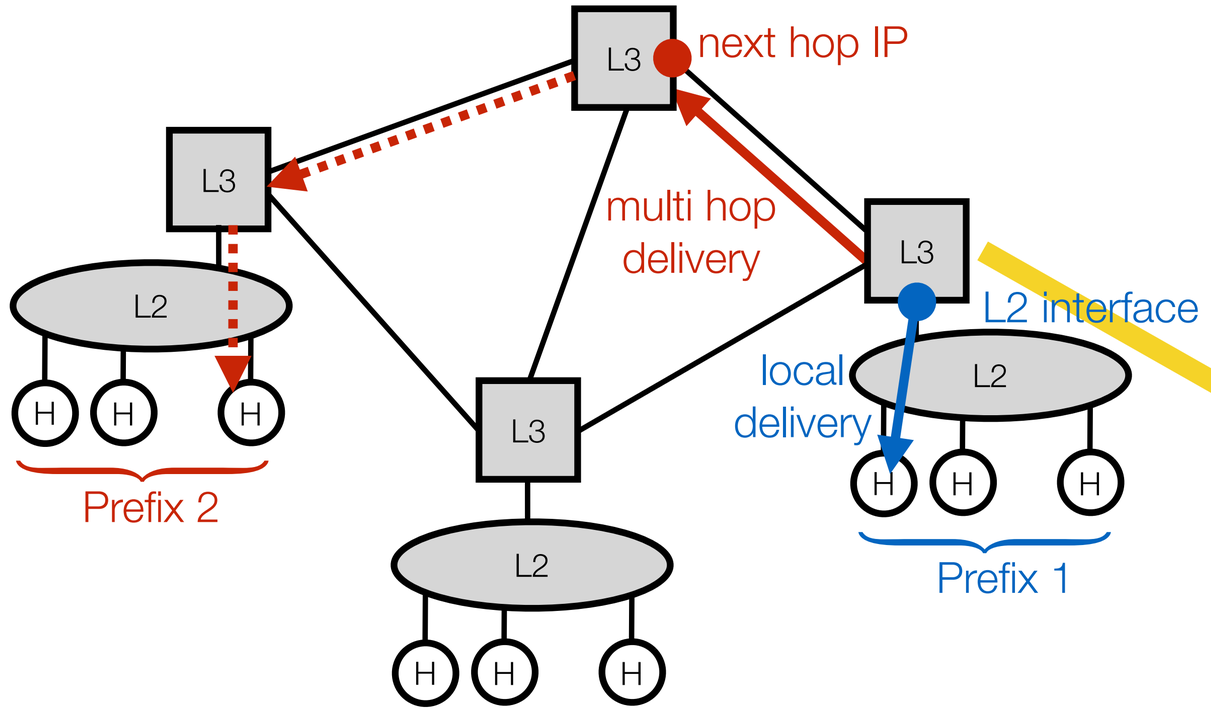
CS 725/825 & IT 725

Lecture 6

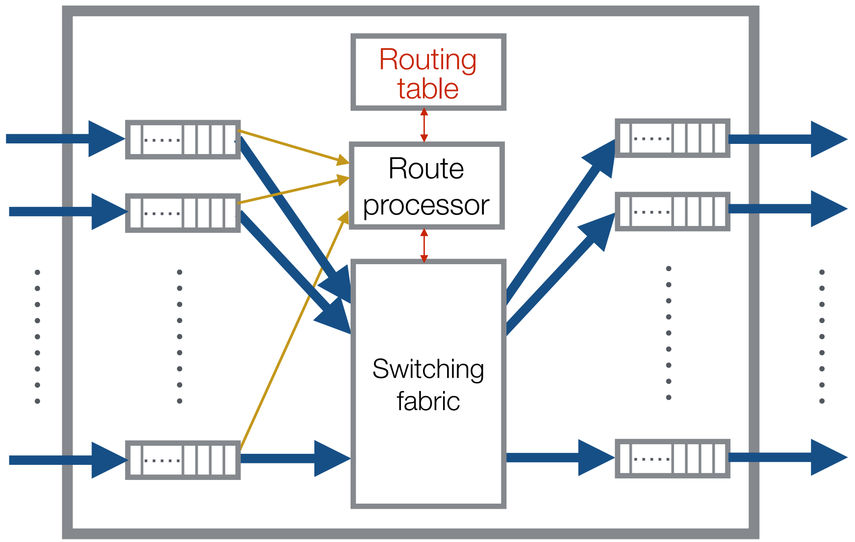
Networking Fundamentals

September 15, 2025

Network Layer Routing



Prefix	Next hop
Prefix 1	L2 interface
Prefix 2	Next hop IP
...	...



Hop-by-hop routing: “your next hop is X, go there and ask for further directions”

Routing table

Prefix	Next hop
Prefix 1	L2 interface
Prefix 2	Next hop IP
...	...

use ARP to find the MAC address of the destination

search the routing table to find the L2 interface to reach the next hop, then use ARP to find out the next hop's MAC address

Longest prefix match

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)

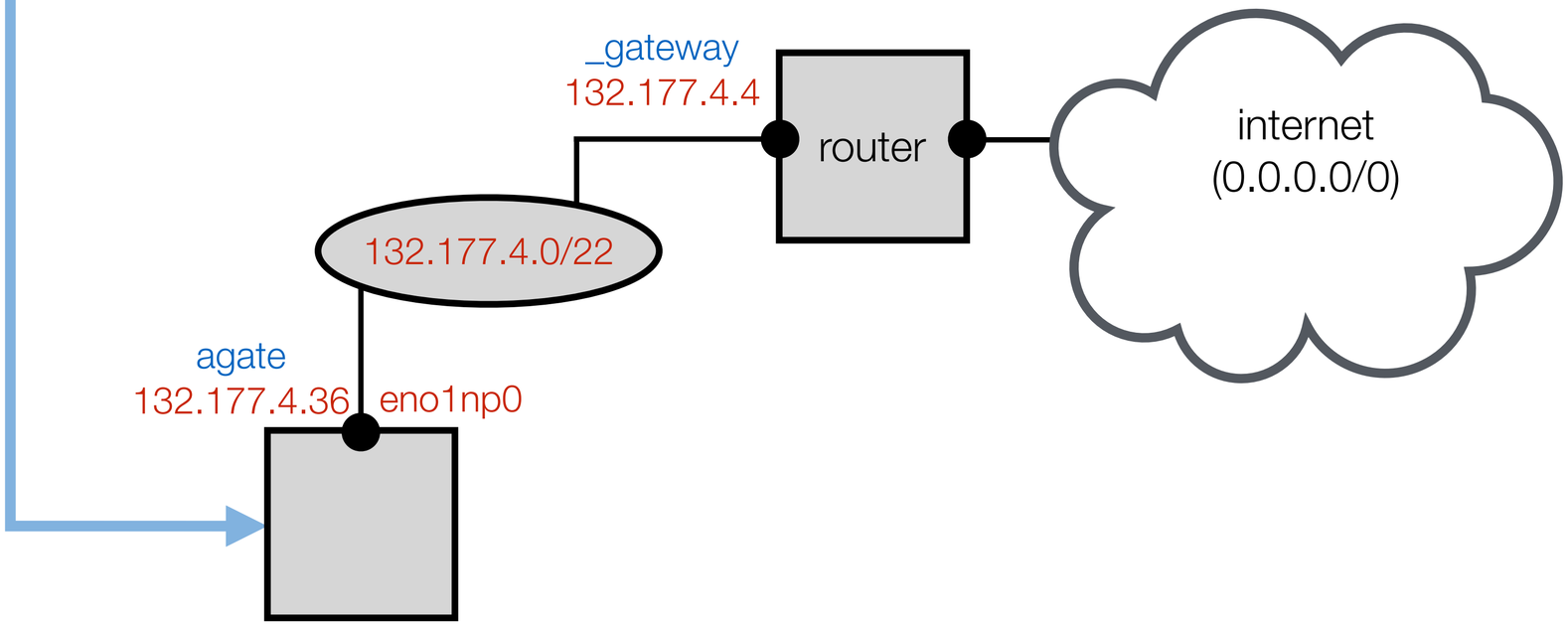
0.0.0.0/0 (everything else) → send to _gateway
132.177.4.4 via eno1np0
(do ARP for 132.177.4.4)

Host routing table

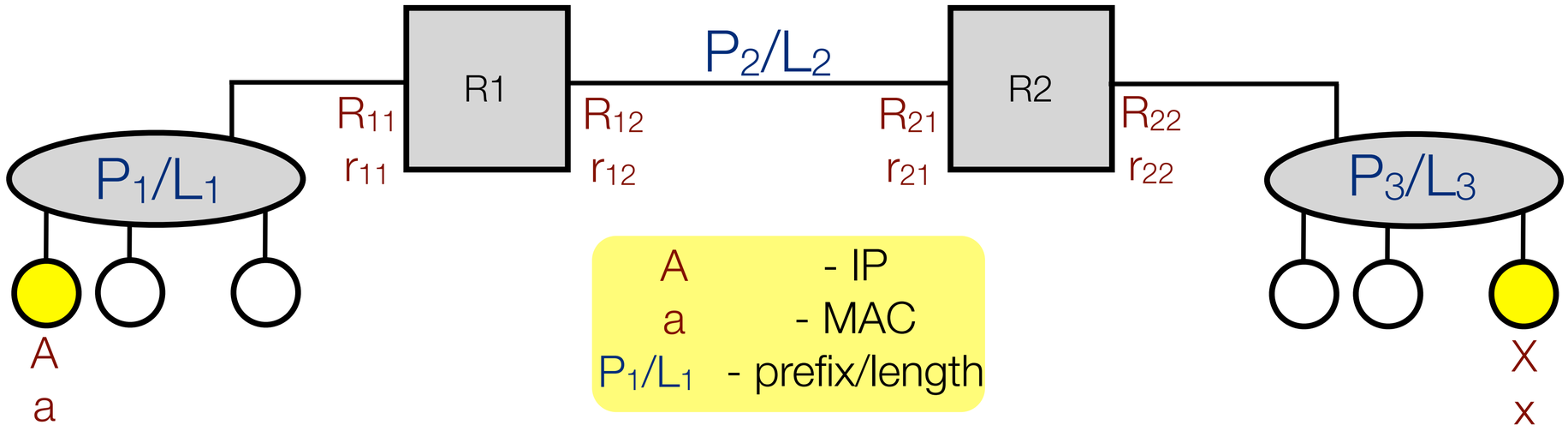
```
rbartos@agate ~$ route
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
default         _gateway        0.0.0.0         UG    100    0        0 eno1np0
unh-cs          0.0.0.0         255.255.252.0   U     100    0        0 eno1np0

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

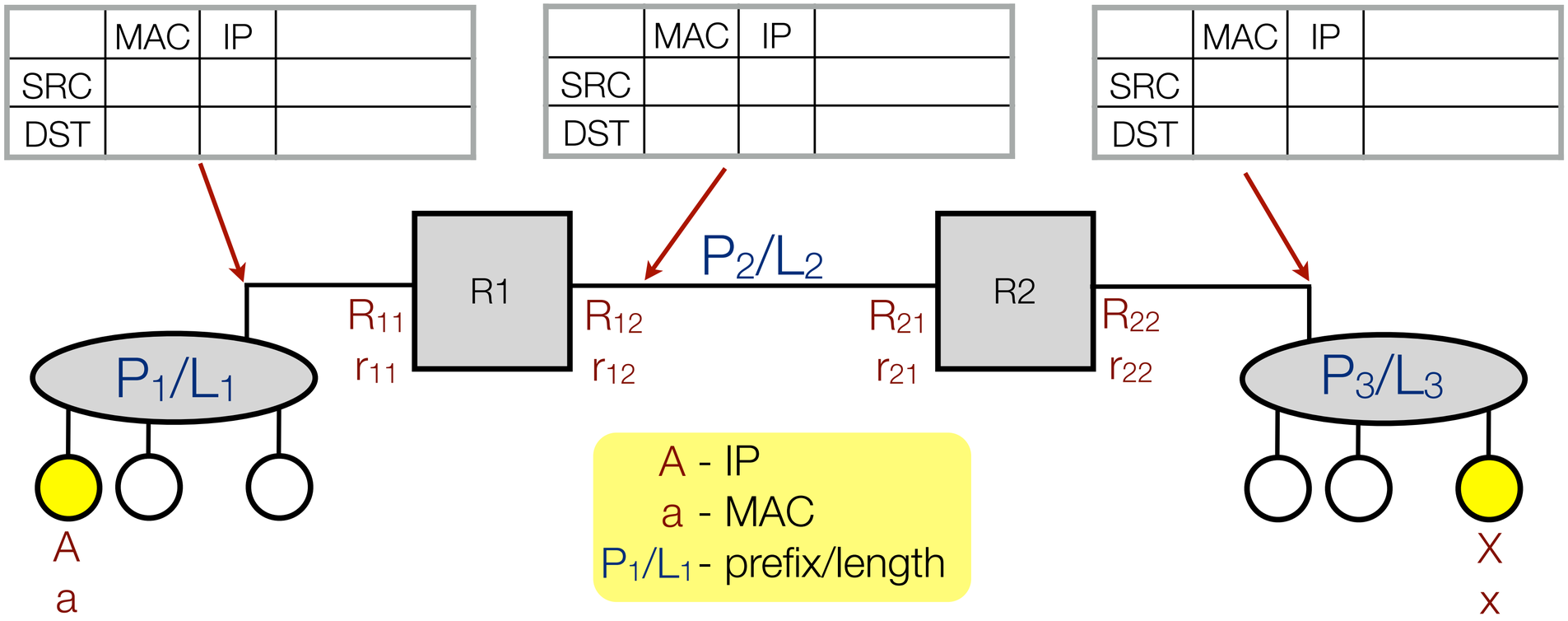


For example: P_1/L_1 10.0.1.0/24

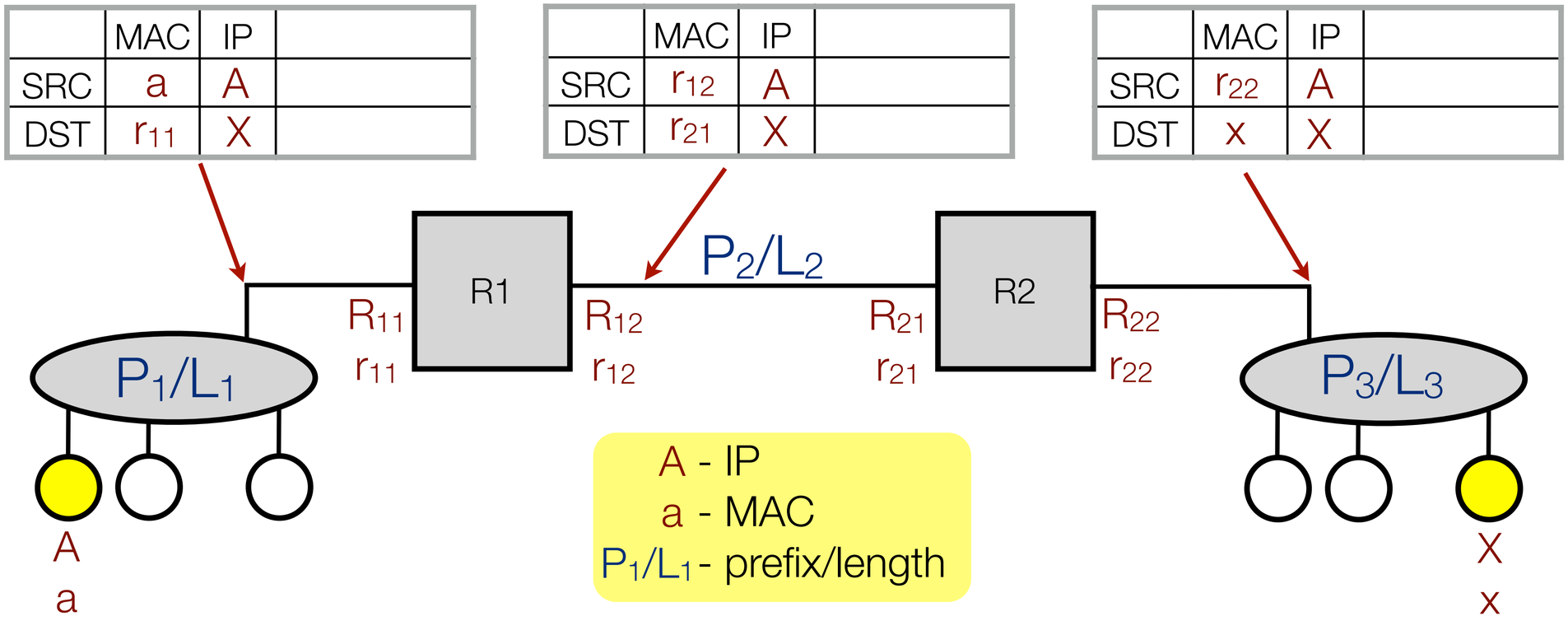
A 10.0.1.101 R_{11} 10.0.1.1

a f8:ff:c2:24:6a:0f r_{11} aa:c2:74:08:cf:12

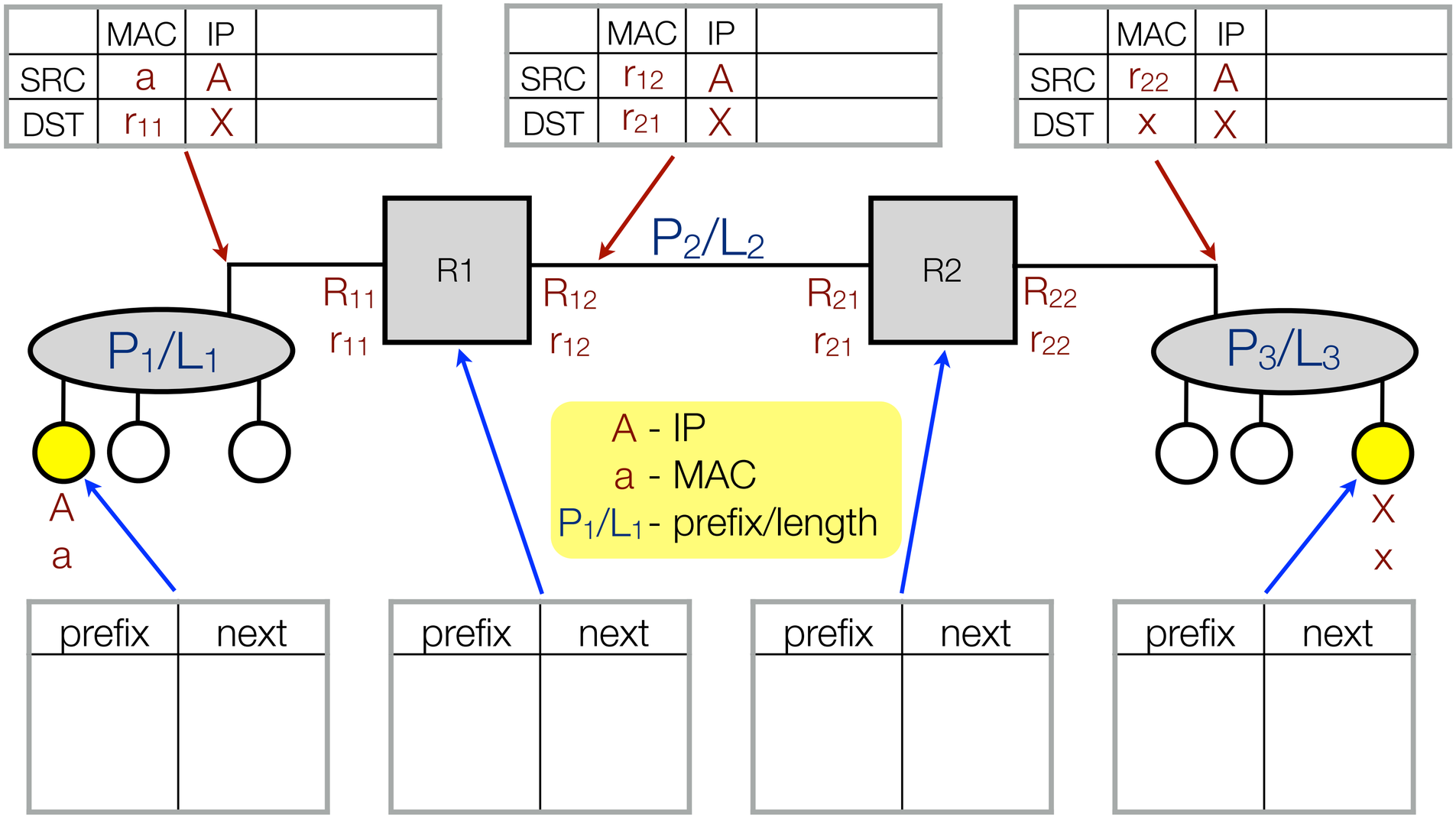
Static IP Routing



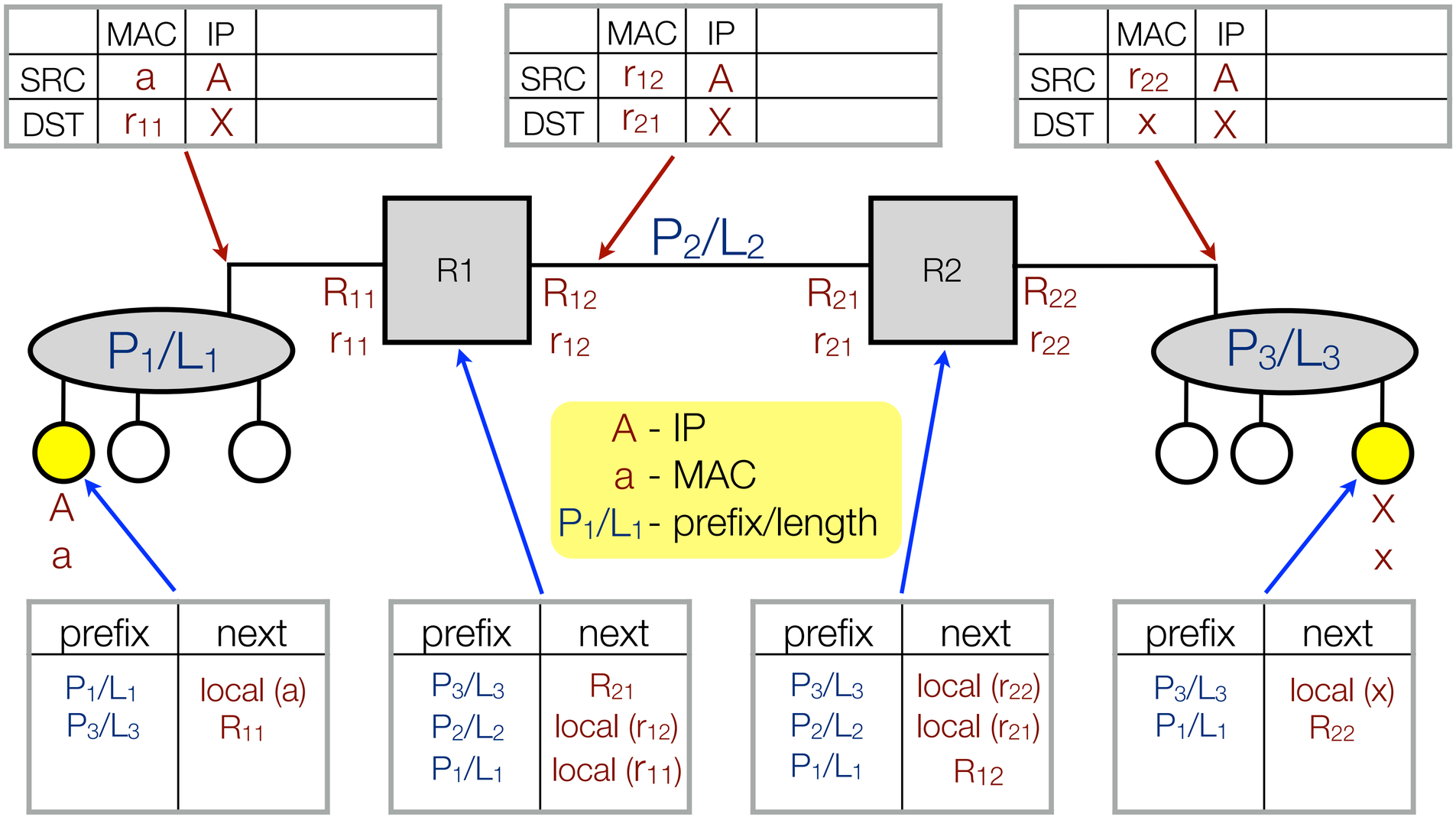
Static IP Routing



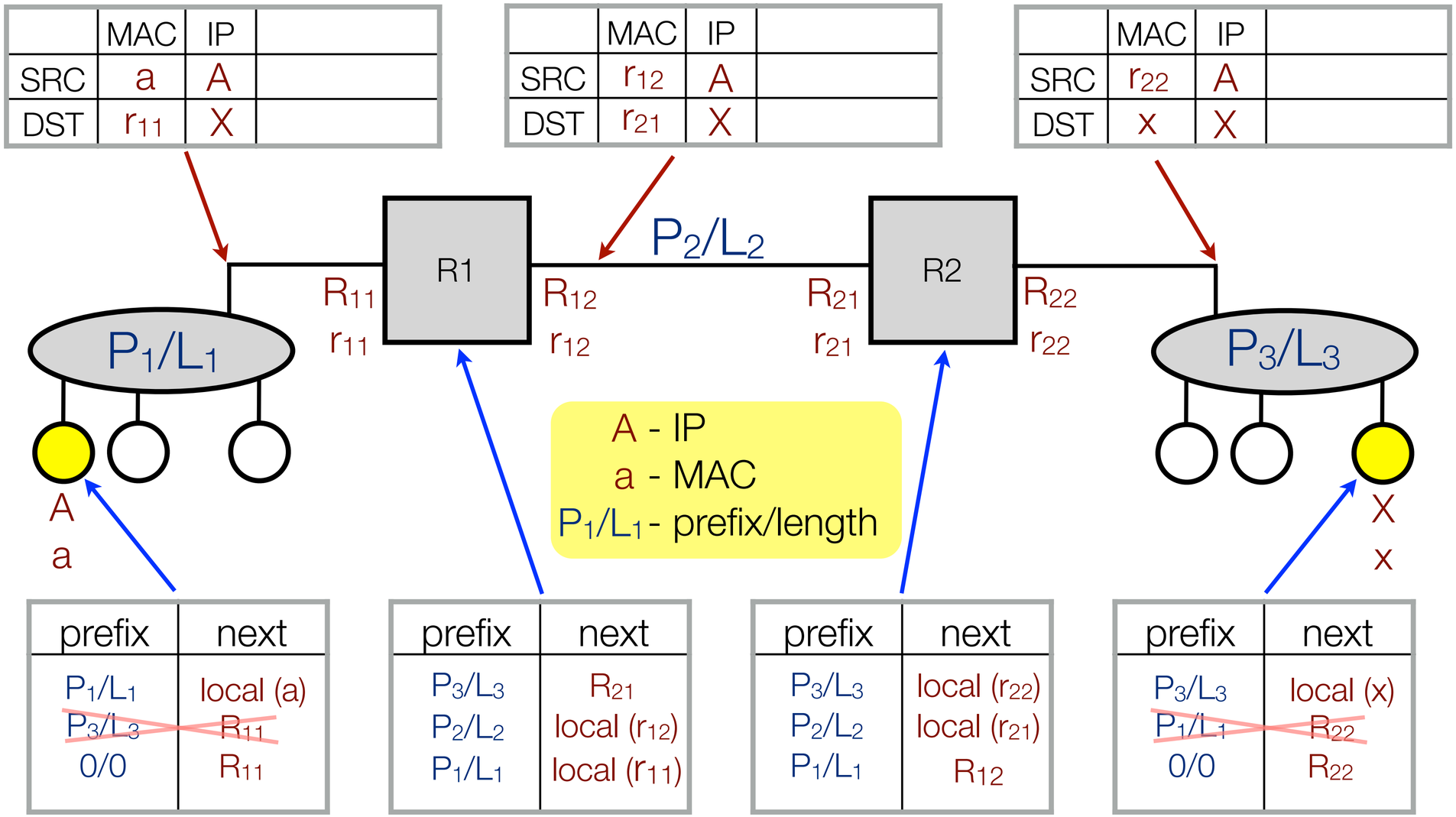
Static IP Routing



Static IP Routing

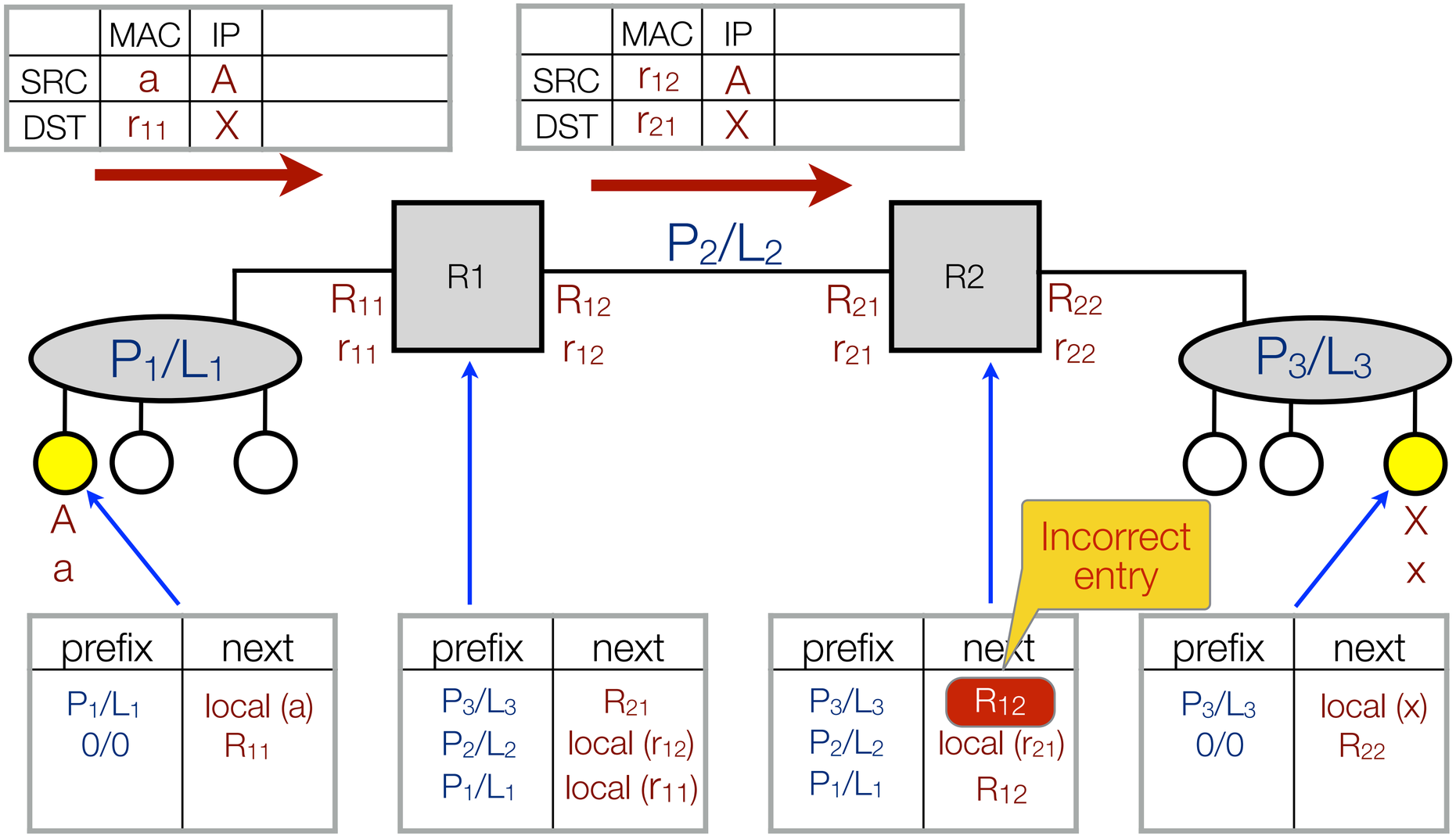


Static IP Routing

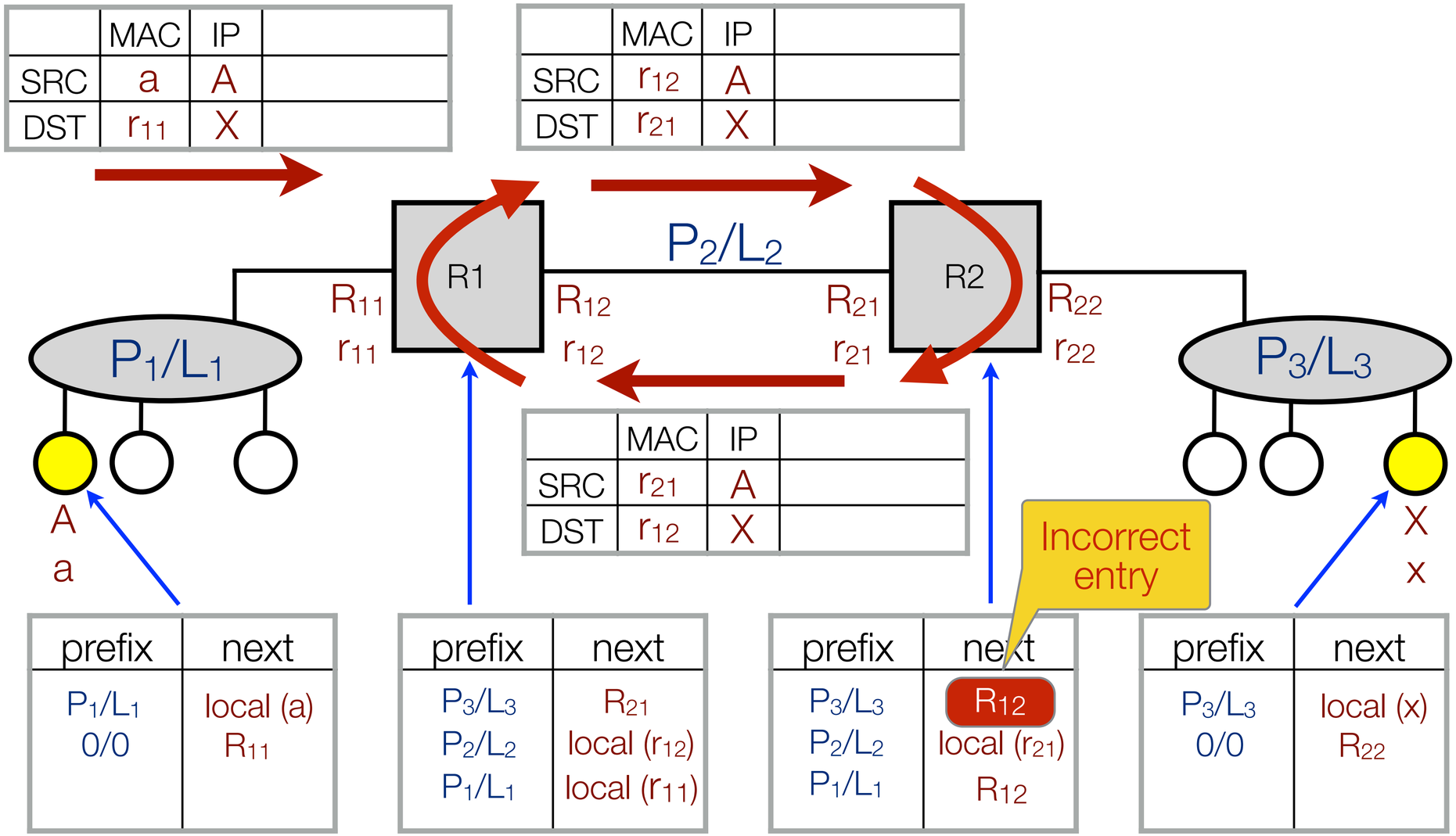


Routing loop

Routing loop



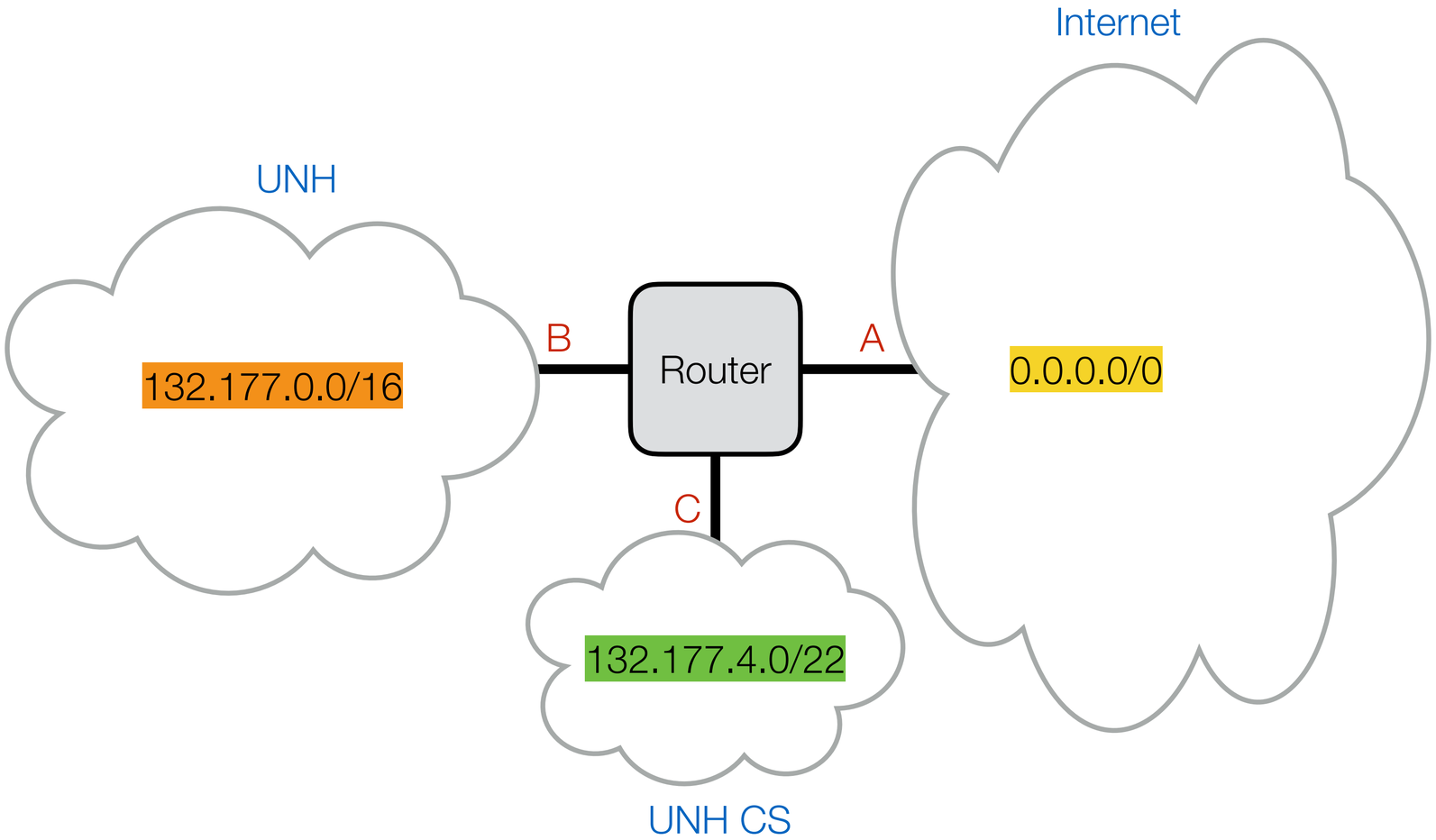
Routing loop



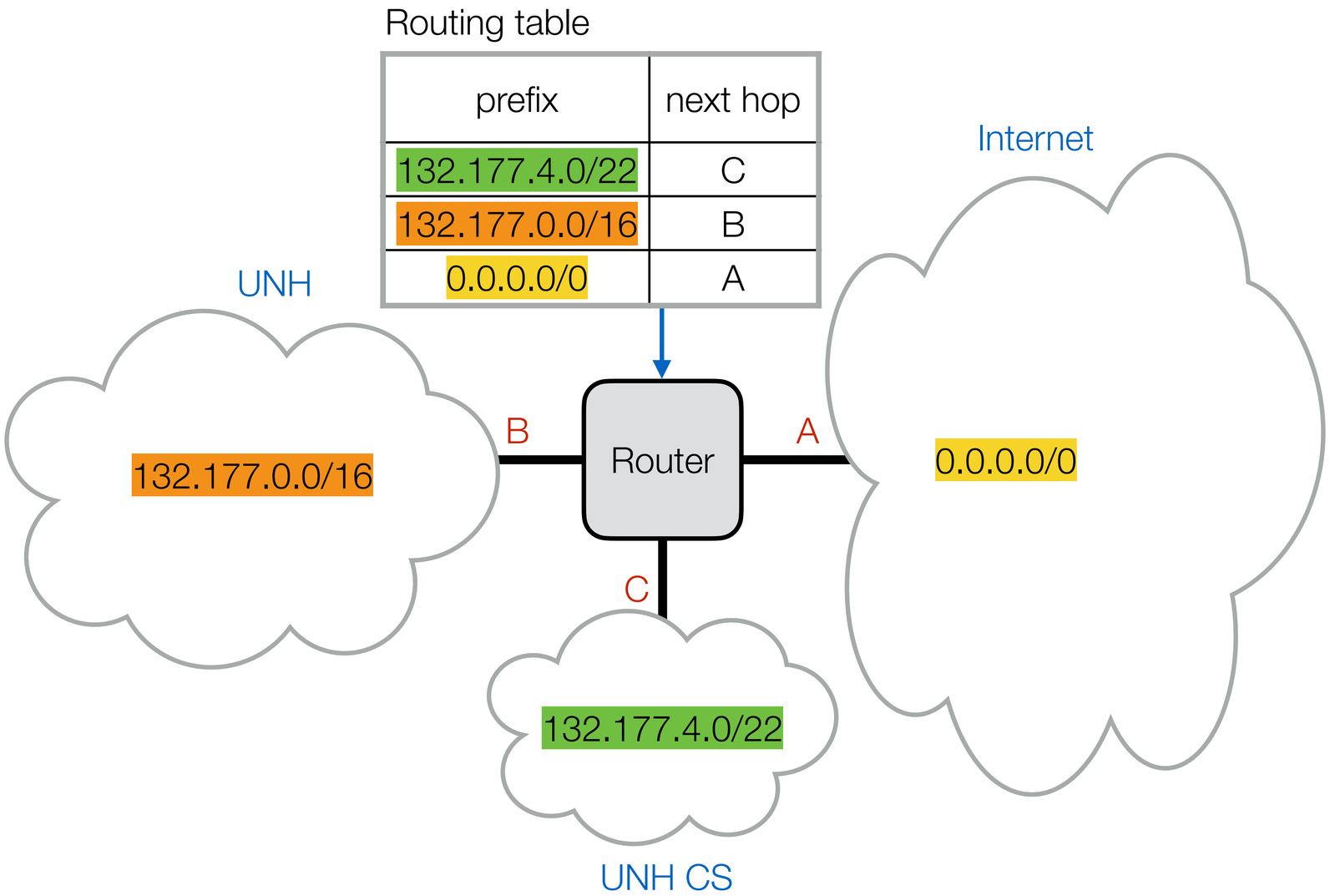
No route to host

Photo courtesy of Chip McNaughton, UNH-CS

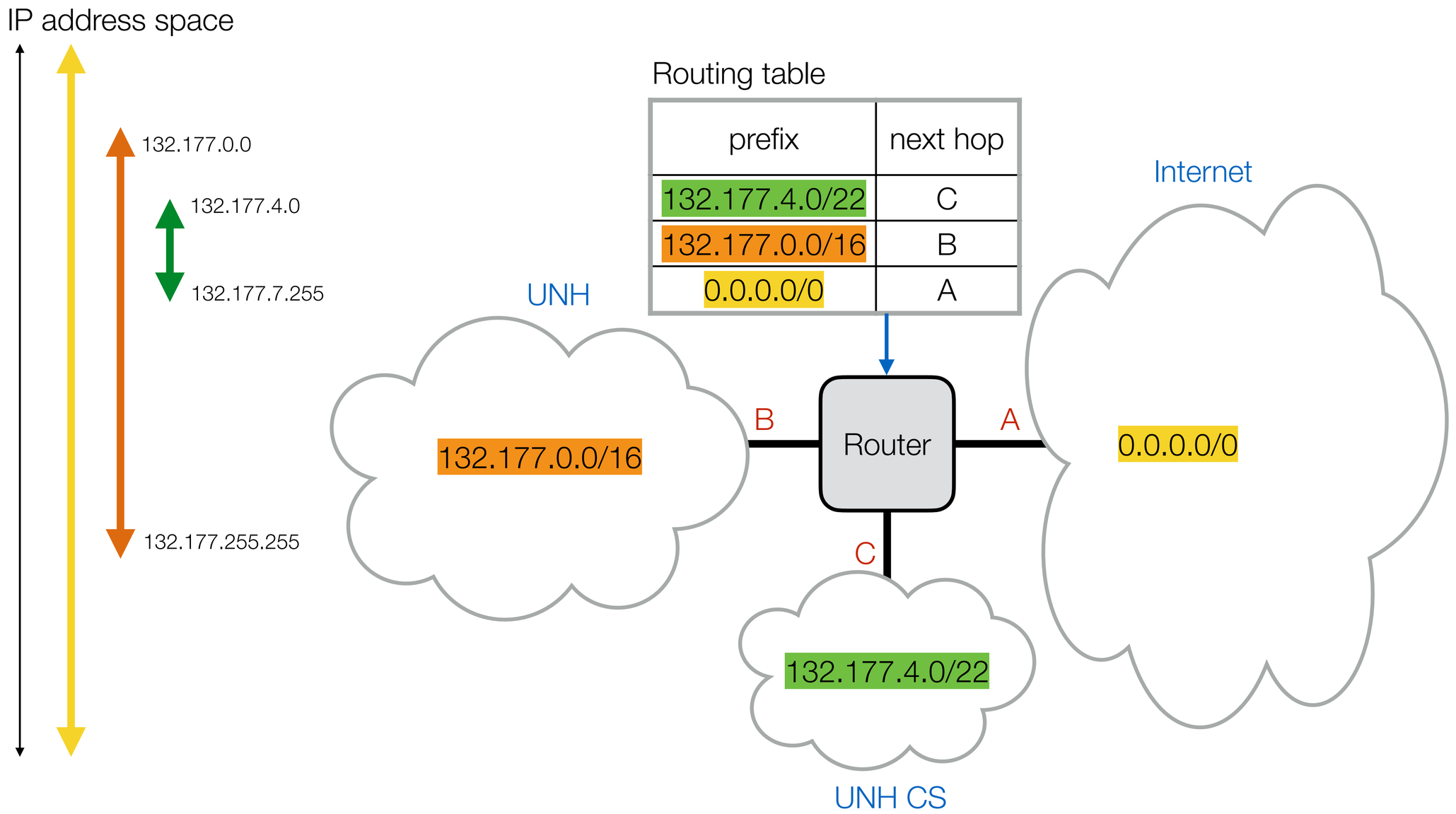
Routing example



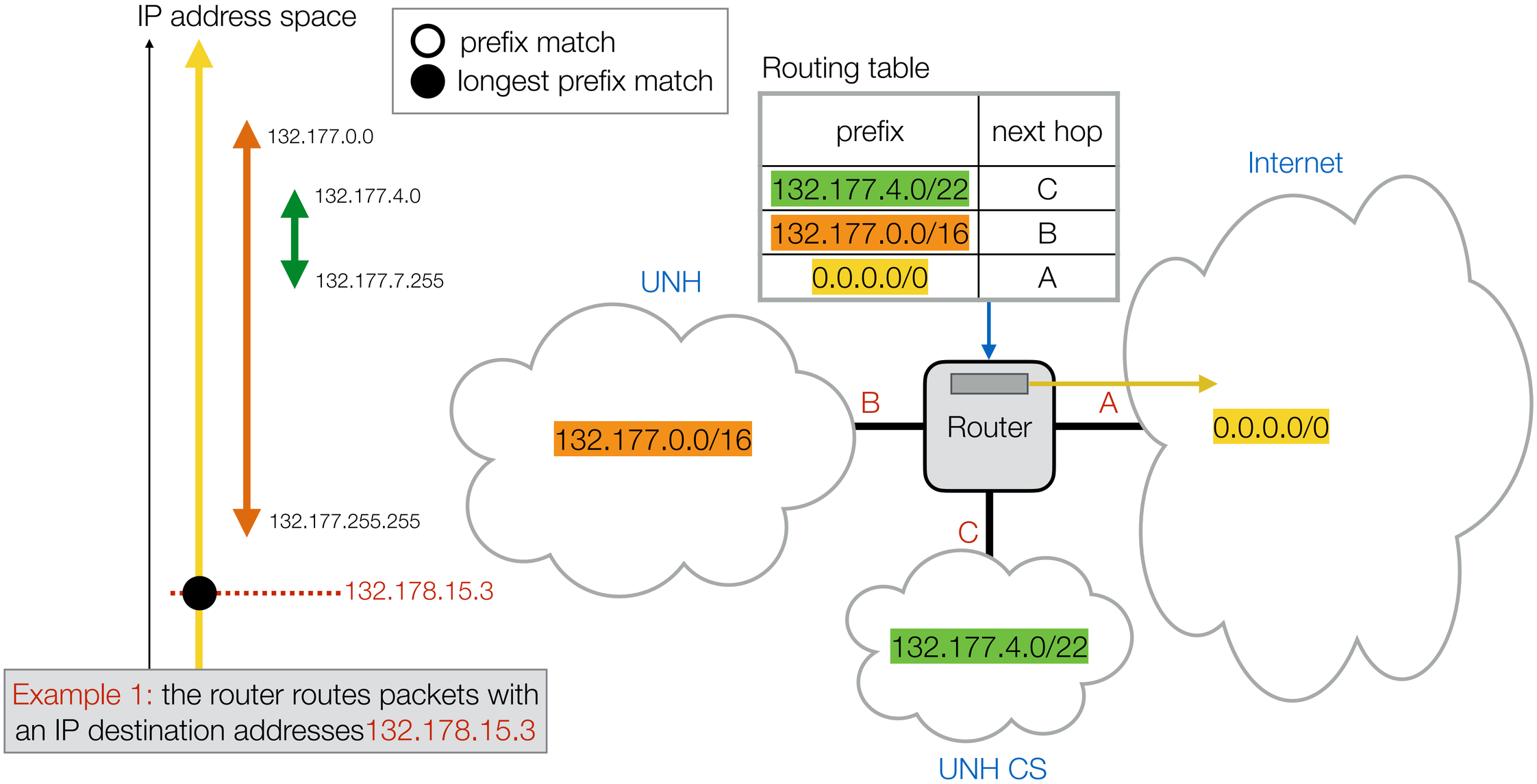
Routing example



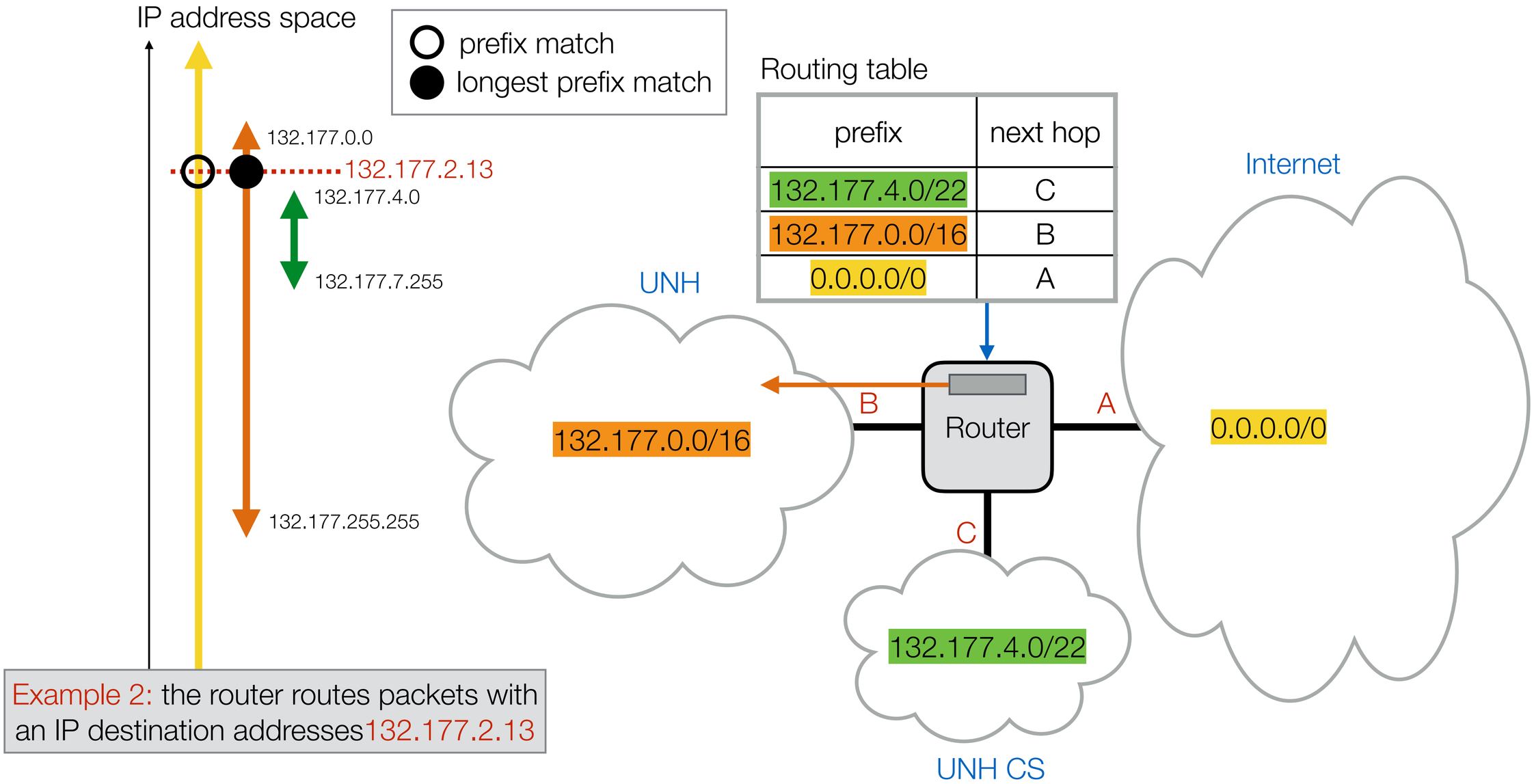
Routing example



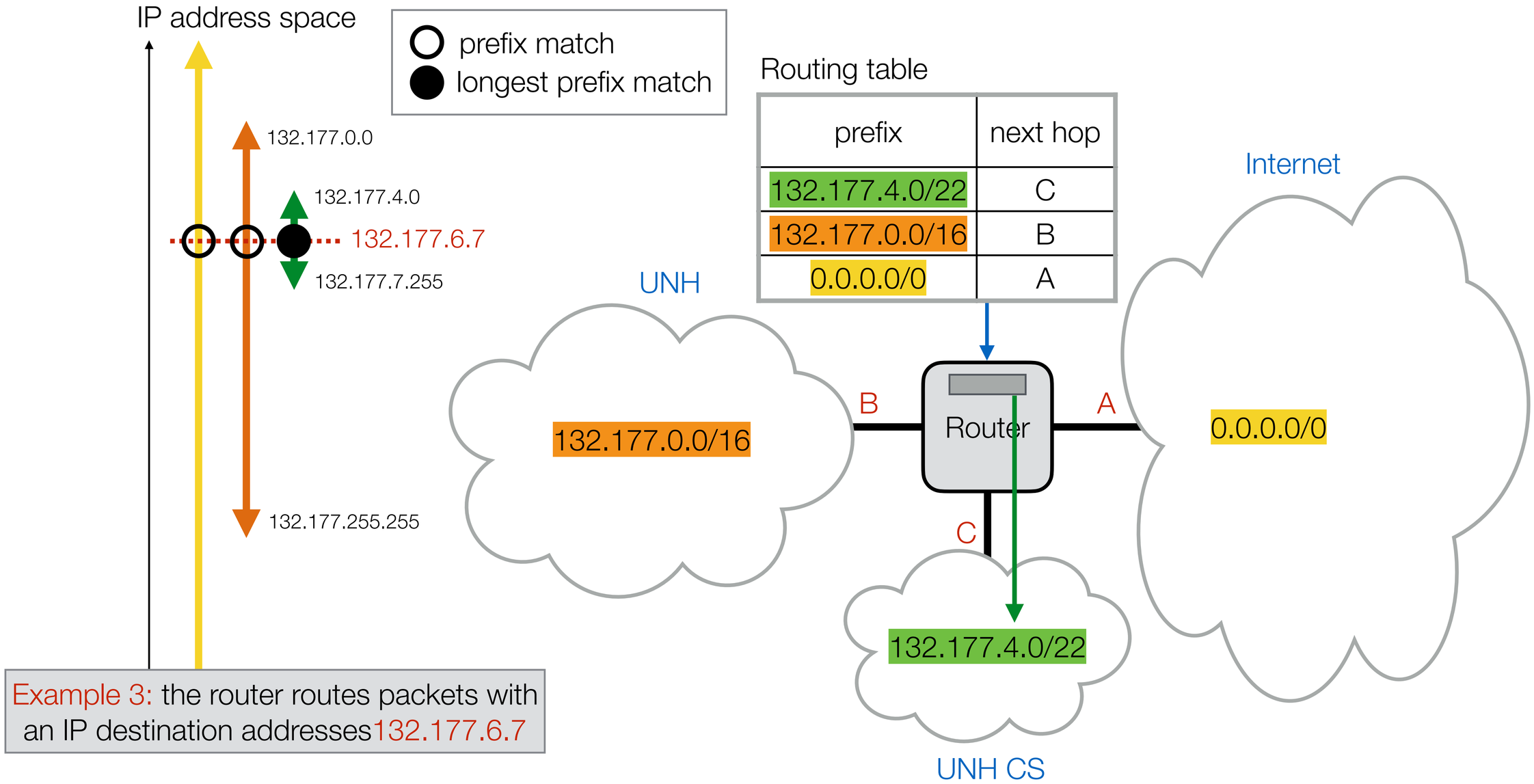
Routing example 1



Routing example 2



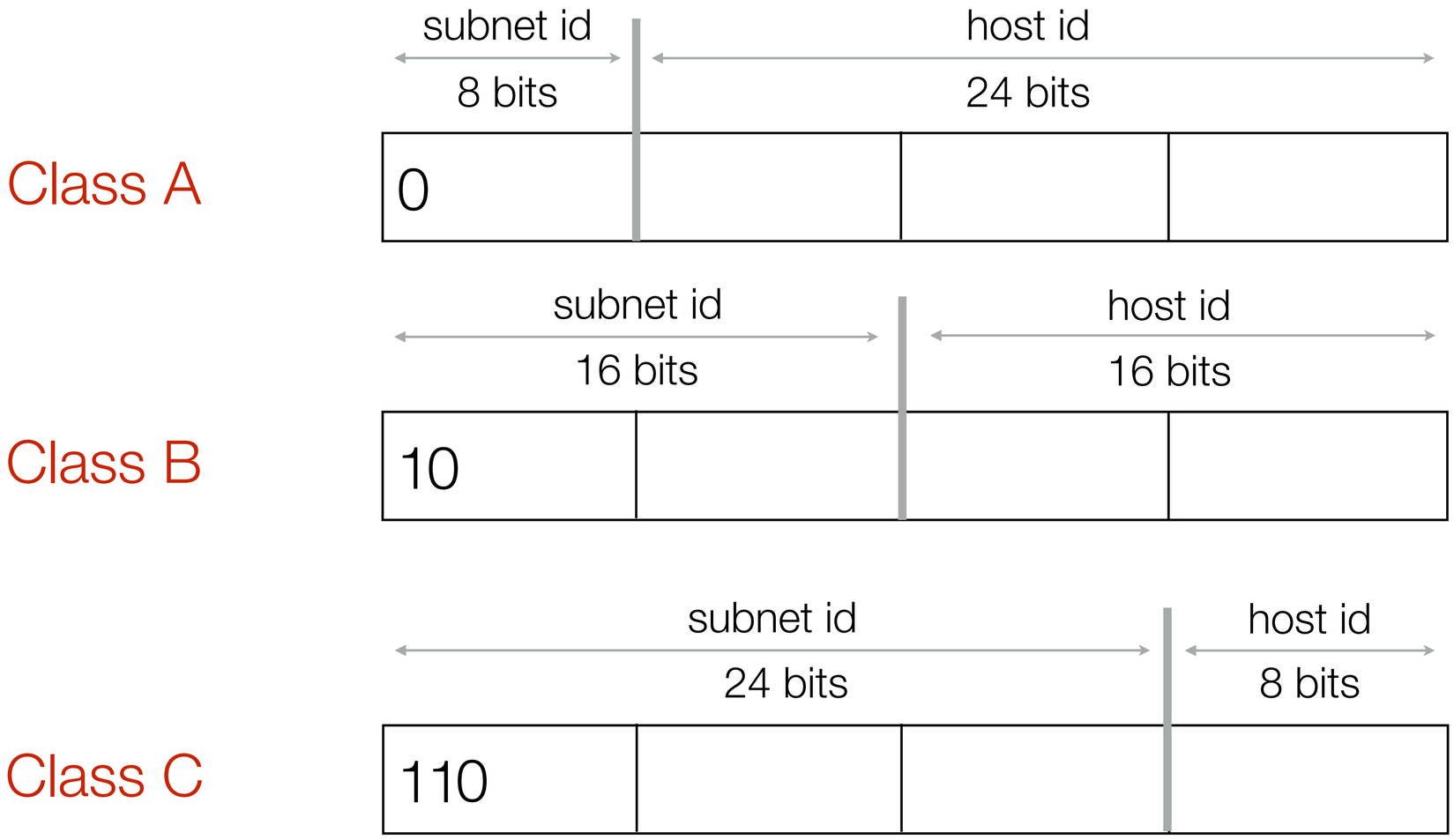
Routing example 3



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

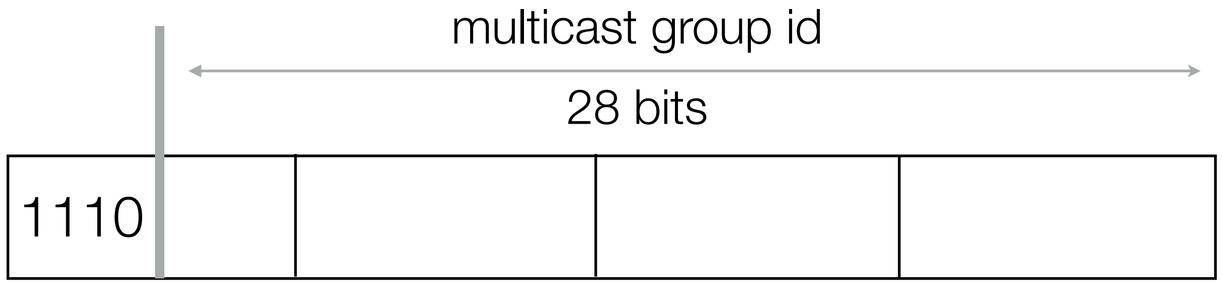


only for historical reference…

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

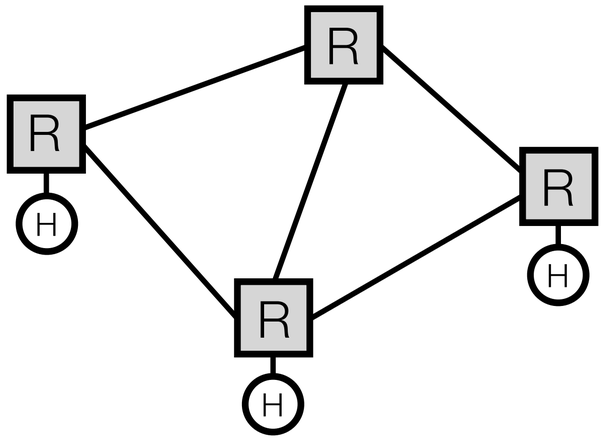
From **RFC 4632**:

`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…

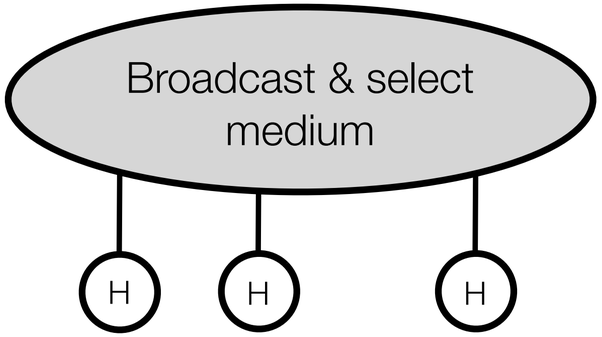
- Routed networks



- 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

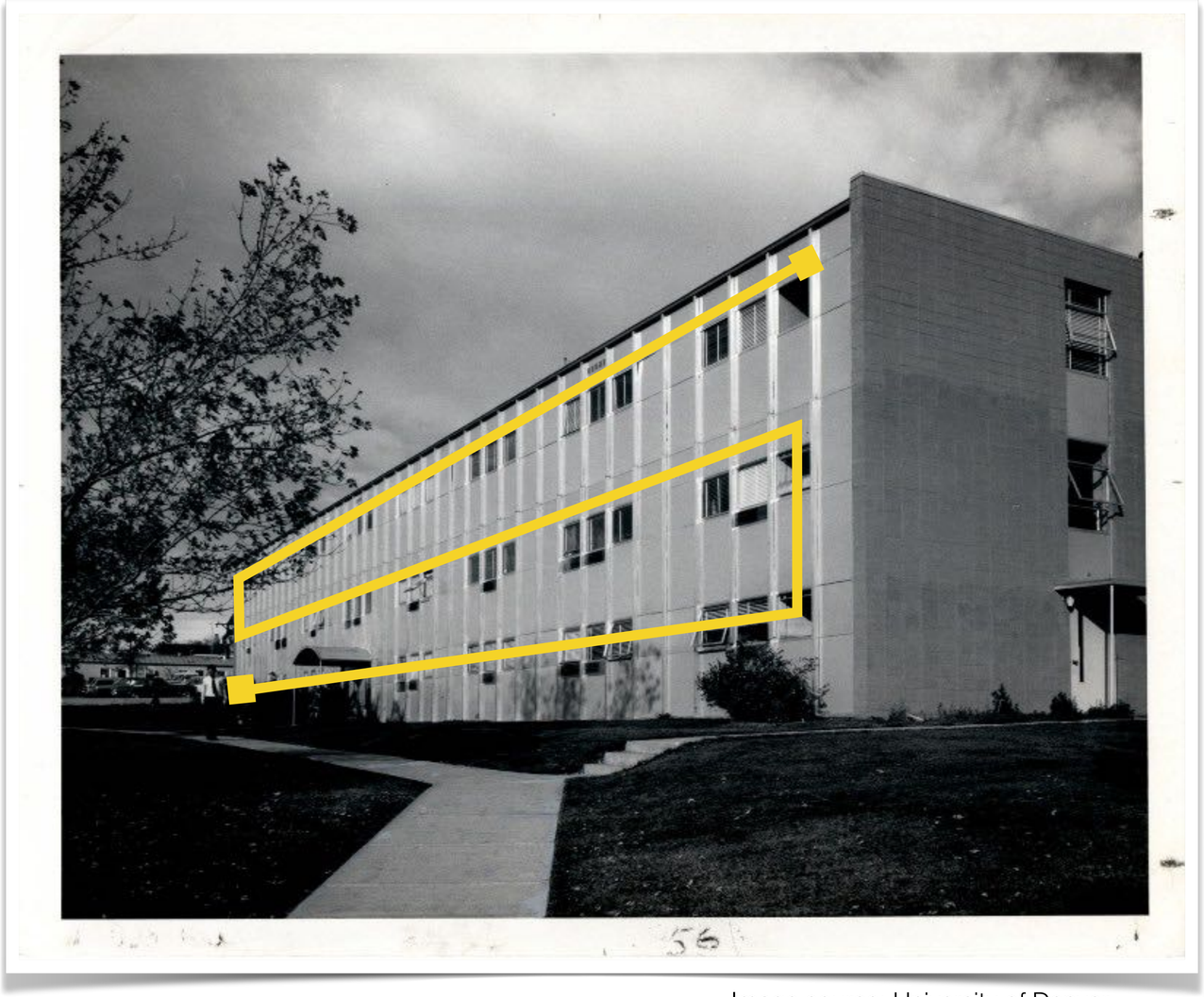


Image source: University of Denver

Historical Evolution