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CA169
Networks & Internet

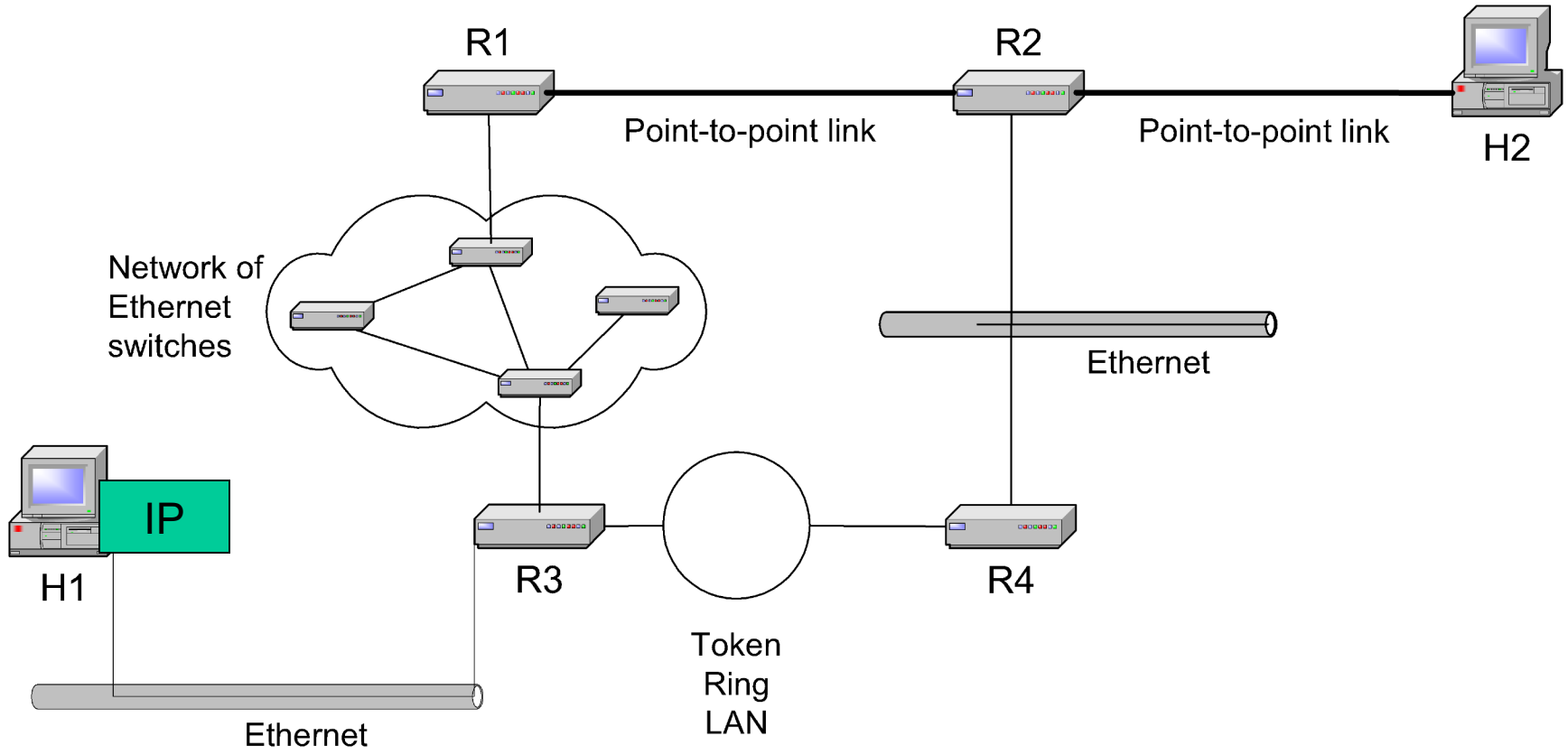
IP Routing

Internet is not made of a single Local Area Network (LAN)

- For several reasons:
  - **Scalability:** number of devices connected to the same switch/cable
  - **Resource allocation:** interference with other devices
  - **Reliability:** risk of failure of the LAN
  - **Evolution:** Internet contains old and new devices
  - **Security:** having all devices in the same broadcast domain is risky

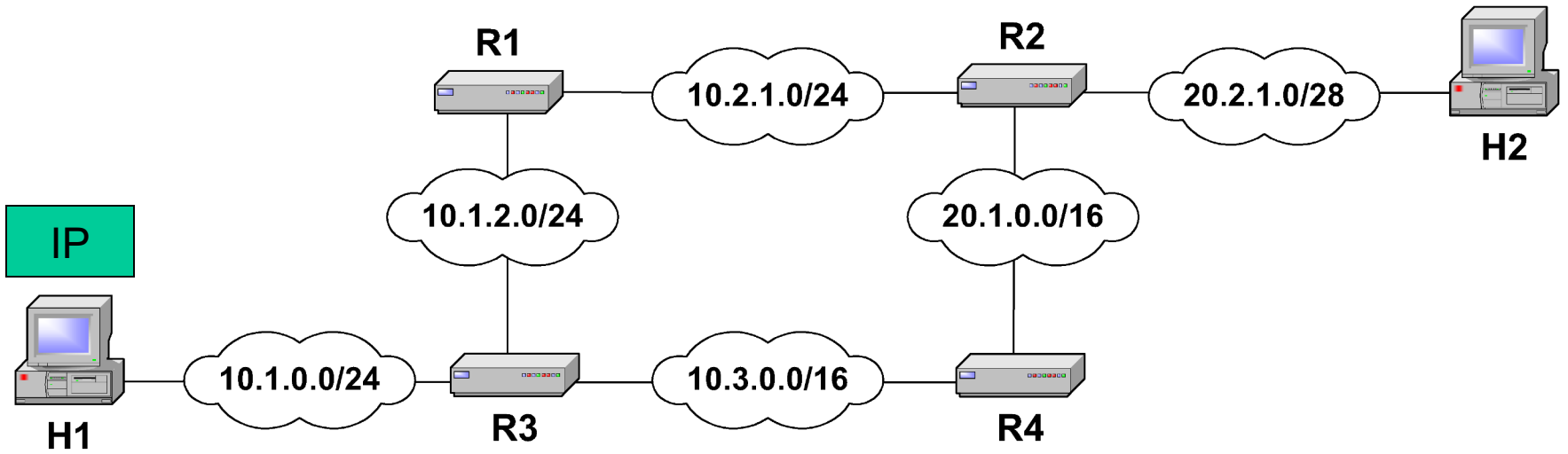
Delivery of an IP datagram

- View at the data link layer:
  - Internetwork is a collection of LANs or point-to-point links or switched networks that are connected by routers



Delivery of an IP datagram

- View at the IP layer:
  - An IP network is a logical entity with a network number
  - We represent an IP network as a “cloud”
  - The IP delivery service takes the view of clouds, and ignores the data link layer view



Principles of end-to-end delivery of datagrams

To successfully deliver an IP datagram:

1. The network prefix of an IP destination address must correspond to a unique data link layer network

2. Routers and hosts that have a common network prefix must be able to exchange IP datagrams using a data link protocol

3. Every data link layer network must be connected to at least one other data link layer network via a router

Routing tables

- Each router and each host keeps a **routing table** which tells the router how to process an outgoing packet
- Main columns:
  1. **Destination address:** where is the IP datagram going to?
     a. Network Address
     b. Netmask
  2. **Next hop:** how to send the IP datagram?
  3. **Interface:** what is the output port?

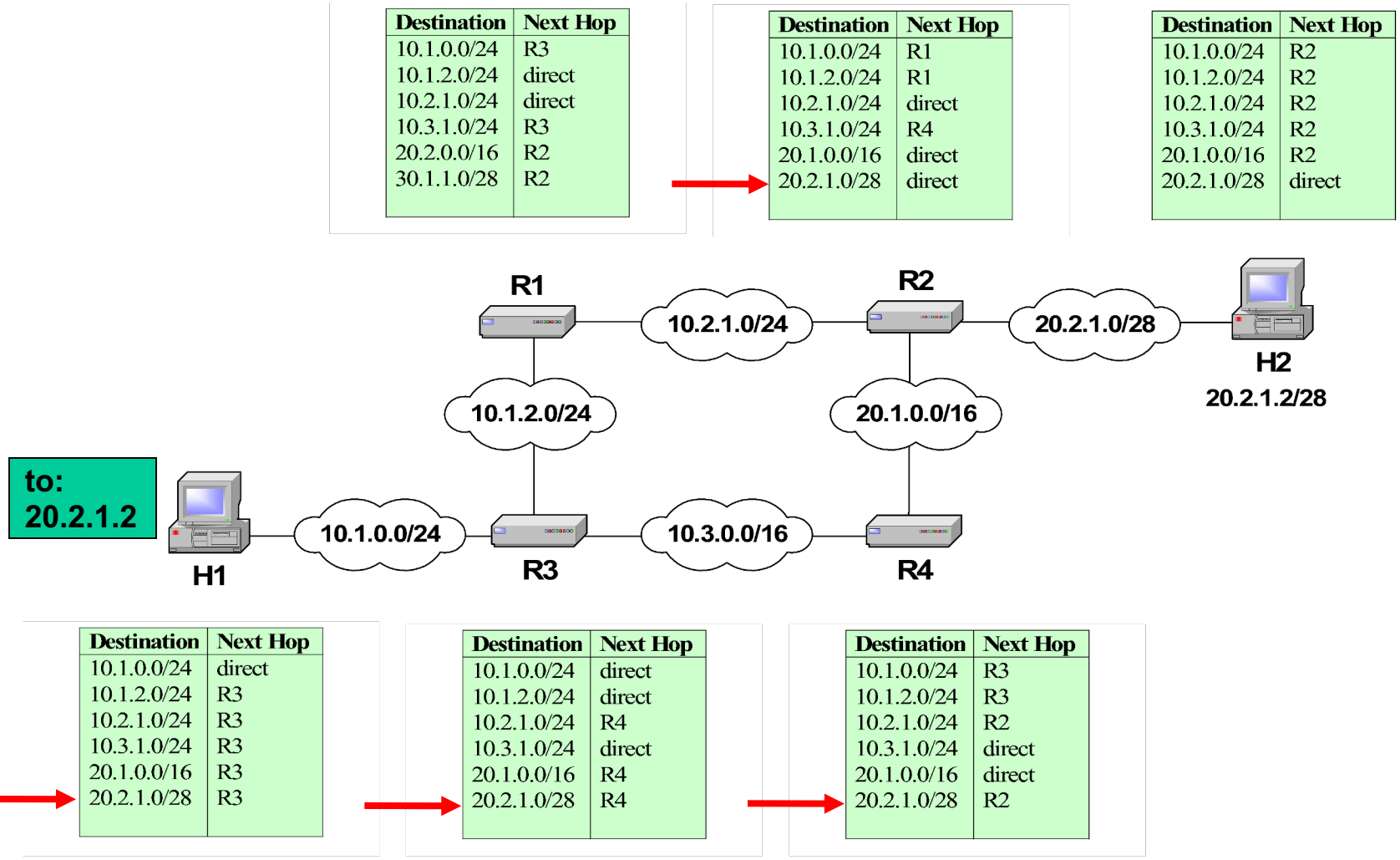
- Next hop and interface column can often be summarized as one column
- Routing tables are set so that datagrams gets closer to the its destination

Routing table of a Host or Router

IP datagrams can be directly delivered ("direct") or is sent to a router (e.g., "R2" or "R4")

Destination	Next Hop	interface
10.1.0.0/24	direct	eth0
10.1.2.0/24	direct	eth0
10.2.1.0/24	R2	wlan0
10.3.1.0/24	direct	eth0
20.1.0.0/16	R4	eth1
20.2.1.0/28	R4	eth1

Delivery with routing tables



Delivery of IP datagrams

- There are two distinct processes to delivering IP datagrams:
  1. **Forwarding:** How to pass a packet from an input interface to the output interface?
  2. **Routing:** How to find and setup the routing tables?

- Forwarding must be done as fast as possible:
  - on routers, is often done with support of hardware
  - on PCs, is done in kernel of the operating system
- Routing is less time-critical
  - On a PC, routing is done as a background process

Type of routing table entries

- **Network route**
  - Destination addresses is a network address (e.g., 10.0.2.0/24)
  - Most entries are network routes
- **Host route**
  - Destination address is an interface address (e.g., 10.0.1.2/32)
  - Used to specify a separate route for certain hosts
- **Default route**
  - Used when no network or host route matches
  - The router that is listed as the next hop of the default route is the **default gateway (for Cisco: "gateway of last resort)**
- **Loopback address**
  - Routing table for the loopback address (127.0.0.1)
  - The next hop lists the loopback (lo0) interface as outgoing interface

Routing table lookup

- When a router or host needs to transmit an IP datagram, it performs a **Routing Table Lookup**
- **Routing table lookup:** Use the IP destination address as a key to search the routing table
- Result of the lookup is the IP address of a next hop router, and/or the name of a network interface

Routing table lookup: Longest Prefix Match

- **Longest Prefix Match:** Search for the routing table entry that has the longest match with the prefix of the destination IP address

1. Search for a match on all 32 bits
2. Search for a match for 31 bits

   …..

32. Search for a match on 0 bits

Host route, loopback entry → 32-bit prefix match
Default route is represented as 0.0.0.0/0 → 0-bit prefix match

128.143.71.21

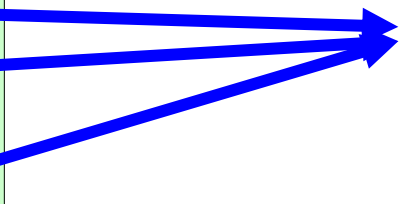
Destination address	Next hop
10.0.0.0/8	R1
128.143.0.0/16	R2
128.143.64.0/20	R3
128.143.192.0/20	R3
128.143.71.0/24	R4
128.143.71.55/32	R3
default	R5

The longest prefix match for 128.143.71.21 is for 24 bits with entry 128.143.71.0/24 Datagram will be sent to R4

Route Aggregation

- Longest prefix match algorithm permits to aggregate prefixes with identical next hop address to a single entry
- This contributes significantly to reducing the size of routing tables of Internet routers

Destination	Next Hop
10.1.0.0/24	R3
10.1.2.0/24	direct
10.2.1.0/24	direct
10.3.1.0/24	R3
192.168.0.0/24	R2
192.168.1.0/24	R2
……	…
192.168.255.0/24	R2



Destination	Next Hop
10.1.0.0/24	R3
10.1.2.0/24	direct
10.2.1.0/24	direct
10.3.1.0/24	R3
192.168.0.0/16	R2

How do routing tables get updated?

- **Adding an interface:**
  - Configuring an interface eth2 with 10.0.2.3/24 adds a routing table entry

Destination	Interface
10.0.2.0/24	eth2

- **Adding a default gateway:**
  - Configuring 10.0.2.1 as the default gateway adds the entry

Destination	Next Hop
0.0.0.0/0	10.0.2.1

- Two ways to configure routing tables
- **Static configuration** of network routes or host routes
- **Dynamic update** of routing tables through routing protocols

- Test reachability of a host:
  - Ping: ICMP echo request