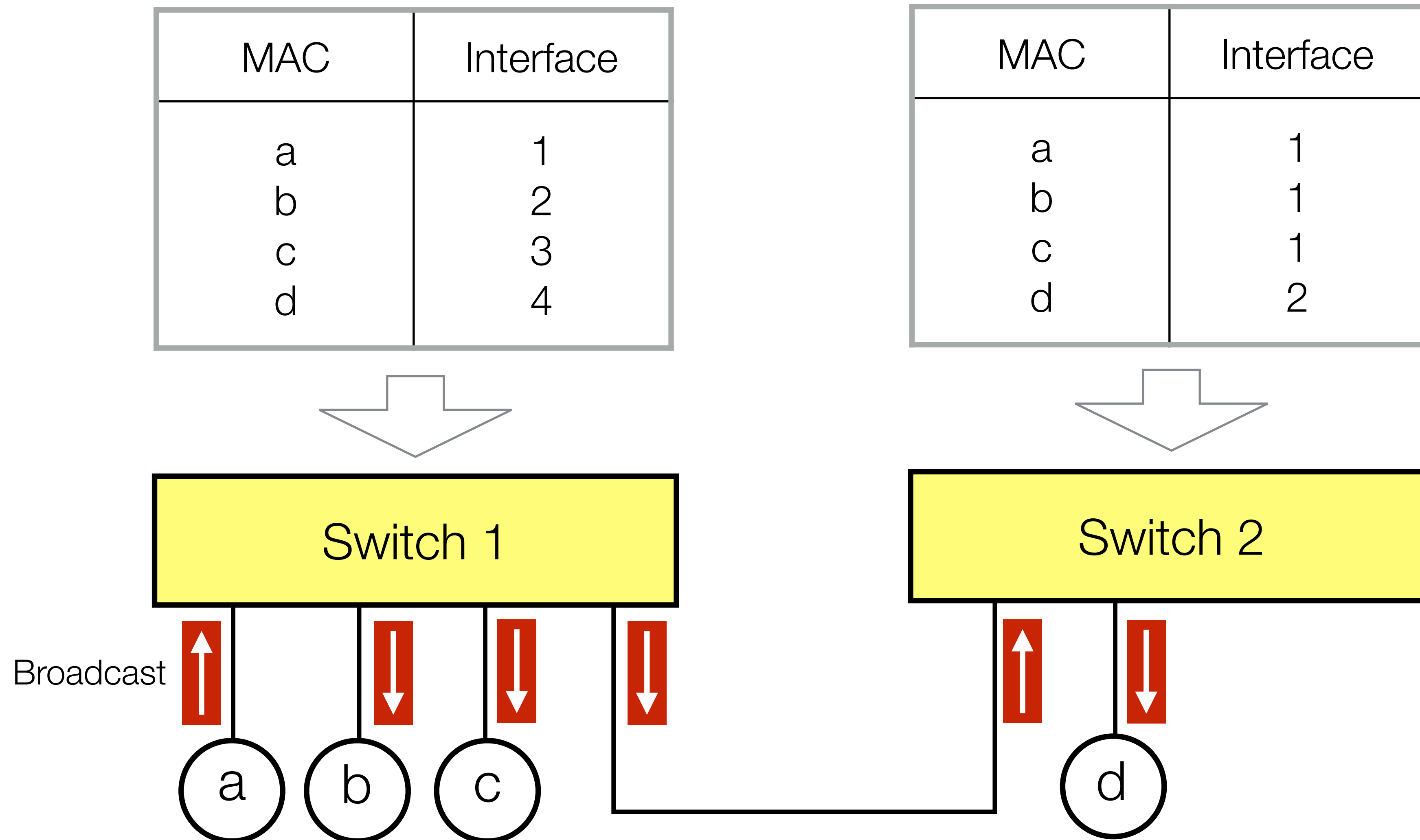
Unicast packet from *a* to *d*



Broadcast packet



Broadcast packet



Standardization

- ▶ **ISO** - International Organization for Standardization
- ▶ **ITU-T** - International Telecommunication Union - Telecommunication Sector
- ▶ **IEEE** - Institute of Electrical and Electronic Engineers
- ▶ **IETF** - Internet Engineering Task Force
- ▶ **x Forum / x Alliance / x Group**