Computer Networks
Principles

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(Slides –mostly– by A. Duda)

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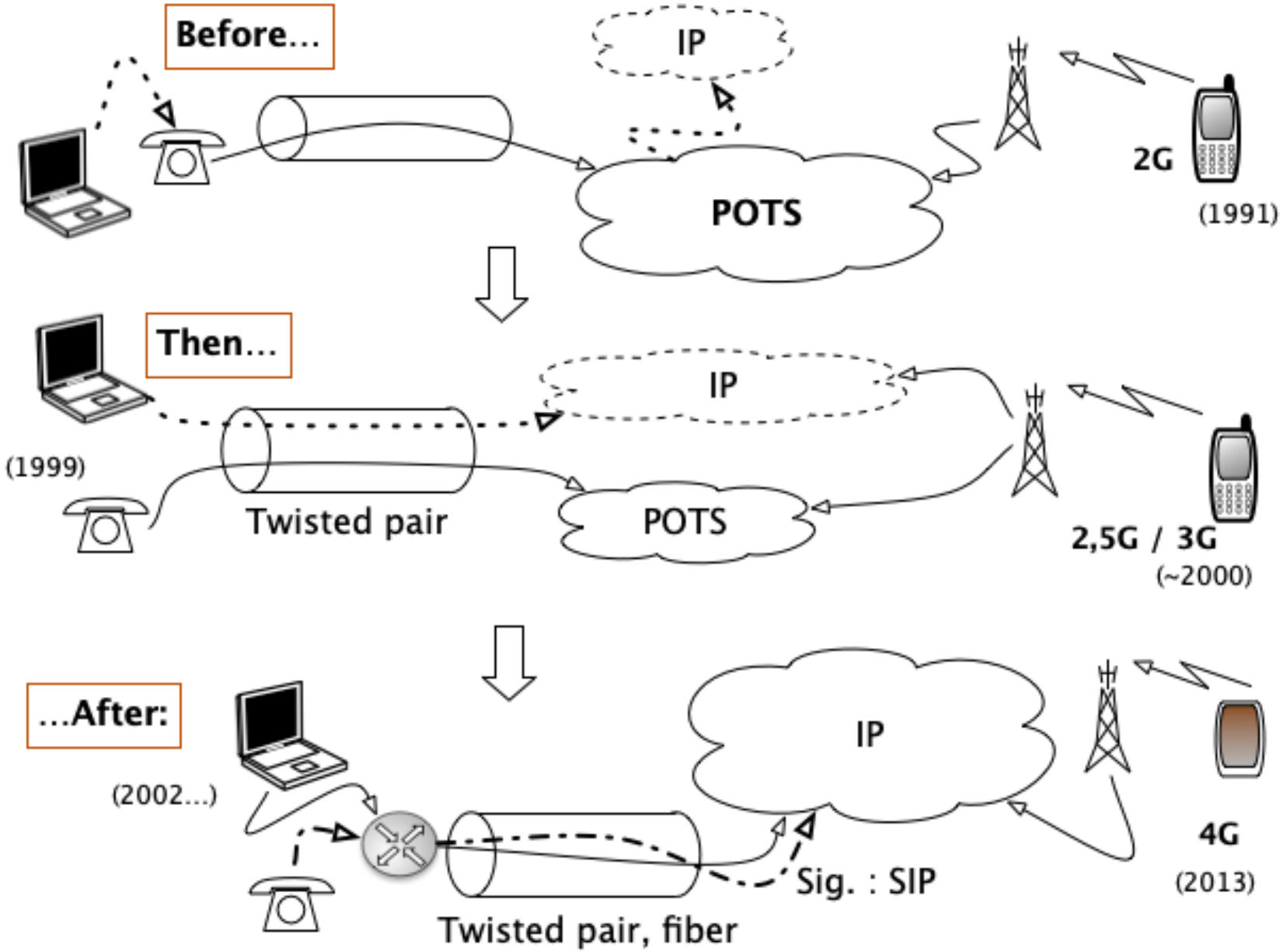
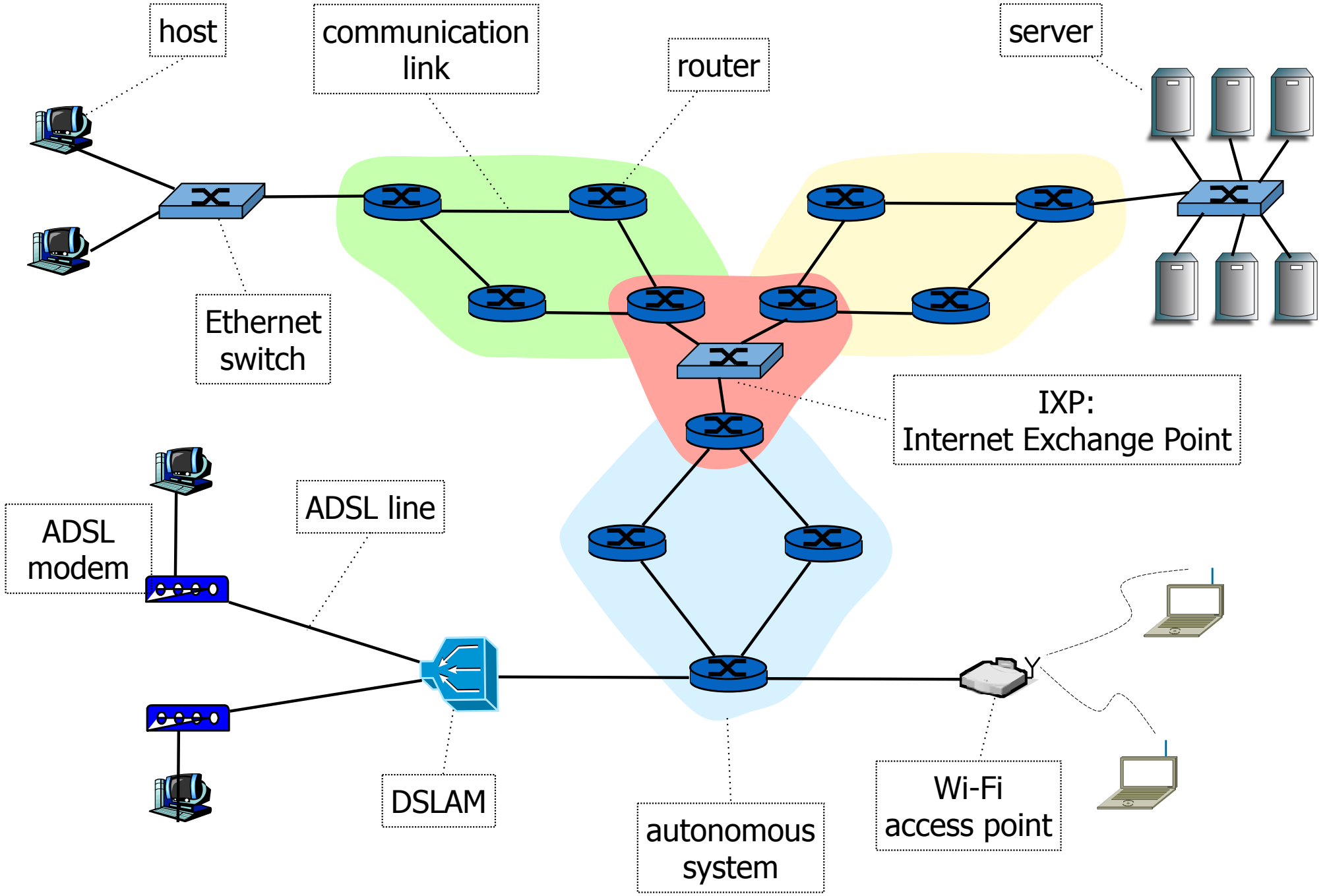
- Introduction
  - Protocols and layered architecture
  - Encapsulation
  - Interconnection structures

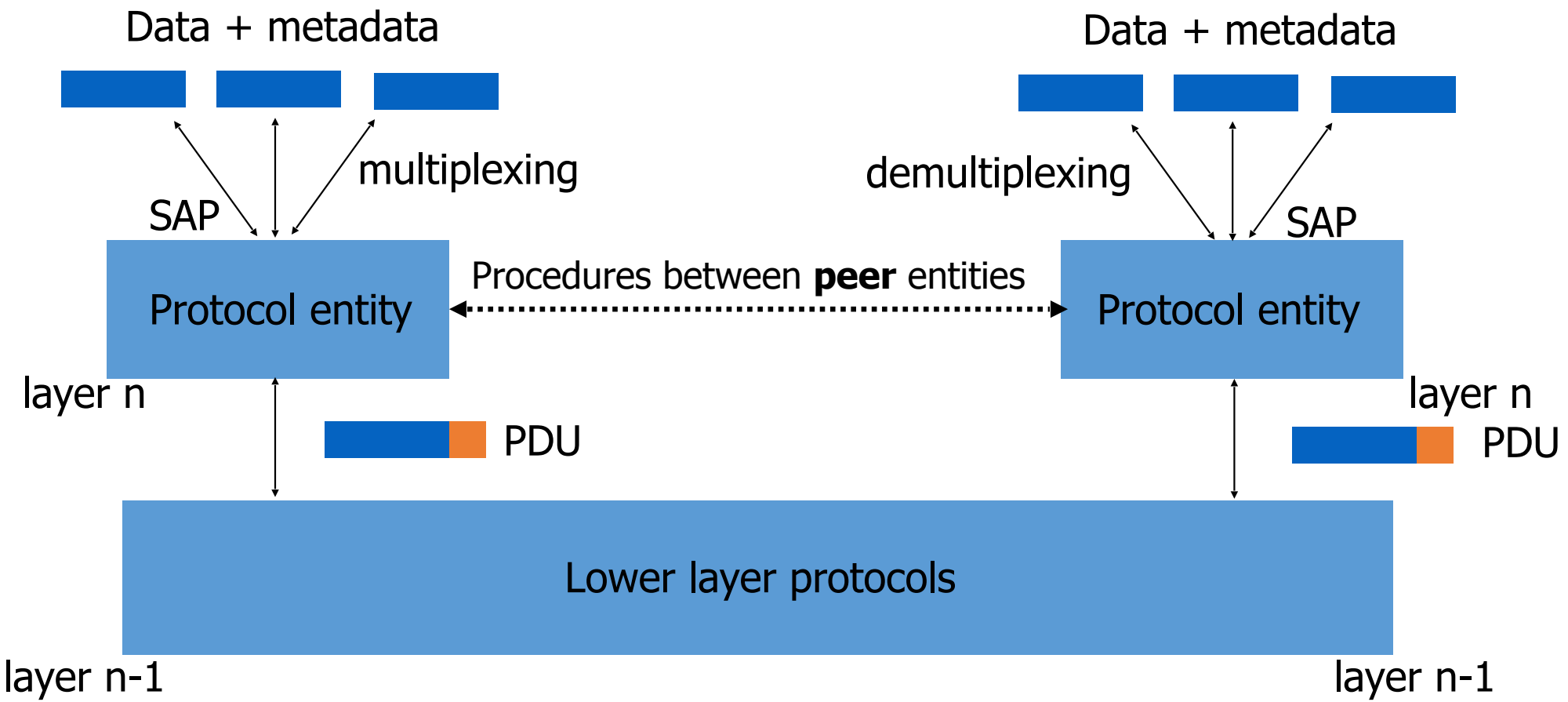
The transition to an all-IP network




host
communication link
router
server
Ethernet switch
IXP:
Internet Exchange Point
ADSL modem
ADSL line
DSLAM
autonomous system
Wi-Fi access point

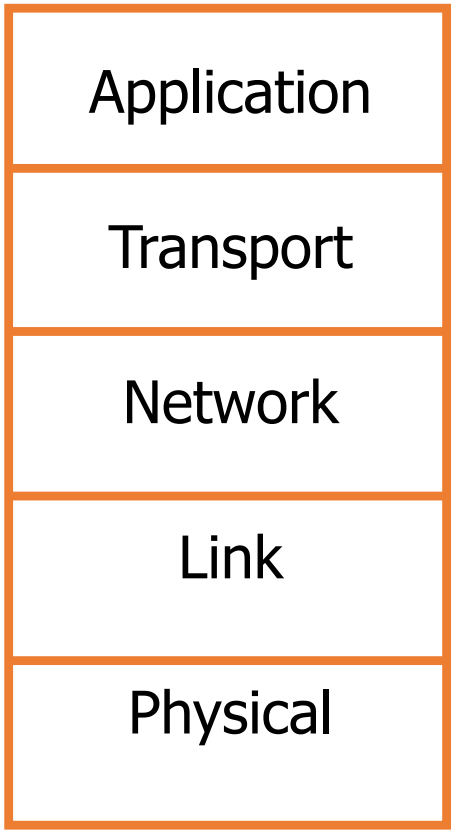
Protocols

Protocol stack

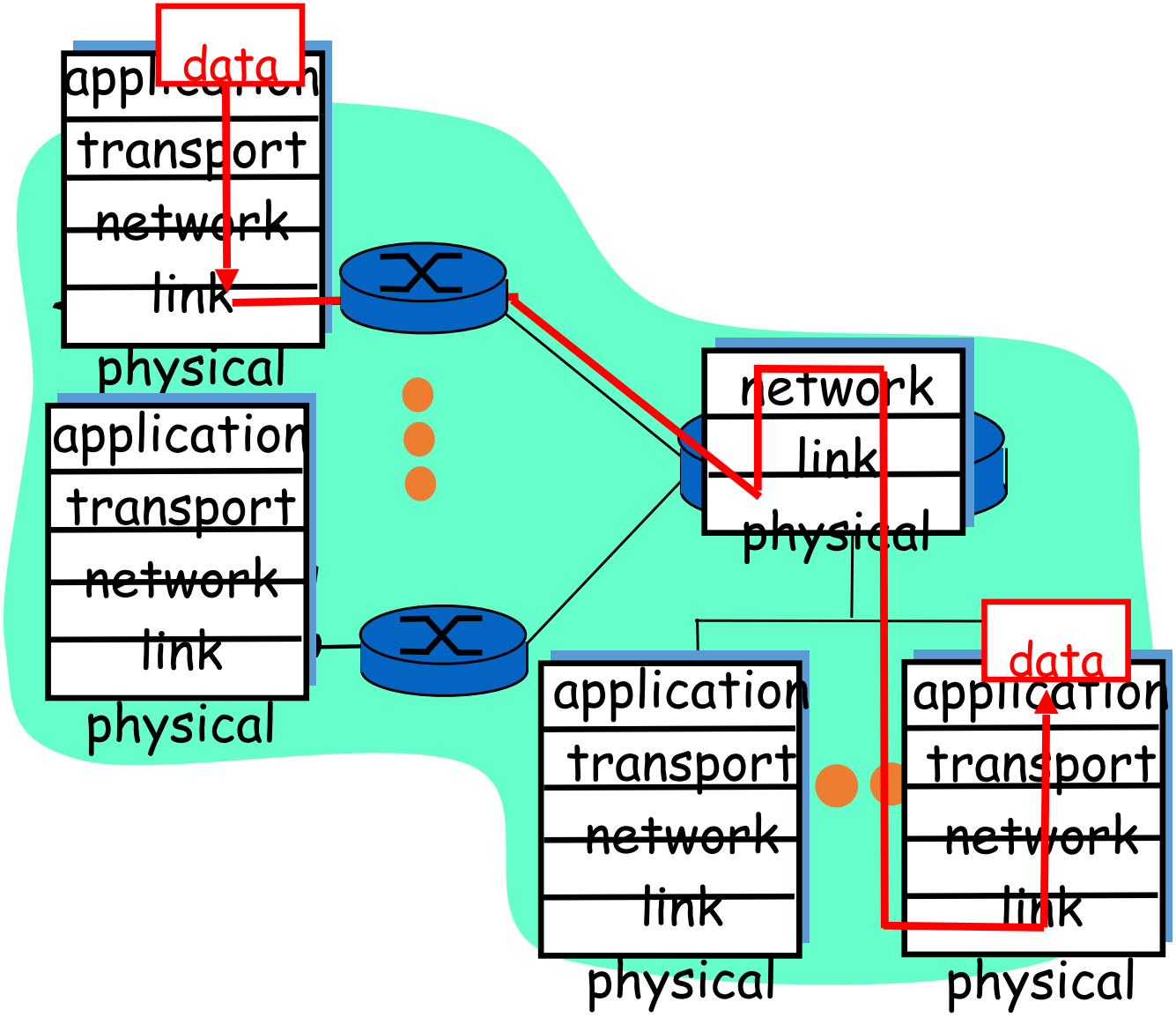


Internet protocol stack

- **Application**: supporting network applications
  - HTTP, FTP, SMTP, IMAP, NTP, SSH
- **Transport**: end-to-end data transfer
  - TCP, UDP
- **Network**: routing of datagrams from source to destination
  - IP
- **Link**: data transfer between neighboring network elements
  - PPP, Ethernet
- **Physical**: bits “on the wire”

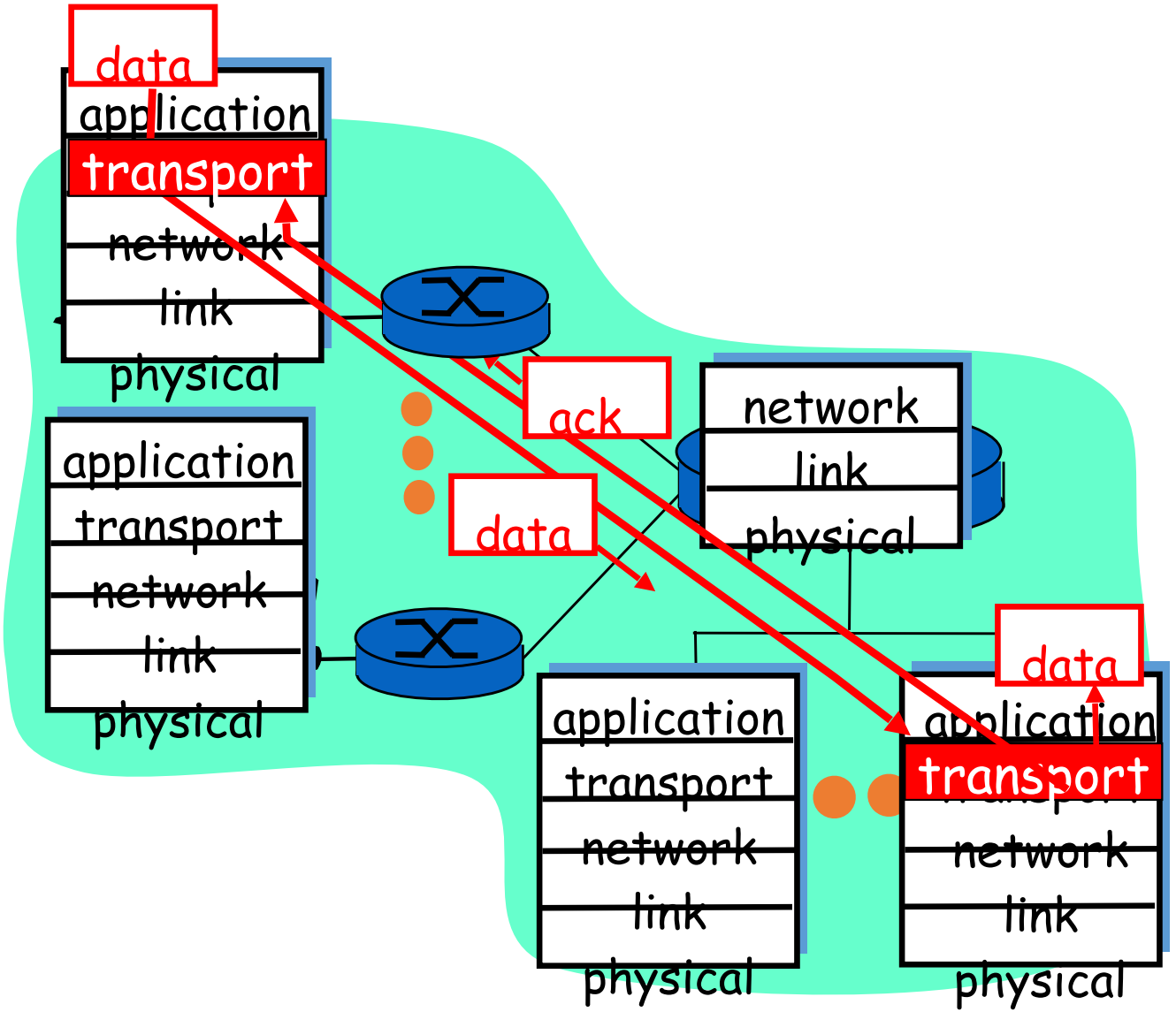


Layering: physical communication

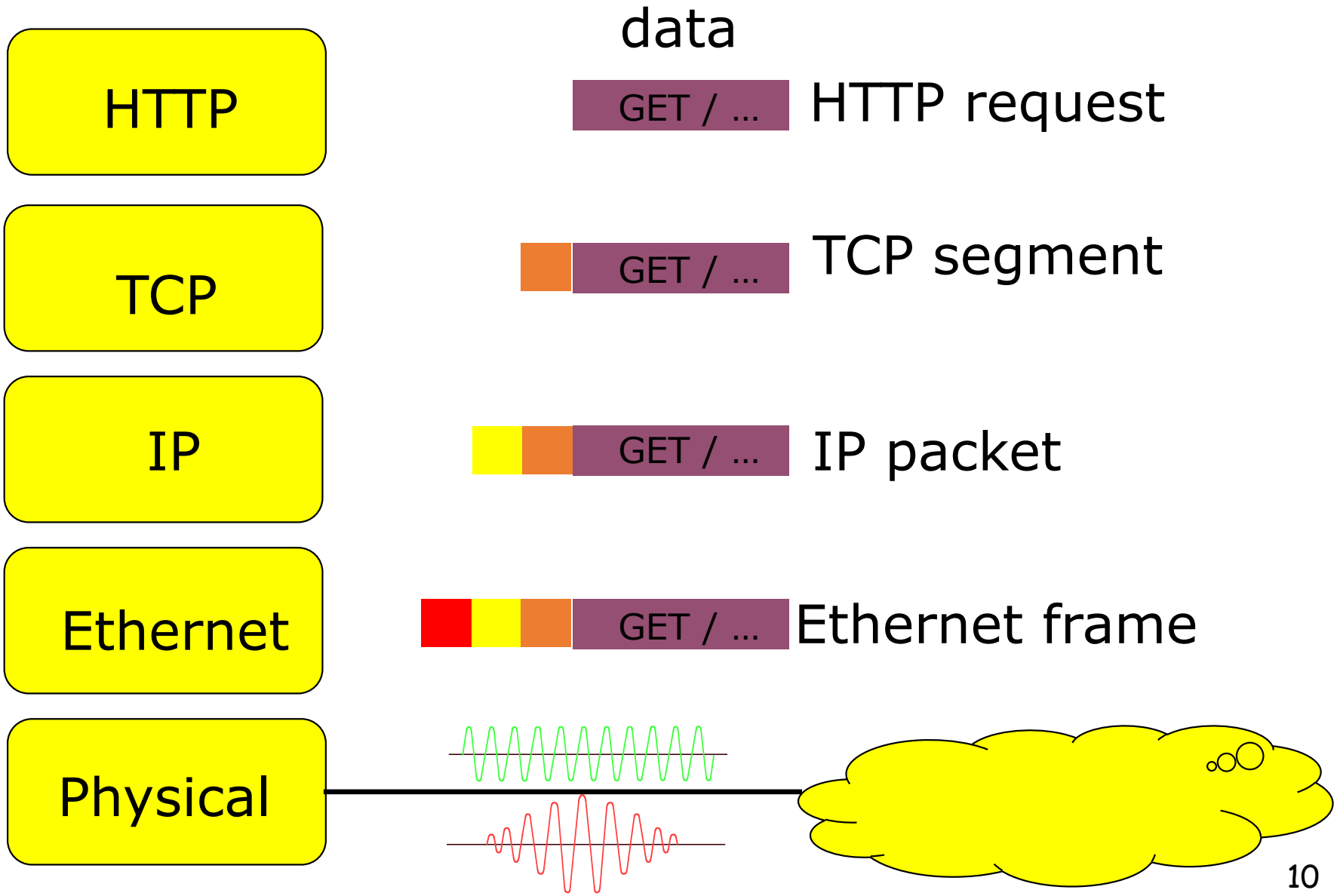


Layering: logical communication

- E.g.: transport
- take data from app
- add addressing, reliability check info to form a "stream"
- send data to peer
- wait for peer to ack receipt
- analogy: post office (for datagrams)

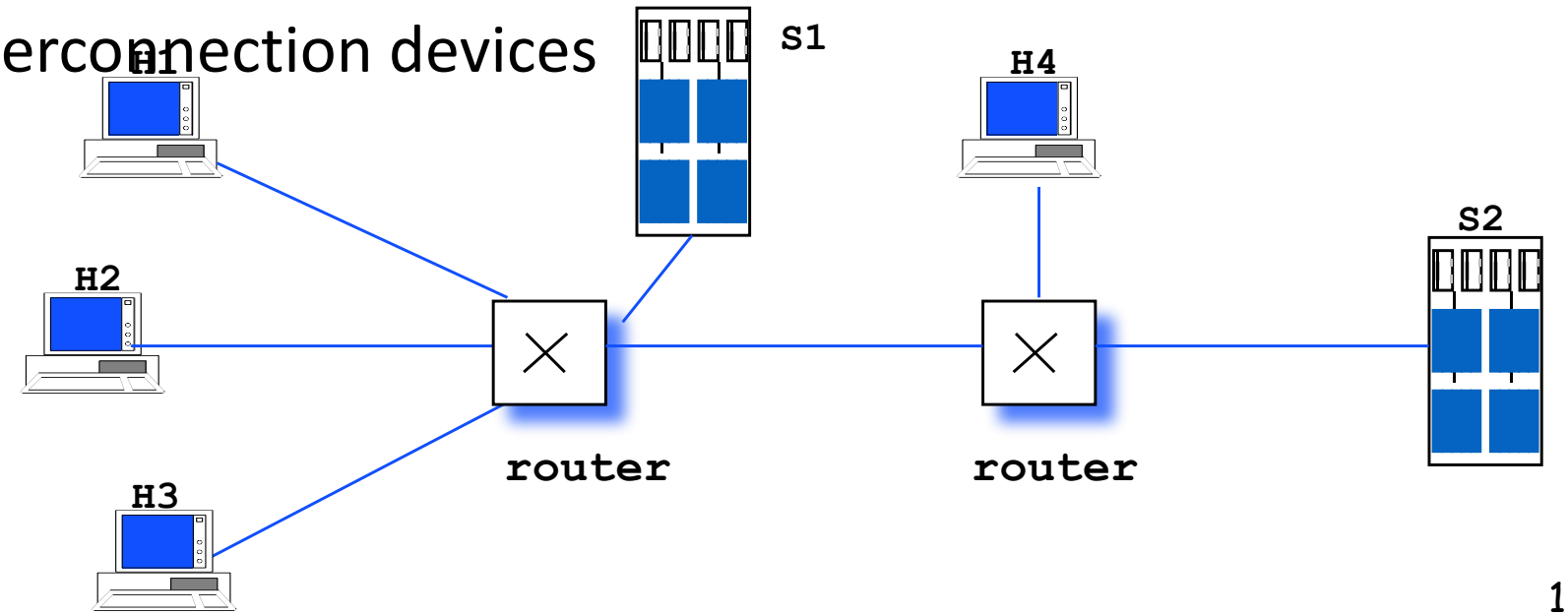


TCP/IP Architecture

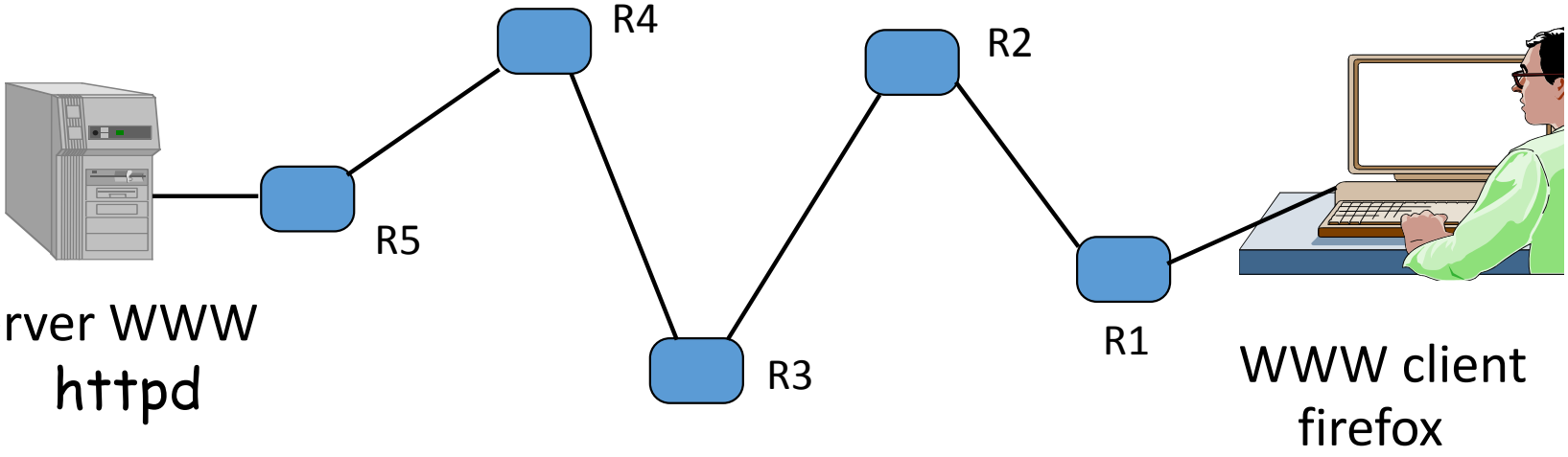


Network Layer

- Set of functions required to transfer packets end-to-end (from host to host)
  - hosts (== “end hosts”) are not directly connected - need for intermediate systems
  - examples: IP, Appletalk, IPX
- Intermediate systems
  - routers: forward packets to the final destination
  - interconnection devices

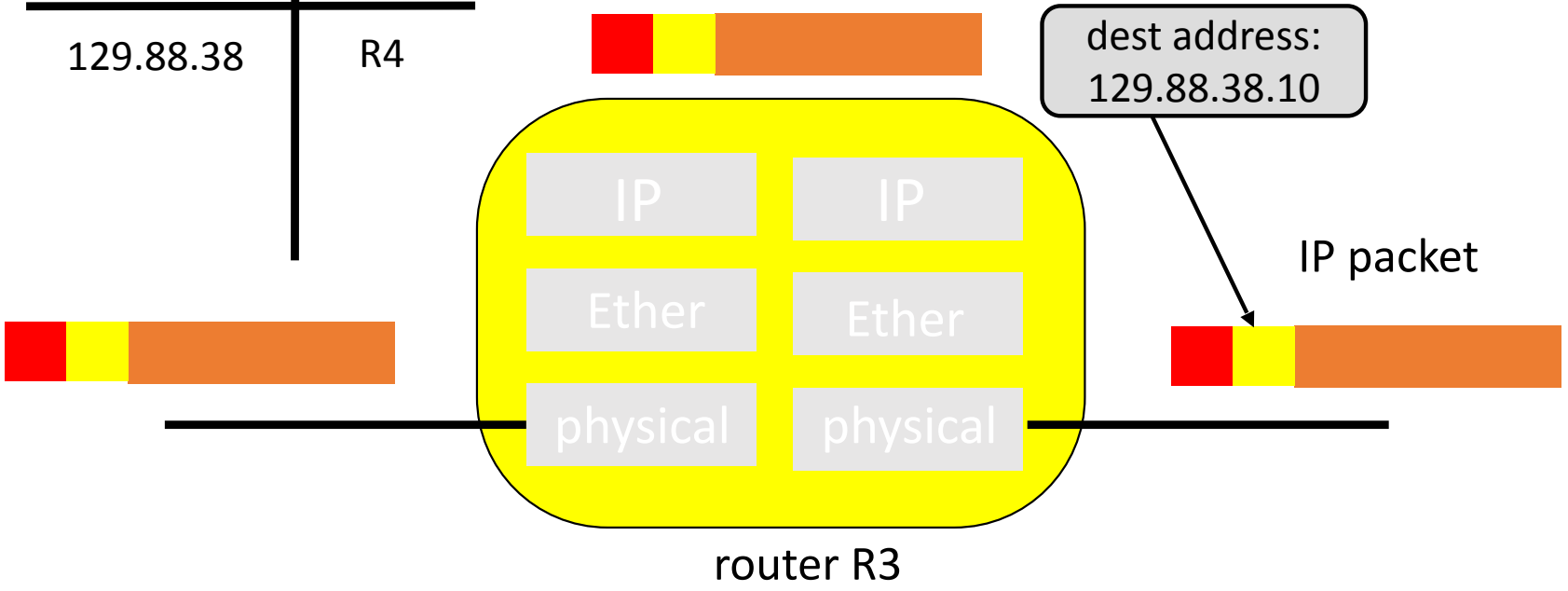


IP

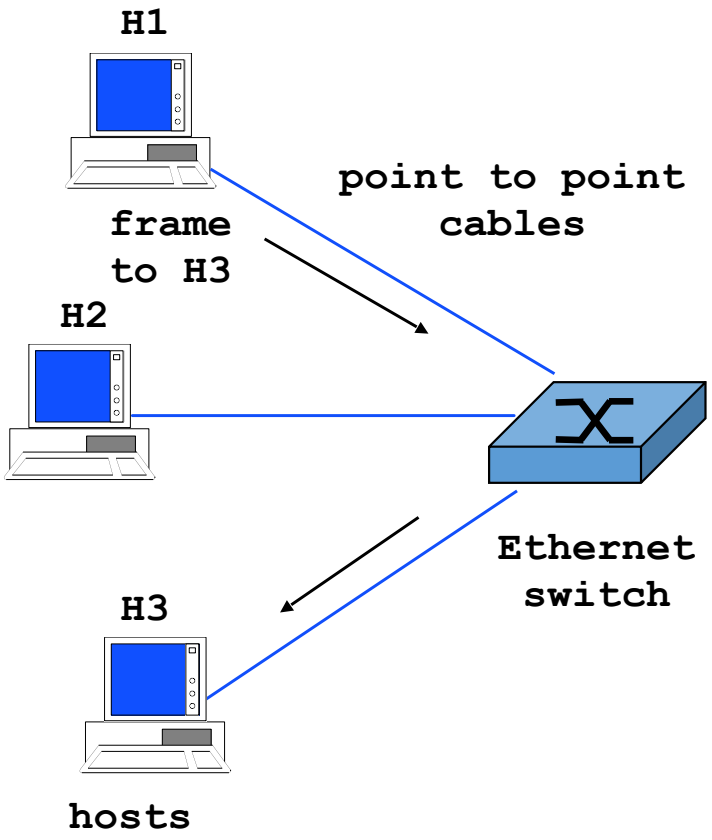


Routing Table of R3

dest	router
129.88.38	R4



Physical Layer
Data Link Layer



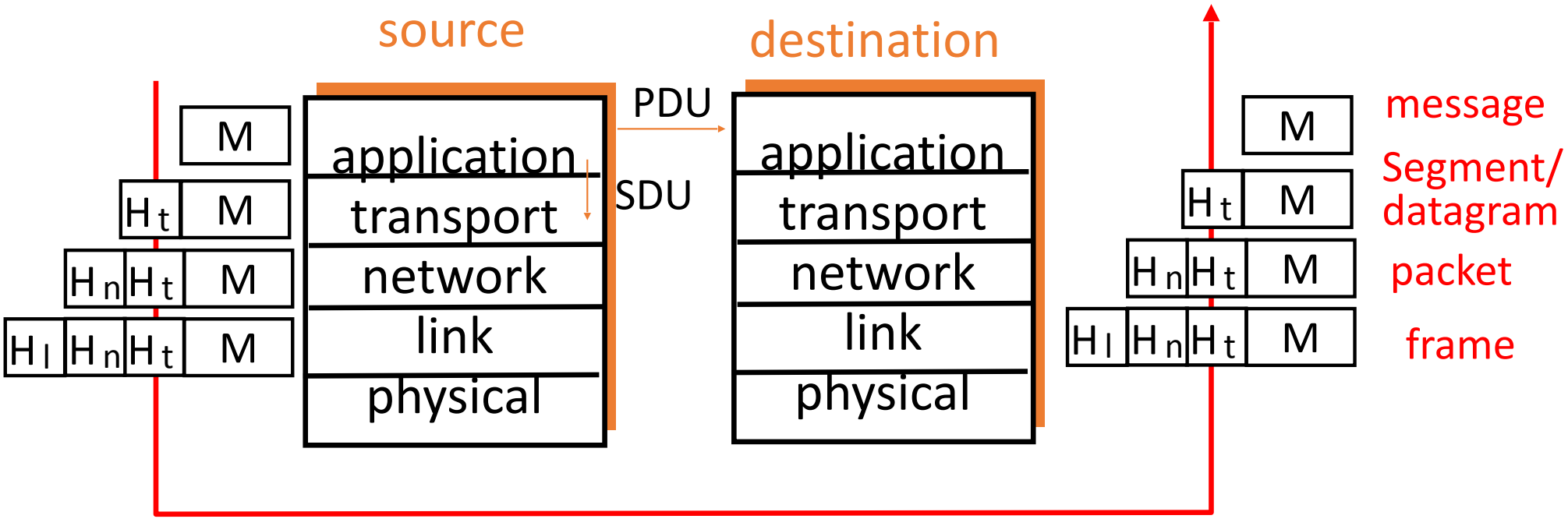
- Physical transmission = **Physical** function
  - bits <-> electrical / optical signals
  - transmit individual bits over the cable: modulation, encoding
- Frame transmission = **Data Link** function
  - bit error detection
  - packet boundaries
  - in some cases: link layer addresses (Ethernet)
  - in some cases: error correction by retransmission (802.11)
- Modems, xDSL, LANs

Encapsulation

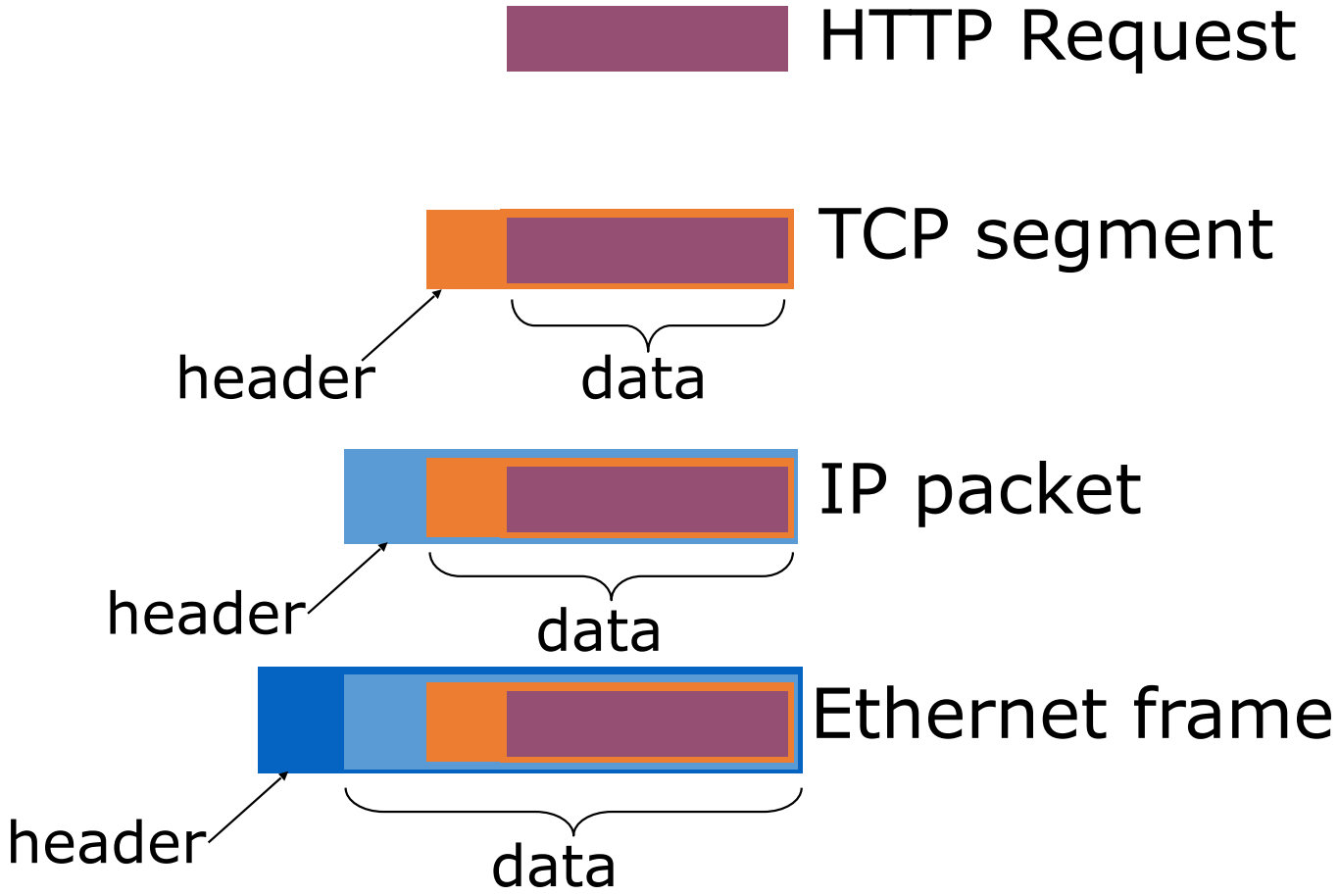
Protocol layering and data

Each layer takes data (and metadata, if needed) from above

- adds header information to create new data unit
- passes new data unit to layer below



Encapsulation



Packet capture

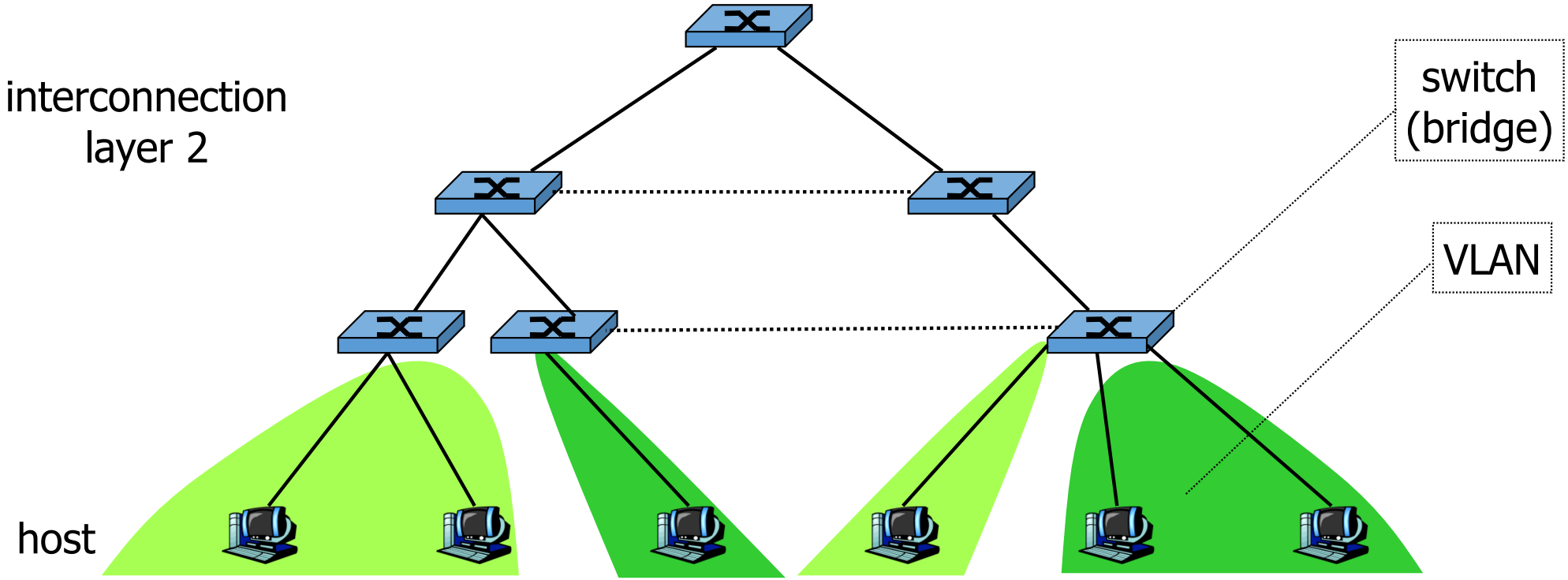
```
Frame 1 (1514 on wire, 1514 captured)
Ethernet II
    Destination: 00:03:93:a3:83:3a (Apple_a3:83:3a)
    Source: 00:10:83:35:34:04 (HEWLETT-_35:34:04)
    Type: IP (0x0800)
Internet Protocol, Src Addr: 129.88.38.94 (129.88.38.94), Dst Addr: 129.88.38.241
   (129.88.38.241)
    Version: 4
    Header length: 20 bytes
    Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
    Total Length: 1500
    Identification: 0x624d
    Flags: 0x04
    Fragment offset: 0
    Time to live: 64
    Protocol: TCP (0x06)
    Header checksum: 0x82cf (correct)
    Source: 129.88.38.94 (129.88.38.94)
    Destination: 129.88.38.241 (129.88.38.241)
```

Ethereal

```
Transmission Control Protocol, Src Port: 34303 (34303), Dst Port:
  6000 (6000), Seq: 4292988915, Ack: 3654747642, Len: 1448
    Source port: 34303 (34303)
    Destination port: 6000 (6000)
    Sequence number: 4292988915
    Next sequence number: 4292990363
    Acknowledgement number: 3654747642
    Header length: 32 bytes
    Flags: 0x0010 (ACK)
    Window size: 41992
    Checksum: 0x9abe (correct)
    Options: (12 bytes)
```

Interconnection

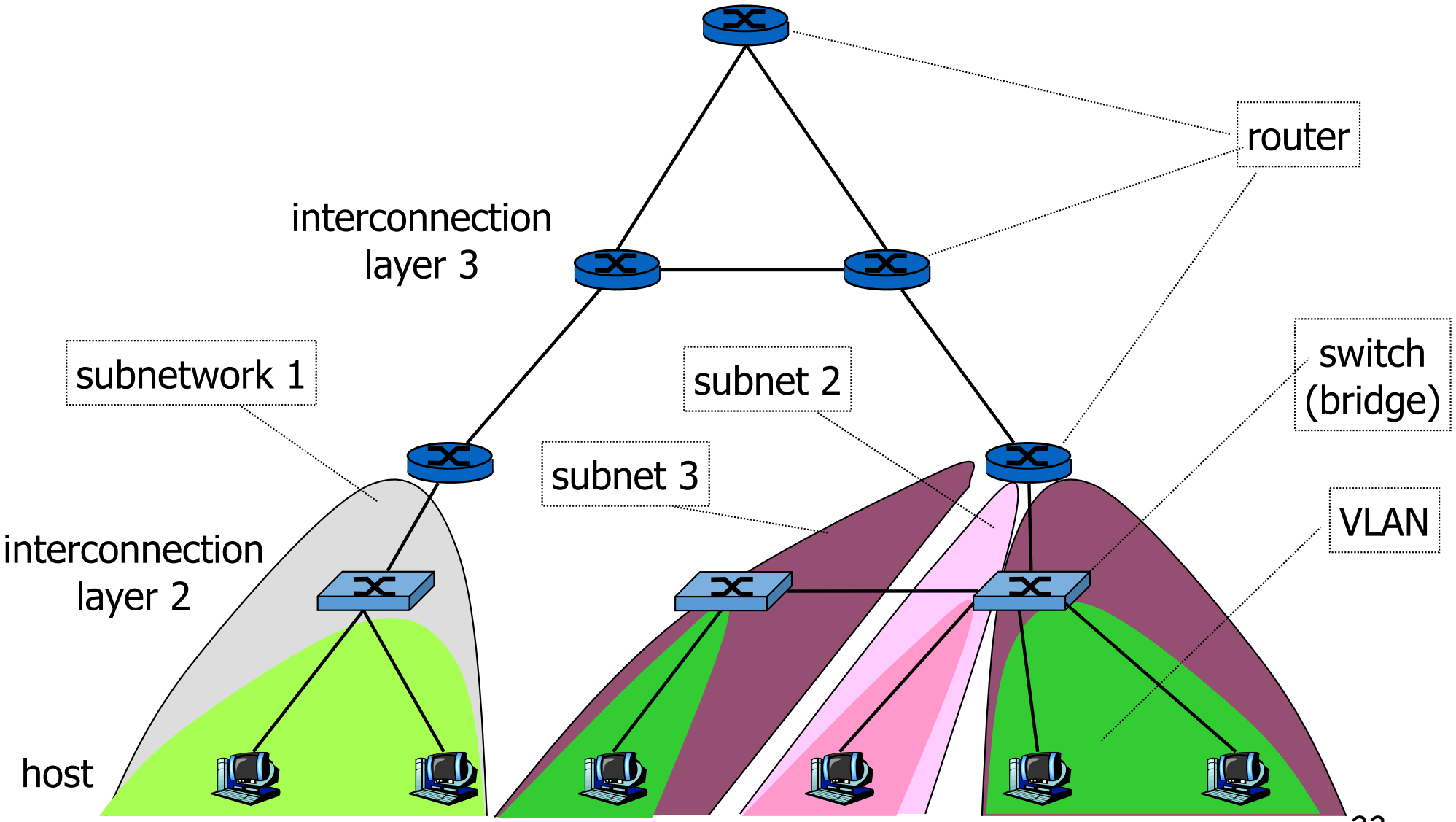
Interconnection structure - layer 2



Interconnection at layer 2

- **Switches** (bridges)
  - interconnect hosts
  - logically separate groups of hosts (VLANs)
  - managed by one entity
- Type of the network
  - **Broadcast** (One packet may reach several end points)
- Forwarding based on MAC address
  - **flat** address space
  - forwarding tables: one entry per host
  - works if no loops
    - careful management
    - Spanning Tree protocol
  - not scalable

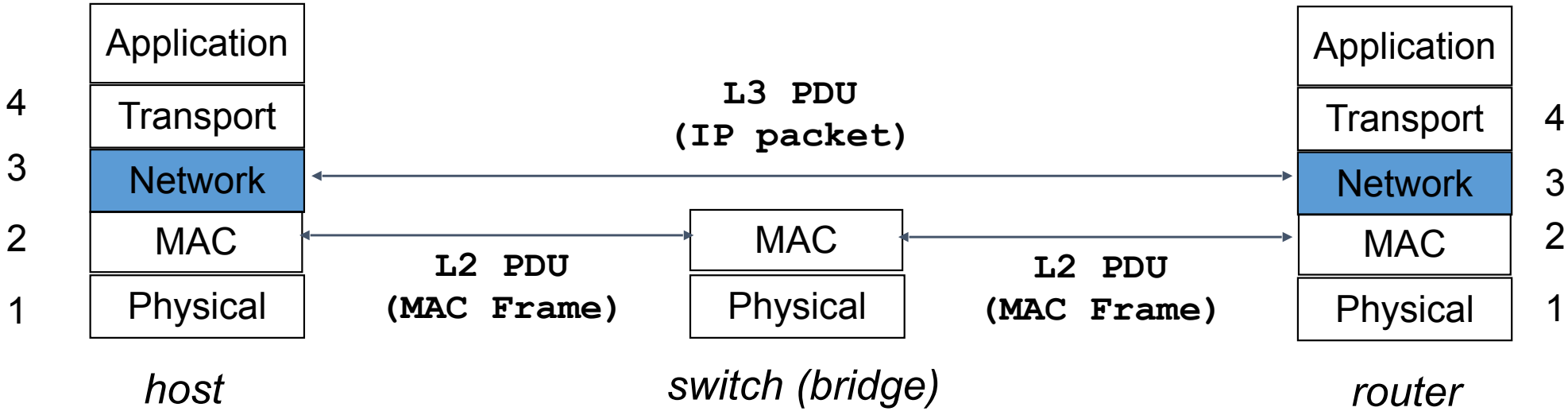
Interconnection structure - layer 3



Interconnection at layer 3

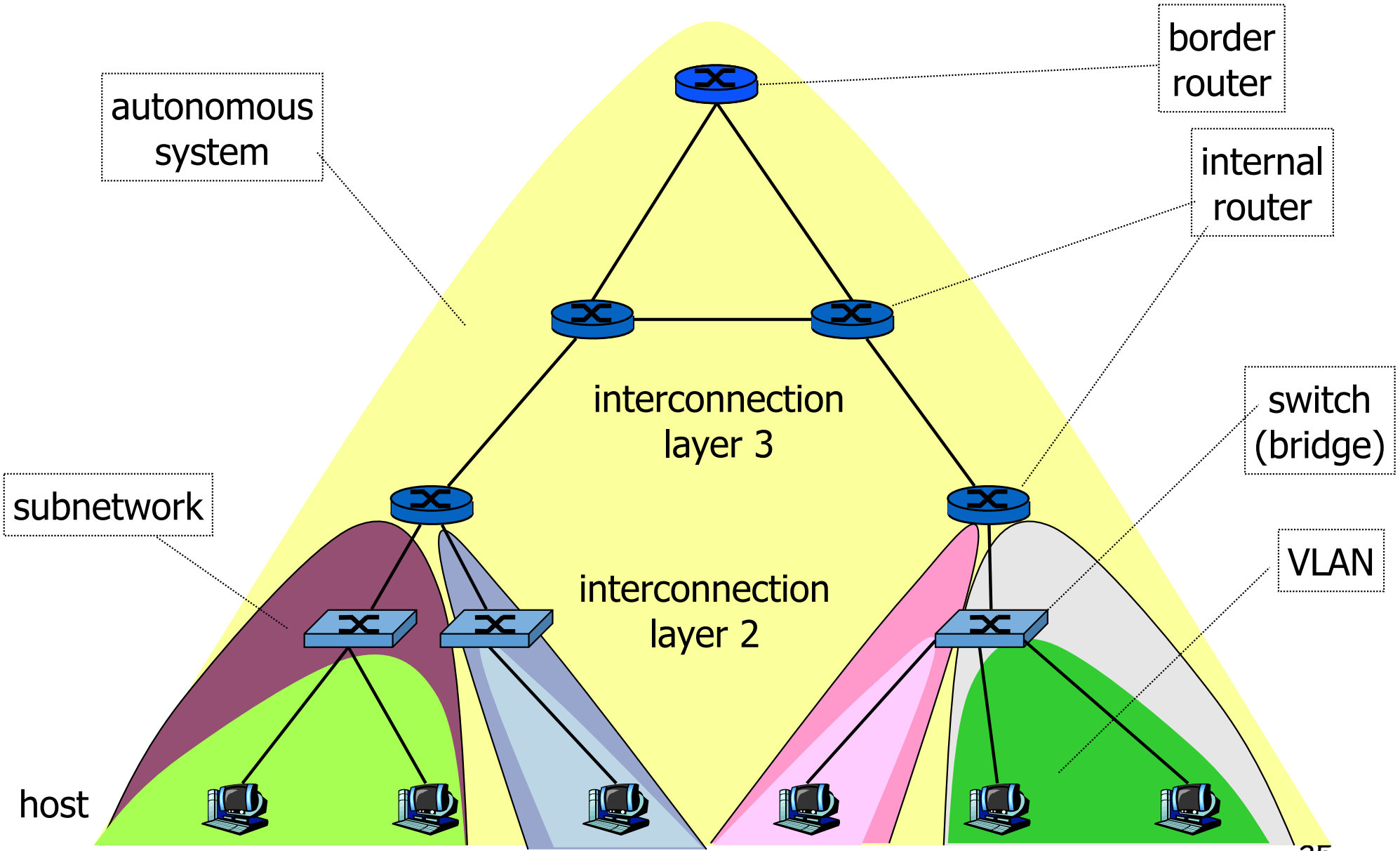
- Routers
  - interconnect subnetworks
  - logically separate groups of hosts
  - managed by one entity
- Forwarding based on IP address
  - structured address space
  - routing tables: aggregation of entries
  - works if no loops - routing protocols (IGP - Internal Routing Protocols)
  - scalable inside one administrative domain

Protocol architecture

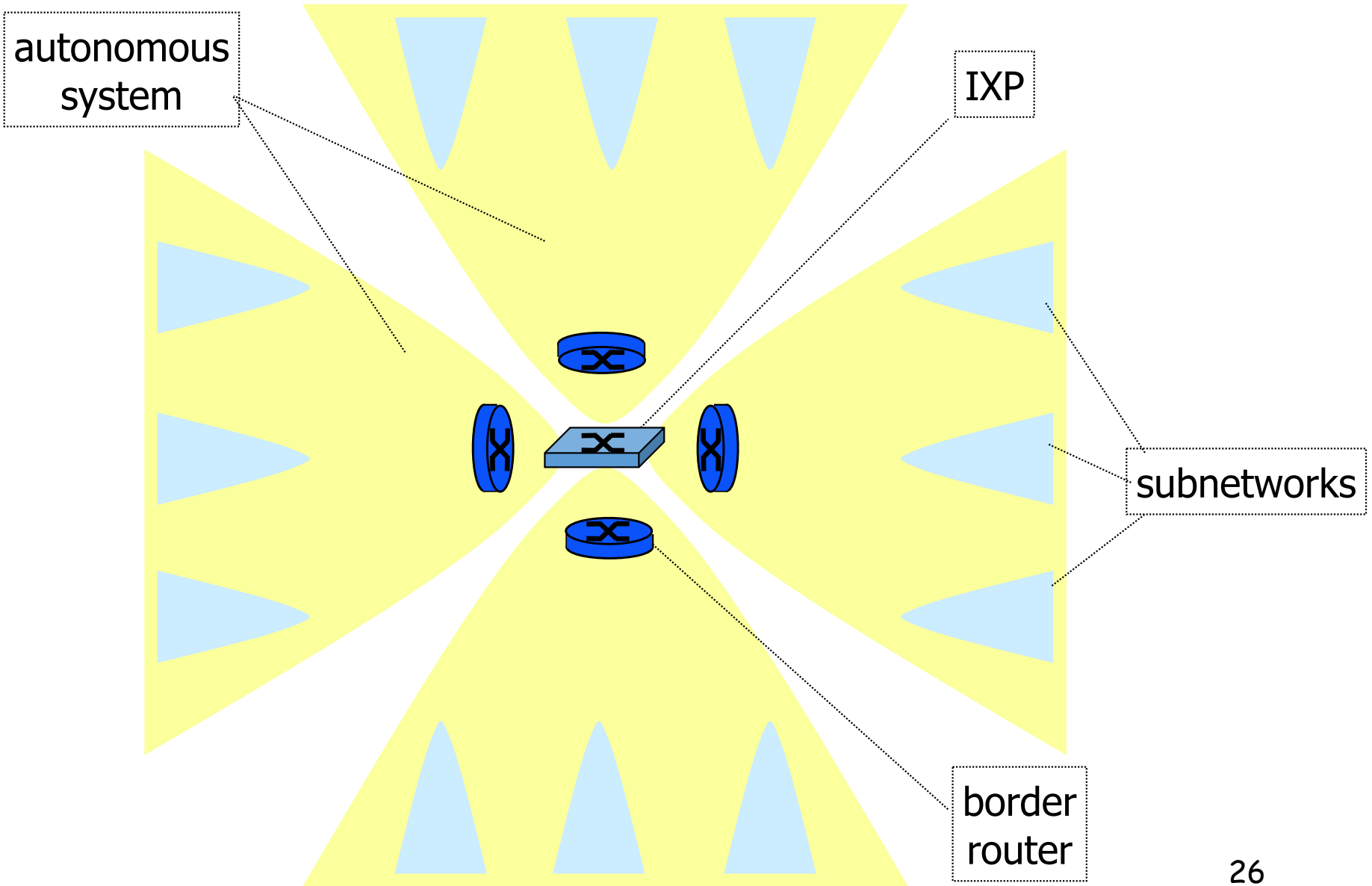


- Routers are layer 3 intermediate systems
- Explicit forwarding
  - host has to know the address of the first router
- Management protocols (control, routing, configuration)

Autonomous systems



Internet



Interconnection of AS

- Border routers
  - interconnect AS
- (NAP or GIX, or) IXP
  - exchange of traffic - peering
- Route construction
  - based on the path through a series of AS
  - based on administrative policies
  - routing tables: aggregation of entries
  - works if no loops and at least one route - routing protocols (BGP- Border Gateway Protocols)