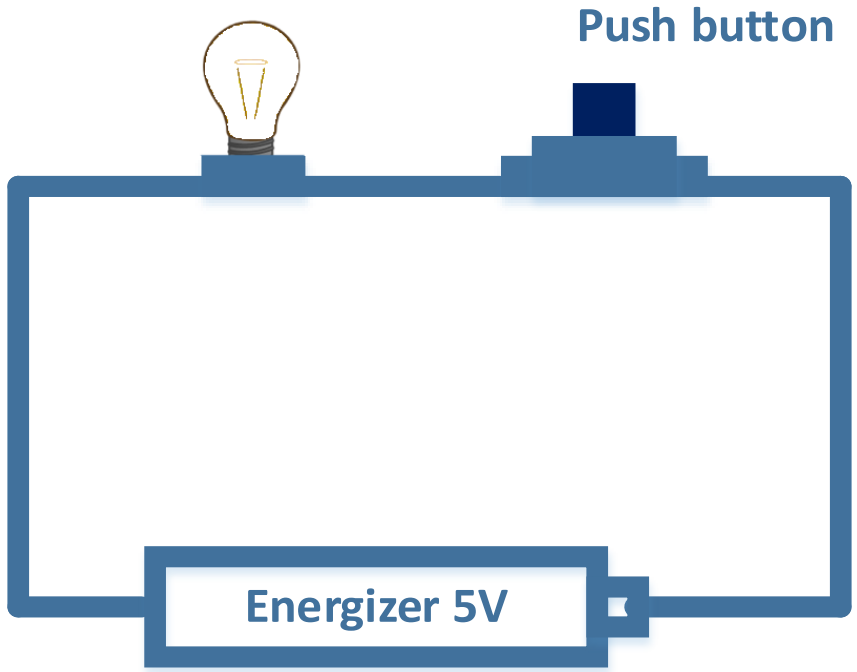
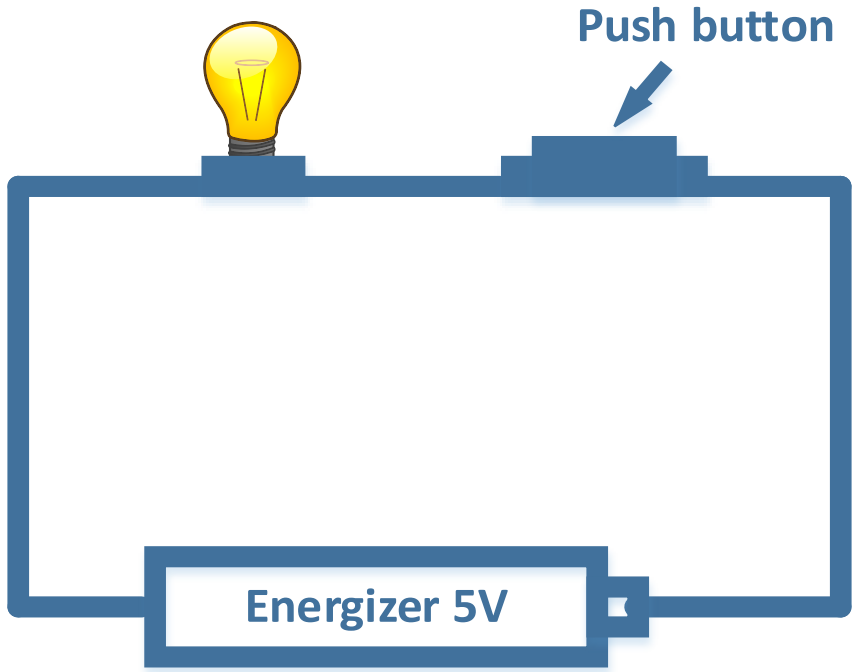
Lecture 1

Introduction to web programming

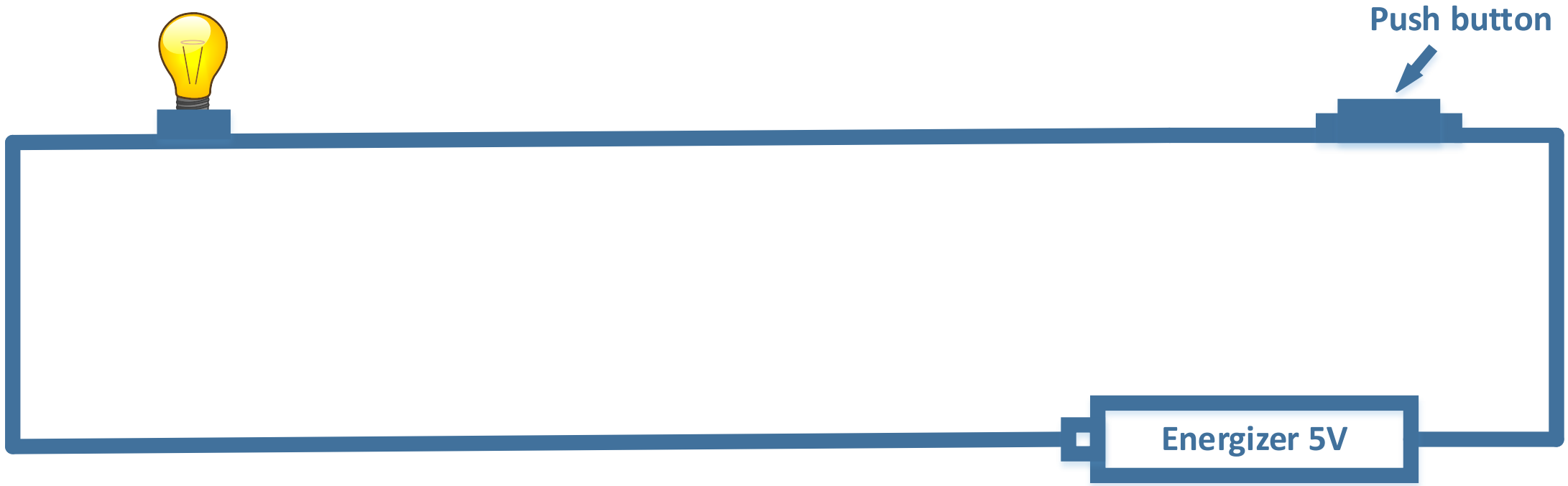
Electrical signaling



Electrical signaling



Saint-Petersburg



Moscow

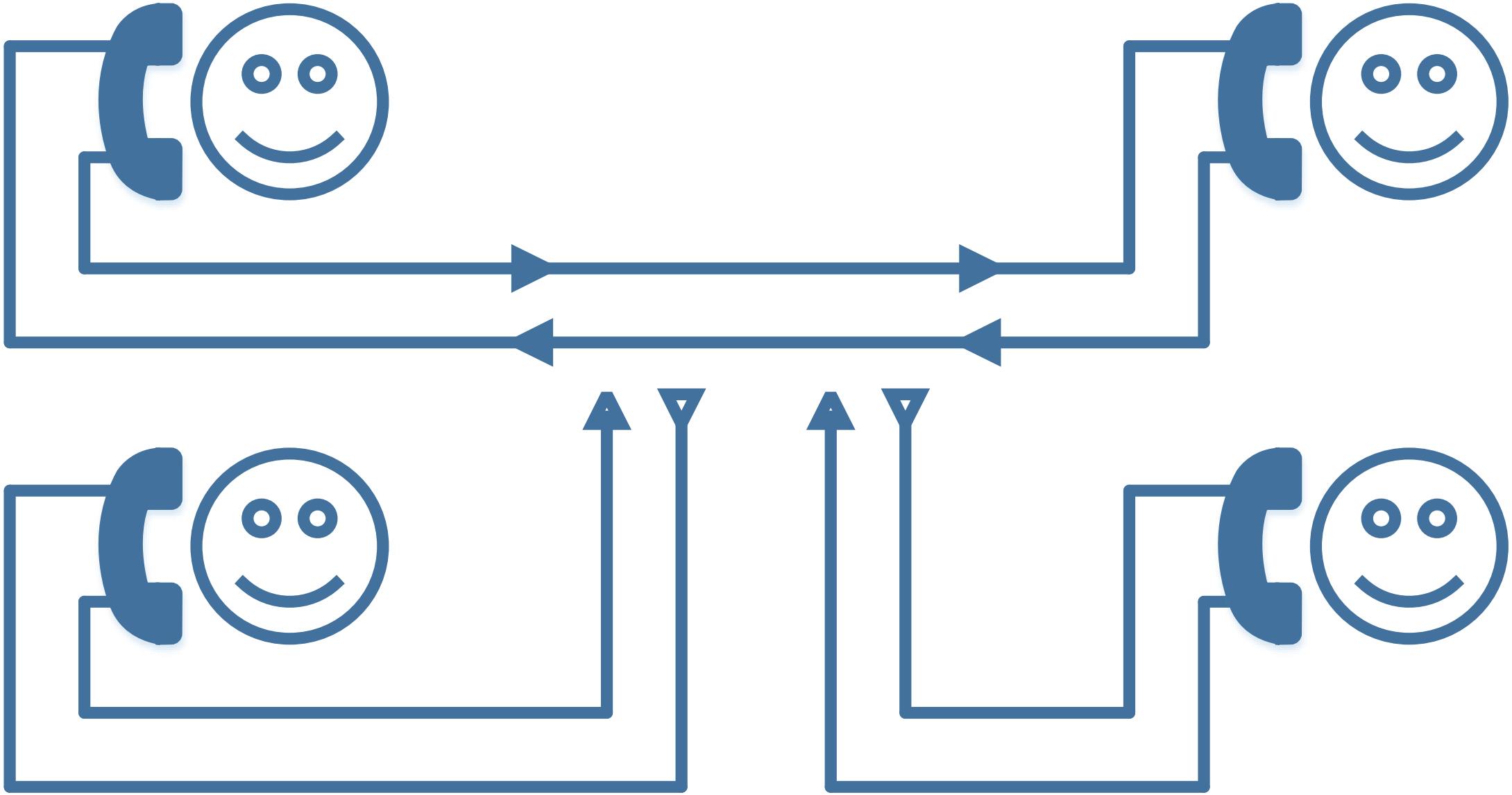
Landline telephone

Saint-Petersburg

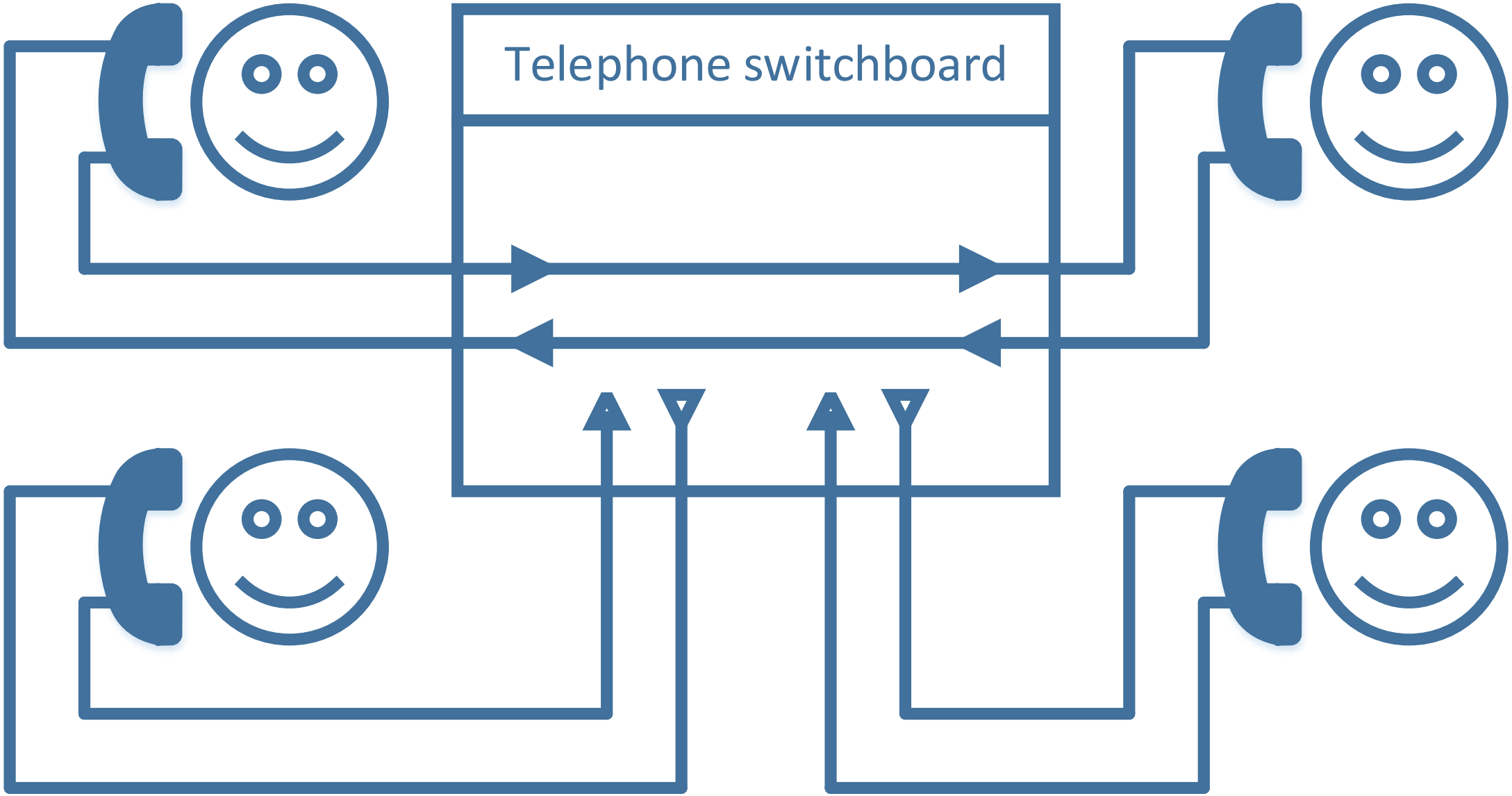
Energizer 5V

Moscow

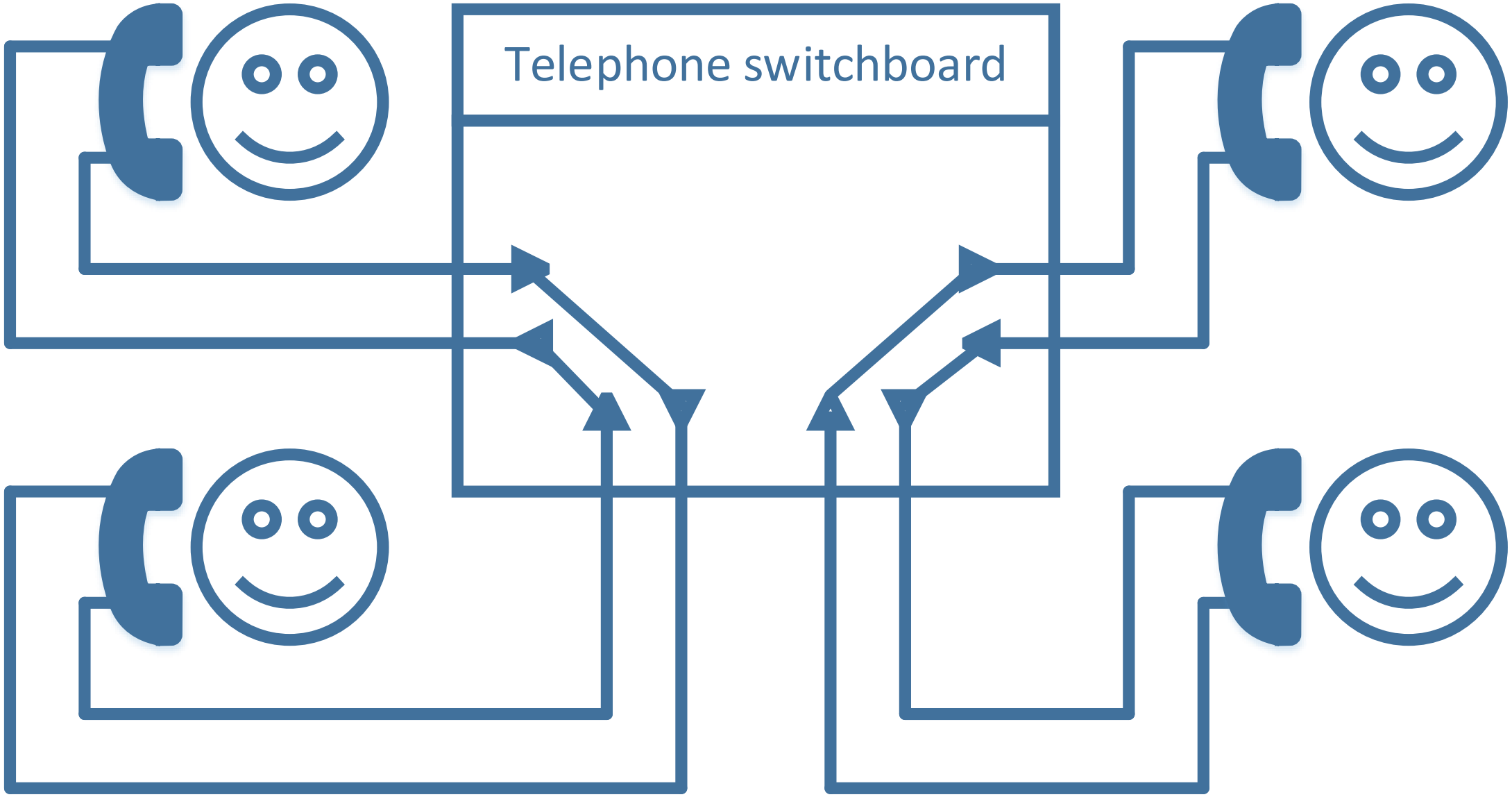
Landline telephone – more participants



Landline telephone – switchboard



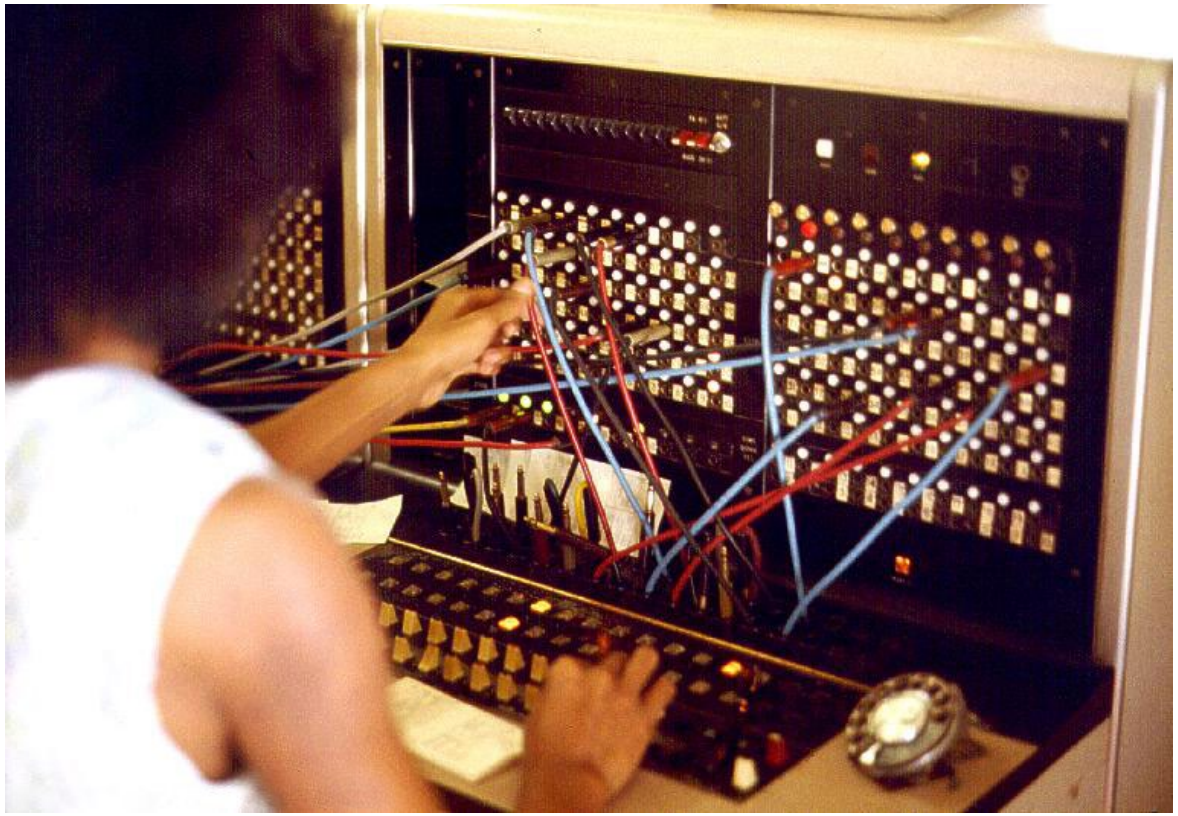
Landline telephone – switchboard



Circuit switching

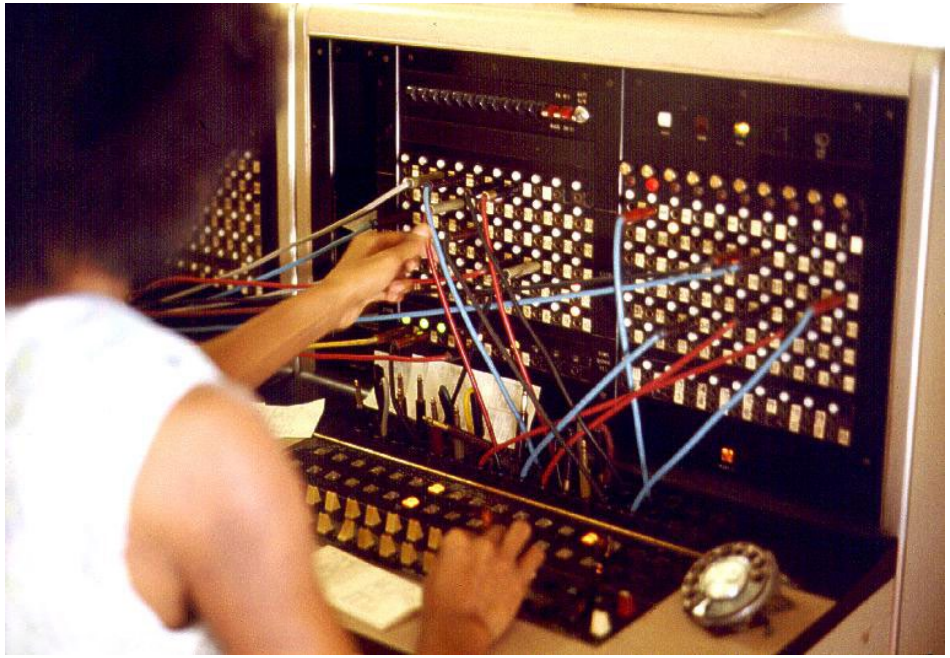
– way of interconnecting communication participants by establishing and maintaining physical communication channel between them.

For example: electrical circuit through landline telephone network.



Circuit switching

For each call participants:

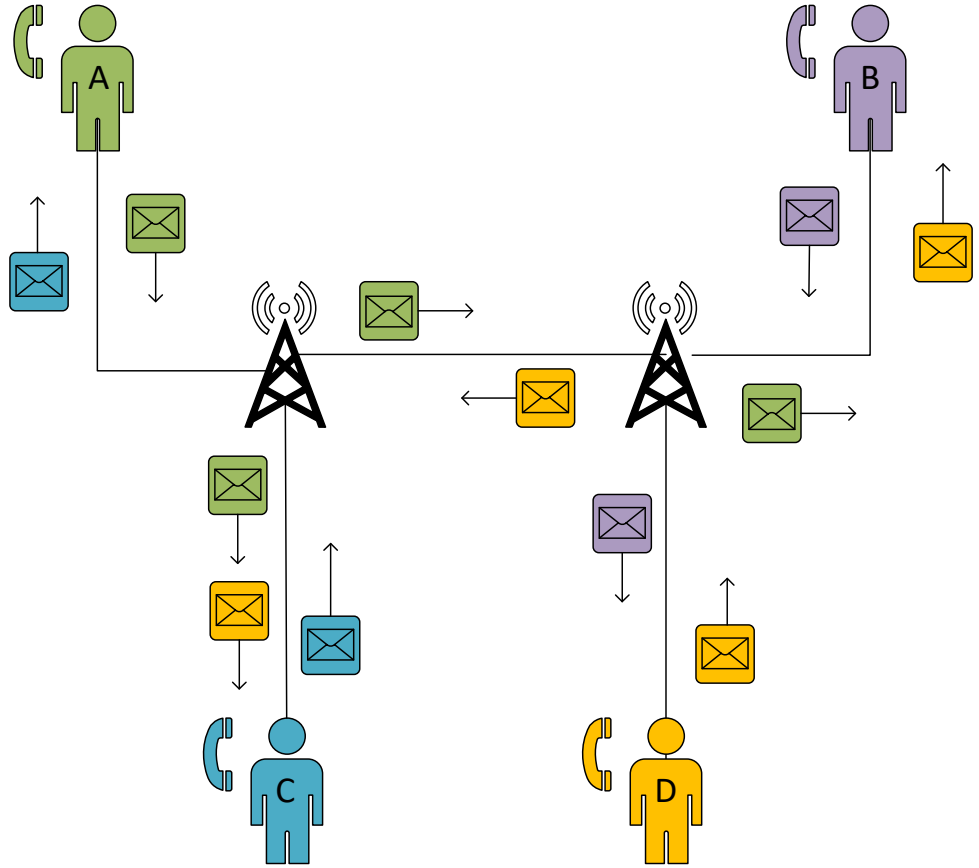


- dedicated channel has to be established in advance of communication itself (route planning problem)
- the channel should be reserved and maintained during the communication (reliability problem)
- established channel cannot be tuned in on the way (quality of service problem)
- number of active channels limited by physical structure of the network (network bandwidth problem)

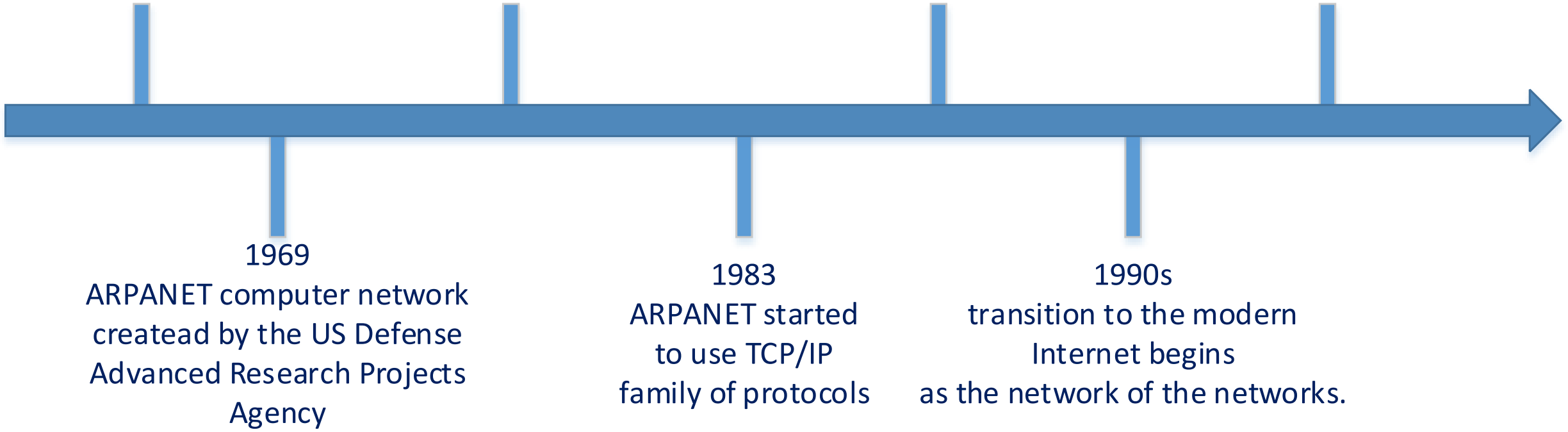
Packet switching

– way of transmitting data between communication participants based on splitting continuous data flow into small finite packets and independent routing or each packet.

- Each packet routed independently
  (when some lost, others would be be delivered)
- Routes could arise and disappear
  (bandwidth can be dynamically adapted)
- Packets can be prioritized
  (urgent deliveries could overcome unnecessary)
- Network channels shared between many users
  (bandwidth on-demand)



Very brief history of the Internet and Web



Networking basics

Data exchange **protocol** - is a formal set of rules, describing organization of data flow between data exchange participants.

Networking basics – OSI

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The Open Systems Interconnection model (OSI model) - is a conceptual model that characterises and standardises the communication functions of a telecommunication or computing system without regard to its underlying internal structure and technology:

1. Physical Layer
2. Data link layer
3. Network layer
4. Transport layer
5. Session layer
6. Presentation layer
7. Application layer

Networking basics – OSI

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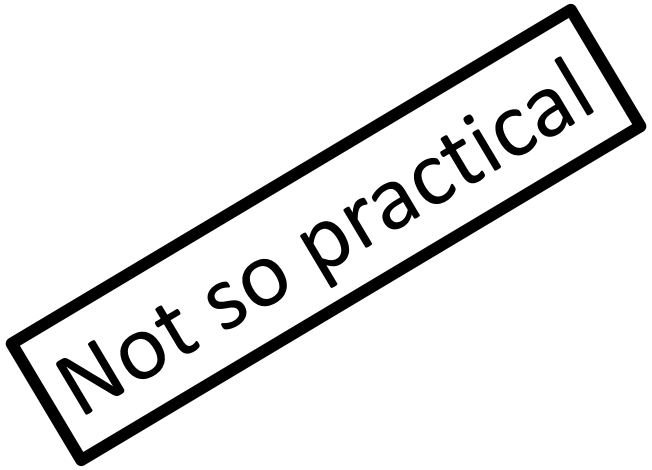


Networking basics – TCP/IP

Data exchange **protocol** - is a formal set of rules, describing organization of data flow between data exchange participants.

The **Internet protocol suite** (also known as **TCP/IP**) is the conceptual model and set of communication protocols used in the Internet and similar networks:

1.
2.
3.
4.

Networking basics – TCP/IP – Link layer

Data exchange **protocol** - is a formal set of rules, describing organization of data flow between data exchange participants.

The **Internet protocol suite** (also known as **TCP/IP**) is the conceptual model and set of communication protocols used in the Internet and similar networks:

1. **Physical (link) networking** – computer's network adapter connectivity through data transmission medium (**Ethernet** for wired connection, **Wi-Fi** for wireless)
   Each network adapter identified by its **MAC address** across physical connectivity area.
2. …
3. …
4. …

Networking basics – TCP/IP – IP layer

Data exchange **protocol** - is a formal set of rules, describing organization of data flow between data exchange participants.

The **Internet protocol suite** (also known as **TCP/IP**) is the conceptual model and set of communication protocols used in the Internet and similar networks:

1. Physical (link) networking – Ethernet, Wi-Fi – MAC address
2. **Logical (internet) connection** – computer's logical network interfaces interaction over number of physical network segments (**IP – Internet protocol** – for local and global networks)
   Each network interface can be identified by one or more **IP addresses** across logical network area over number of physical networks.
3. …
4. …

Networking basics – TCP/IP – Transport layer

Data exchange **protocol** - is a formal set of rules, describing organization of data flow between data exchange participants.

The **Internet protocol suite** (also known as **TCP/IP**) is the conceptual model and set of communication protocols used in the Internet and similar networks:

1. Physical (link) networking – Ethernet, Wi-Fi – MAC address
2. Logical (internet) connection – IP – IP address
3. **Transport protocols** – particular programs or applications interaction over logical network connection (**UDP, TCP, …** - depending on desired mode of communication)
   Each application identified by **port number** (for UDP and TCP protocols) across particular computer network interface.
4. …

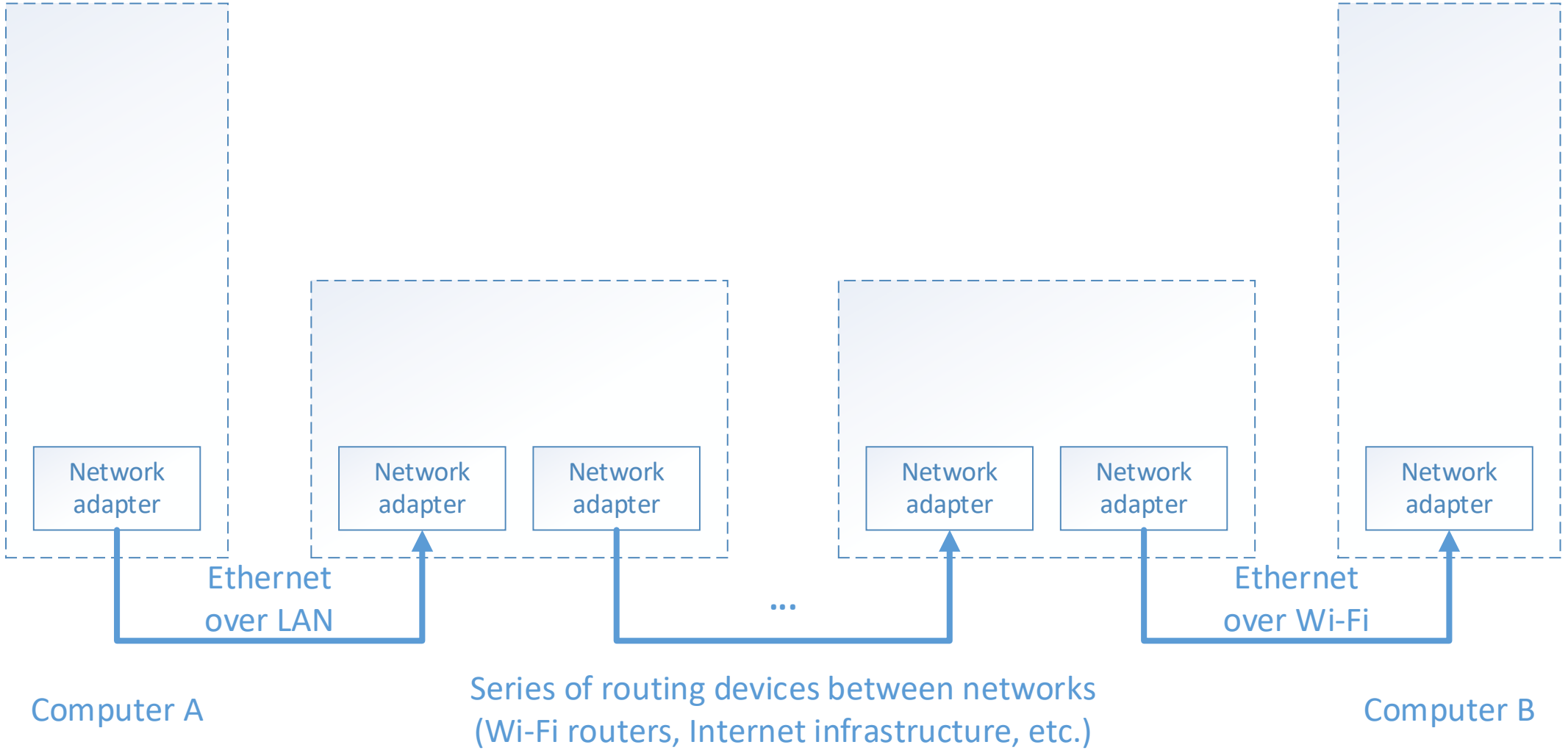
Networking basics – TCP/IP – Application layer

Data exchange **protocol** - is a formal set of rules, describing organization of data flow between data exchange participants.

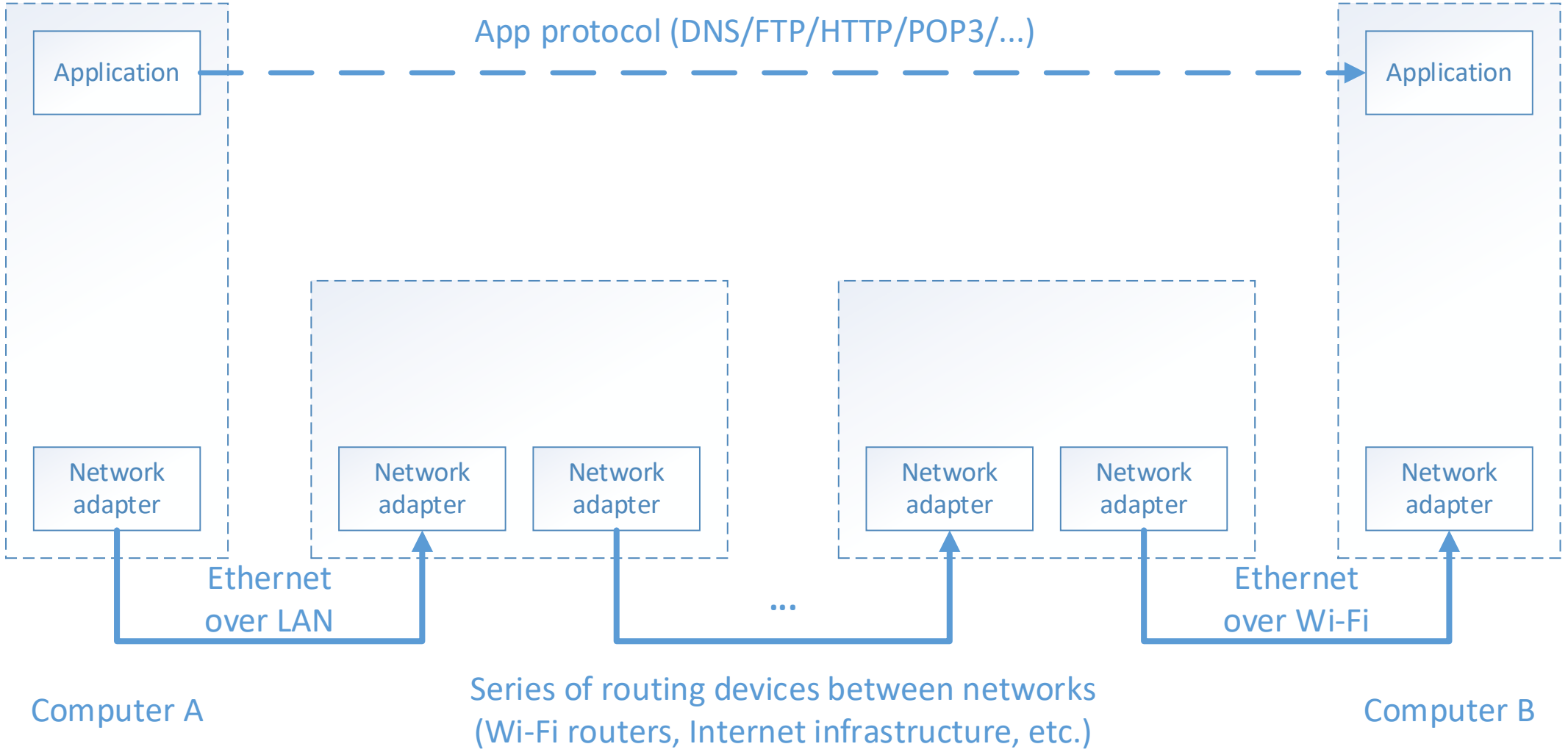
The **Internet protocol suite** (also known as **TCP/IP**) is the conceptual model and set of communication protocols used in the Internet and similar networks:

1. Physical (link) networking – Ethernet, Wi-Fi – MAC address
2. Logical (internet) connection – IP – IP address
3. Transport protocols – UDP, TCP – port number
4. **Application protocol** – purpose-specific set of rules describing, how some applications should interact to solve particular networking-related task (**DNS, FTP, HTTP, POP3, …** - depending or particular task)

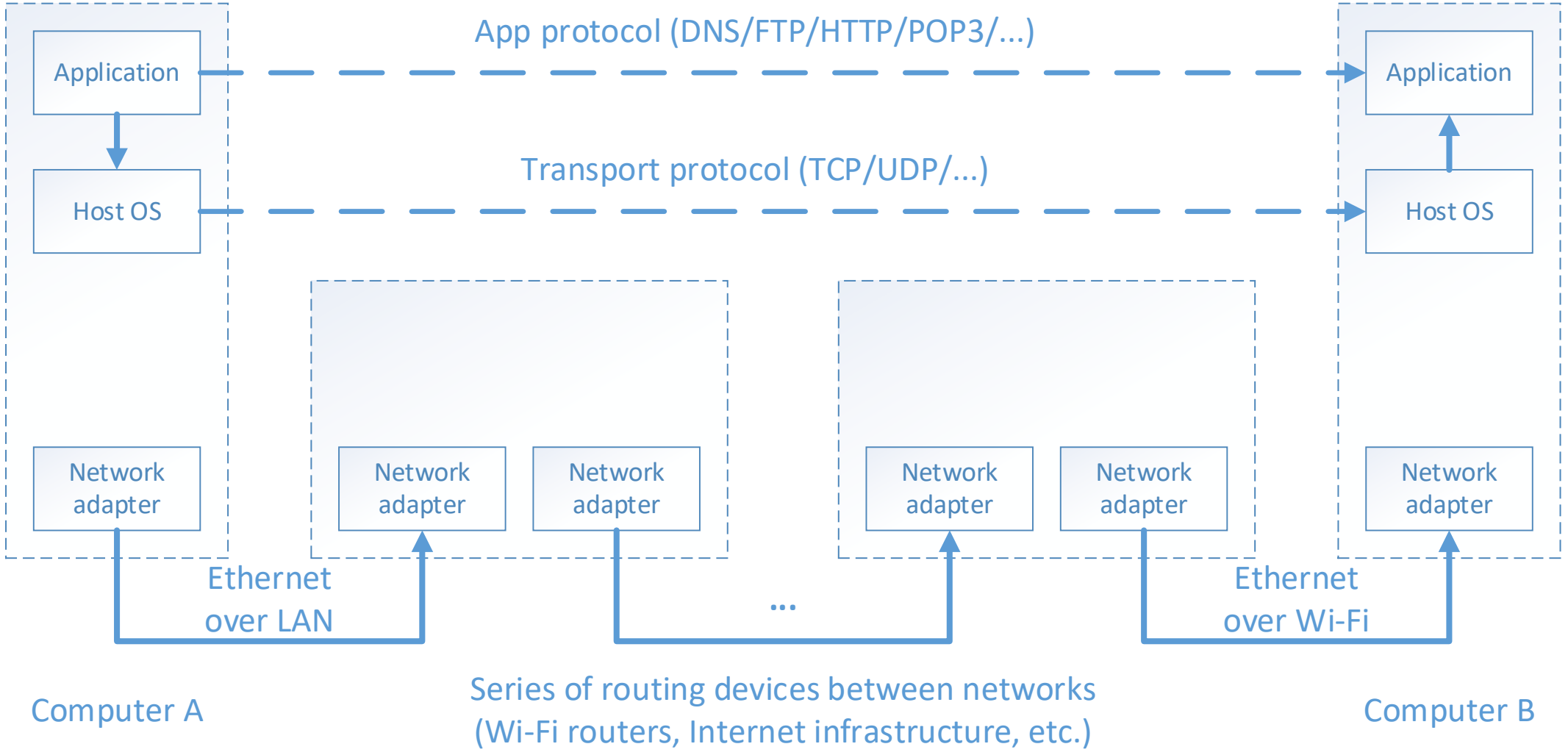
Data flow – Physical links



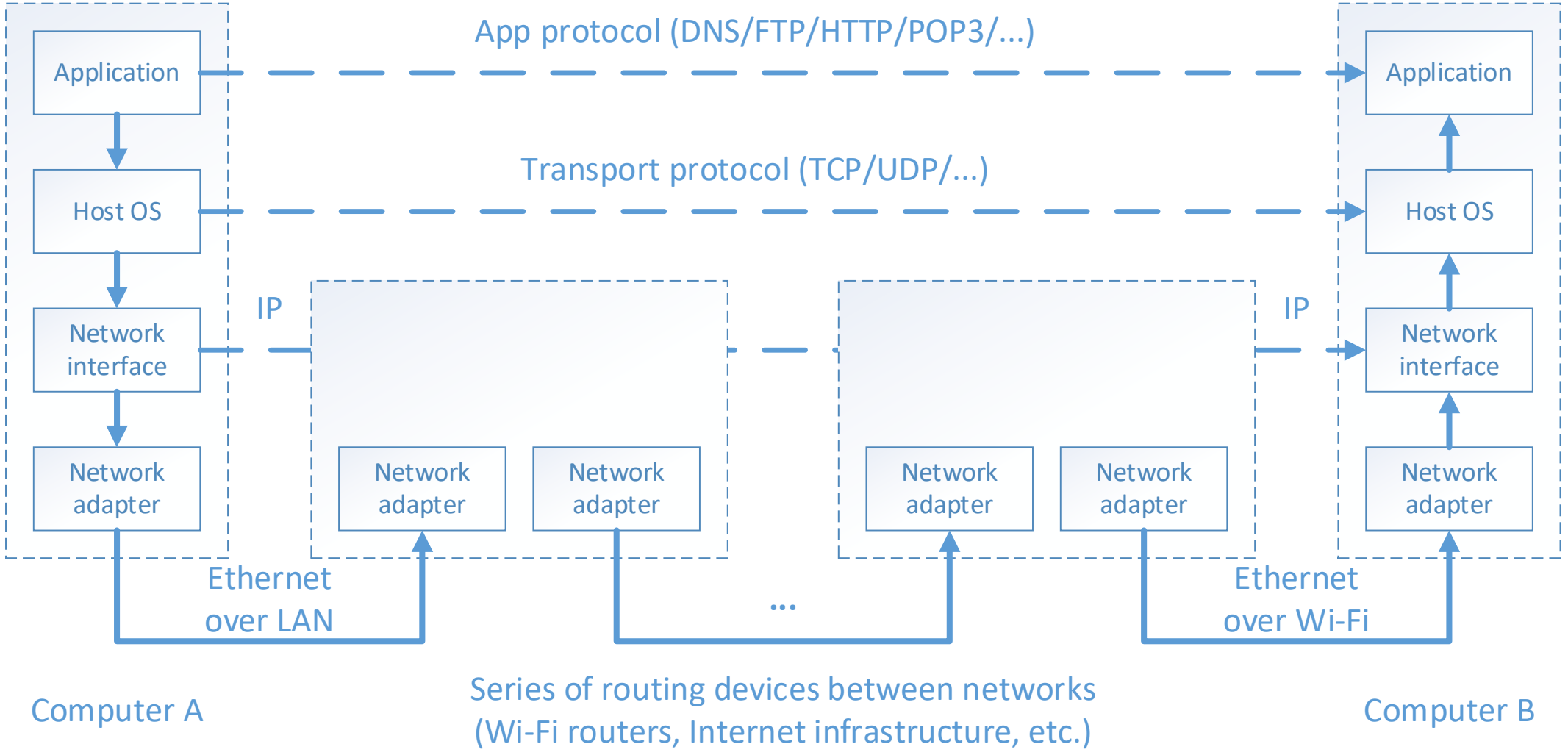
Data flow – Application layer



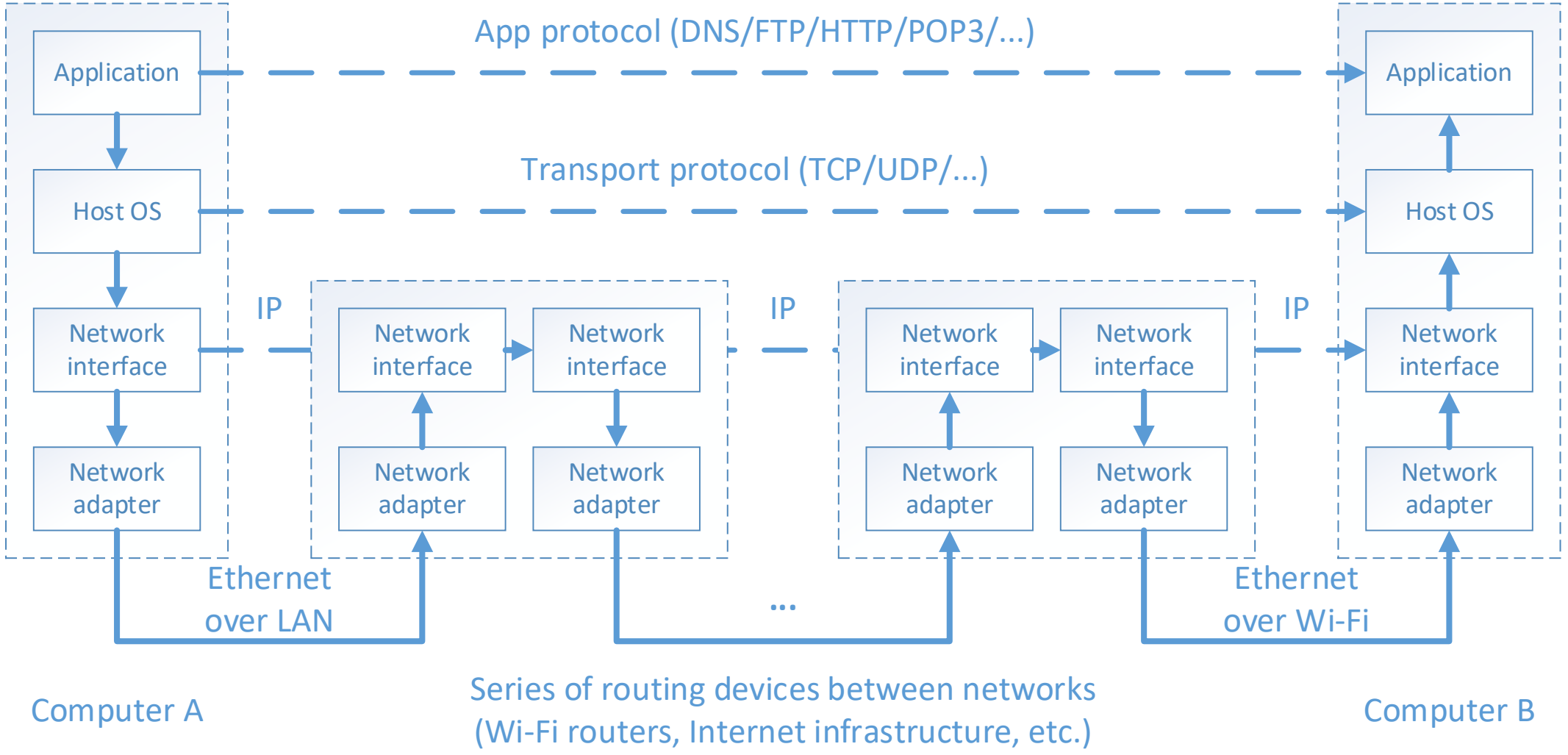
Data flow – Transport layer



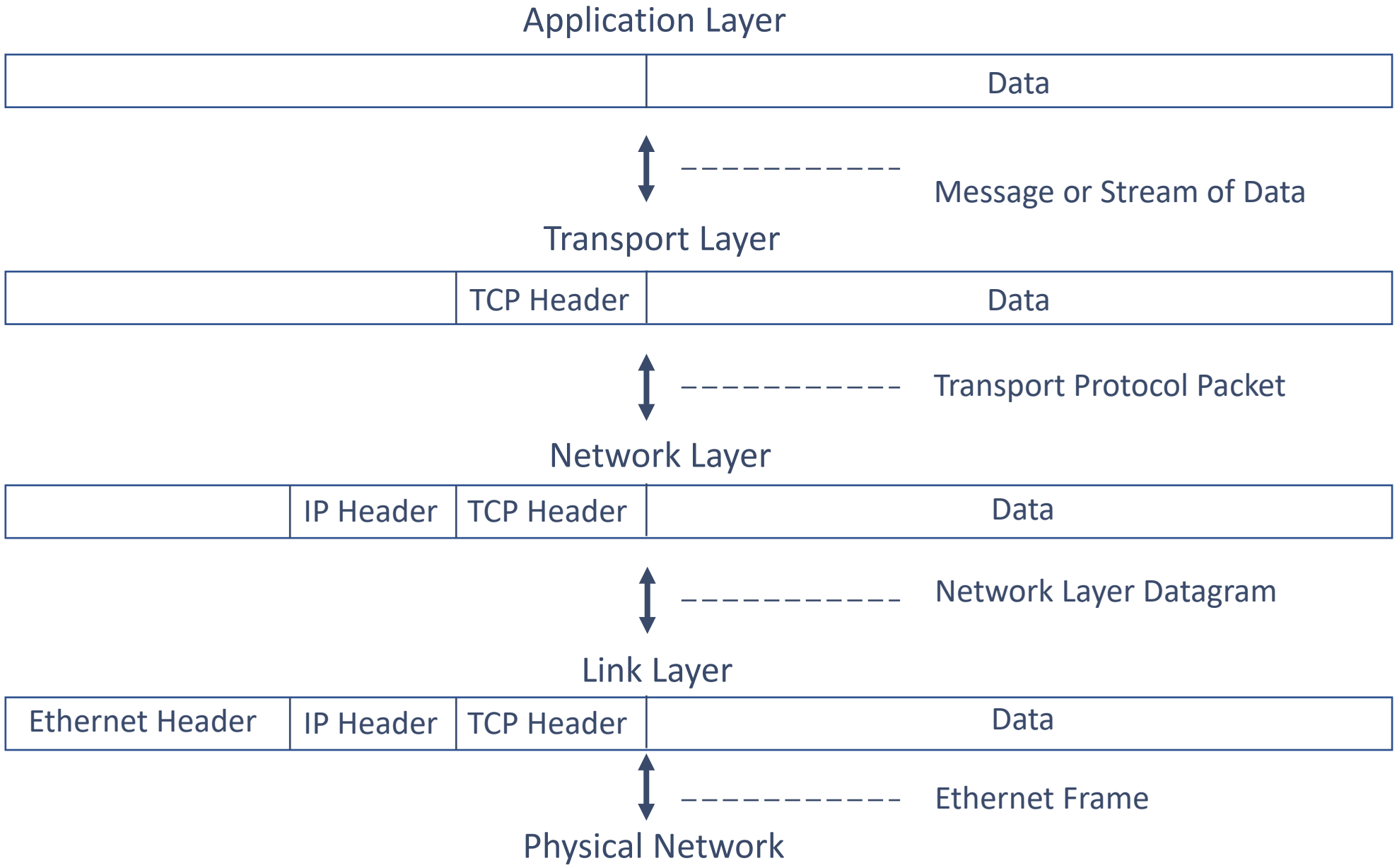
Data flow – Network layer



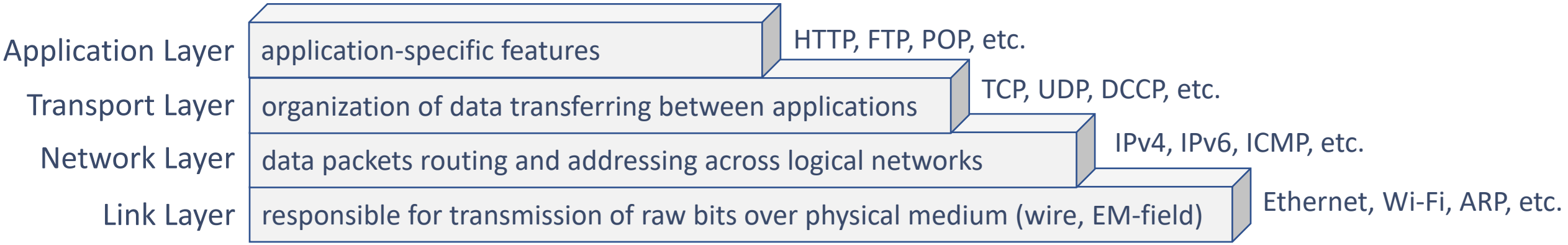
Data flow – Network layer



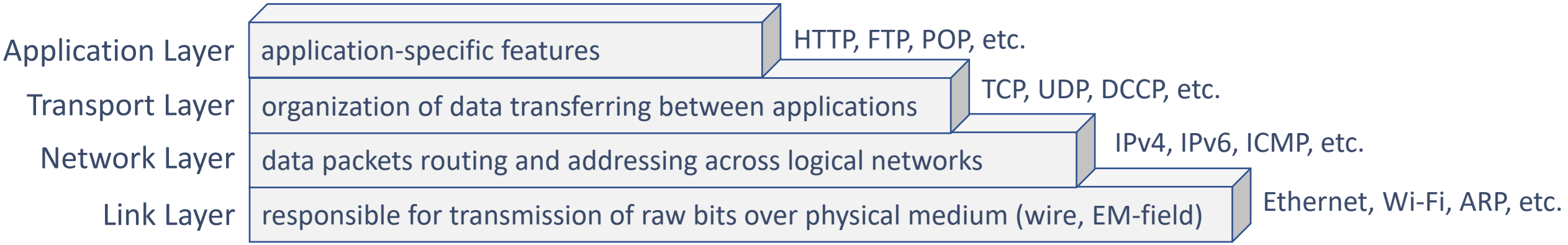
Data flow – Structure of data portion



Addressing endpoints – layers overview



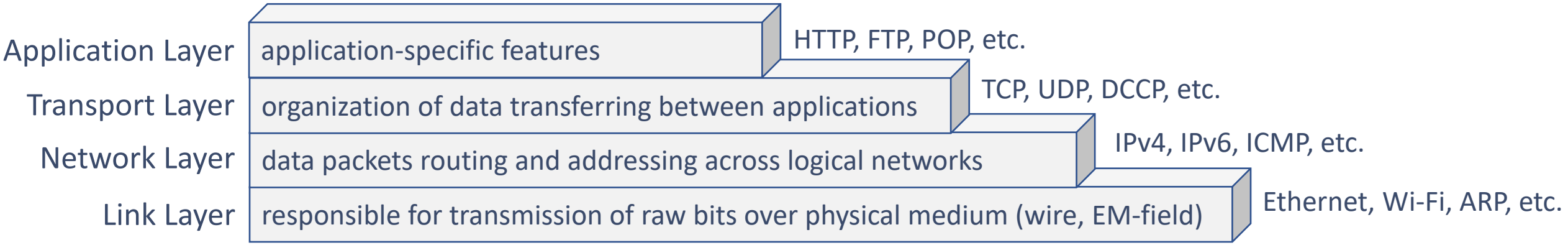
Addressing endpoints - address



Endpoint address – identifier of the participant of network data interchange.

- Typically particular endpoint and its address associated with particular network protocol, used for data interchange in the particular application.

Addressing endpoints - socket



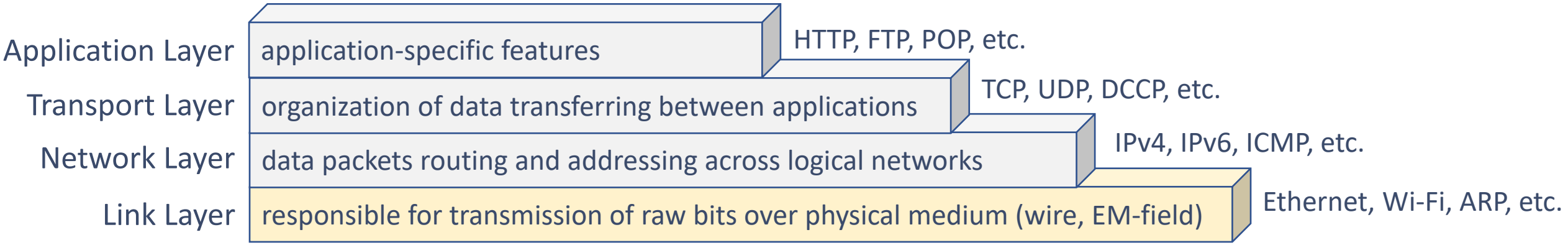
Endpoint address – identifier of the participant of network data interchange.

- Typically particular endpoint and its address associated with particular network protocol, used for data interchange in the particular application.

Network socket – programming interface intended for an application to interact with networking environment: to send data and to receive data over network.

- Can be treated as “window” into the networking environment on a certain level having built-in algorithms about corresponding protocols and functions to send and receive data.

Addressing endpoints - MAC



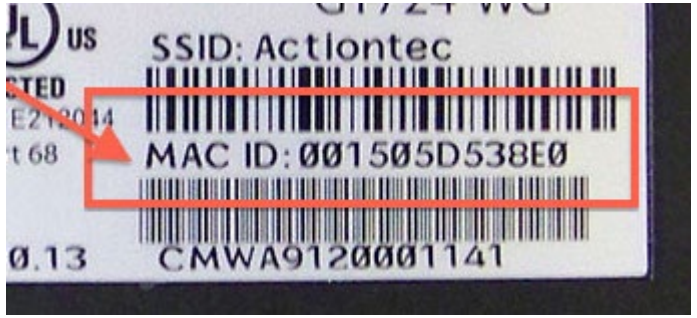
MAC (media access control) address – unique 48- or 64-bit identifier assigned to network hardware.

Used to identify wired network adapter, WiFi adapter or virtual network adapter across “physical” network segment.

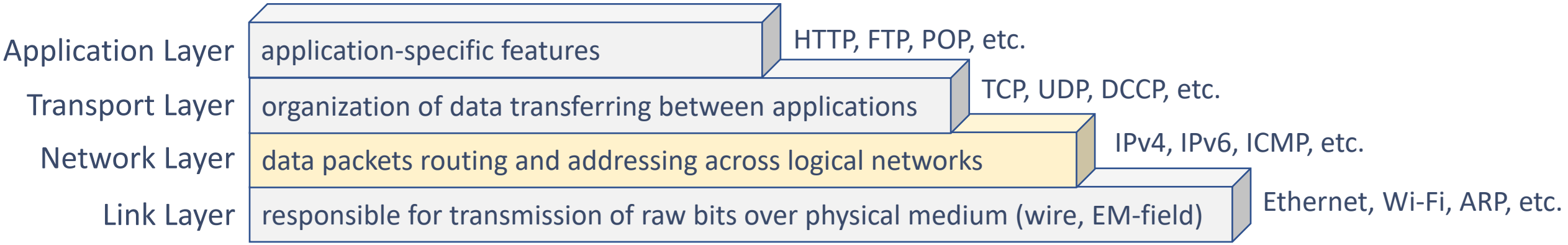
```
eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.42.136  netmask 255.255.255.0  broadcast 192.168.42.255
        ether 00:15:5d:64:0d:06  txqueuelen 1000  (Ethernet)
```

```
Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   Physical Address. . . . . . . . . : 00-15-5D-64-0D-00
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::d4c9:8757:da50:c914%3(Preferred)
   IPv4 Address. . . . . . . . . . . : 192.168.42.99(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
```



Addressing endpoints - IP



IP (internet protocol) address – identifier assigned to the logical network interface associated with a certain network hardware.

Used to identify network interface of the computer system or a networking device across "logical" network area (Local, Wide or Global).

```
eth1: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.42.136  netmask 255.255.255.0  broadcast 192.168.
        inet6 fe80::215:5dff:fe64:d06  prefixlen 64  scopeid 0x20<link
        ether 00:15:5d:64:0d:06  txqueuelen 1000  (Ethernet)
```

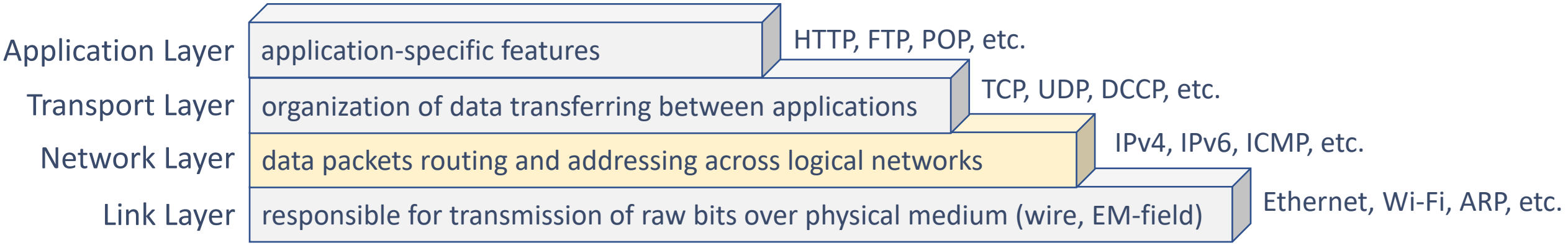
```
Ethernet adapter Ethernet:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Microsoft Hyper-V Network Adapter
   Physical Address. . . . . . . . . : 00-15-5D-64-0D-00
   DHCP Enabled. . . . . . . . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::d4c9:8757:da50:c914%3(Prefe
   IPv4 Address. . . . . . . . . . . : 192.168.42.99(Preferred)
```

Can be of different versions:
IPv4, IPv6;

Also used to route data between different networks.

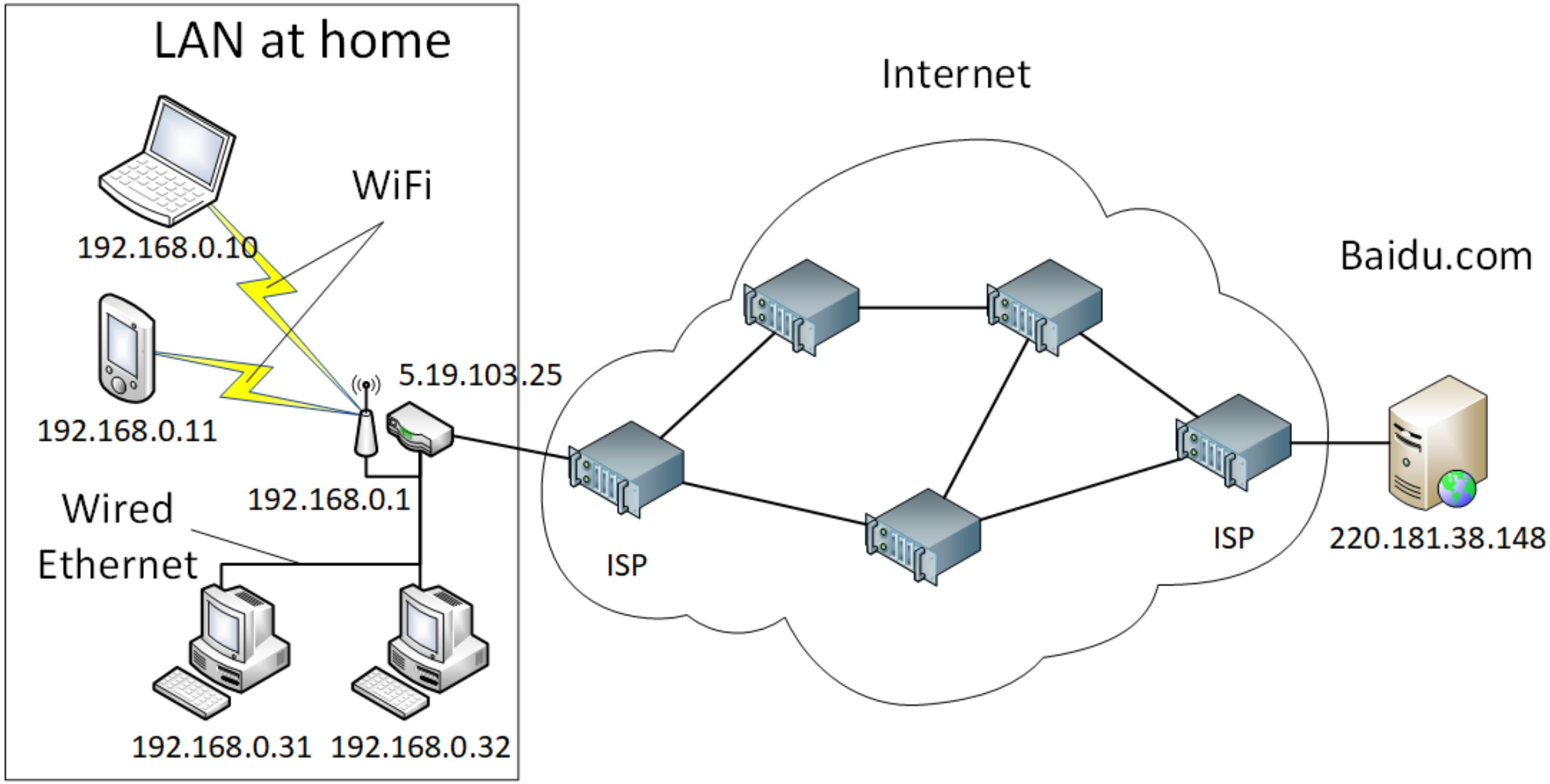
Addressing endpoints – IP versions



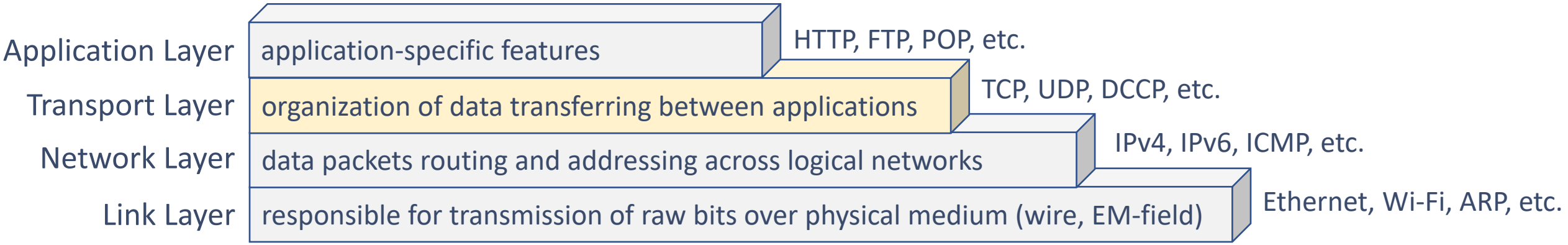
IP (internet protocol) address – identifier assigned to the logical network interface associated with a certain network hardware.

Protocol version	Address size	Amount of addresses	Kind	Examples
IPv4	4 bytes = 32 bits	2^{32}	Private, Public	192.168.21.10, 172.16.10.25, 5.19.208.160
IPv6	16 bytes = 128 bits	2^{128}	Uniform space	2001:0db8:11a3:09d7:1f34:8a2e:07a0:765d, 2001:0db8:0000:0000:0000:0000:ae21:ad12, 2001:db8::ae21:ad12

Network example



Addressing endpoints – TCP&UDP



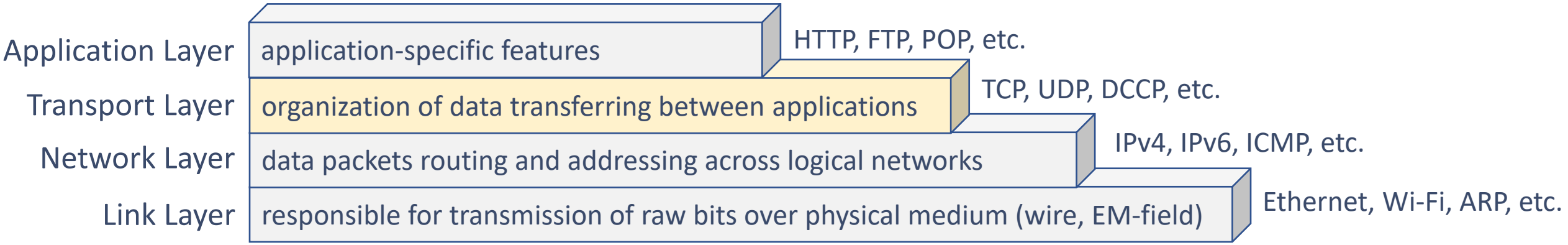
UDP (User Datagram Protocol) – operates by passing independent messages called datagrams between given endpoints without any control of delivery.

UDP endpoint consists of IP address and Port number (integer in range 0-65535):

192.168.0.24:12345 — DNS request datagram → 208.67.220.220:53

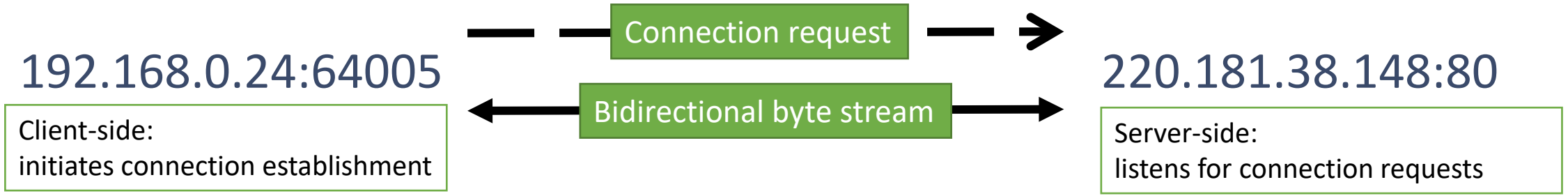
IP address identifies machine, Port number identifies application whishing to transfer some datagrams.

Addressing endpoints – TCP&UDP



TCP (Transmission Control Protocol) – operates by establishing logical connection between two endpoints and transferring stream of data between them.

TCP endpoint consists of IP address and Port number (integer in range 0-65535):



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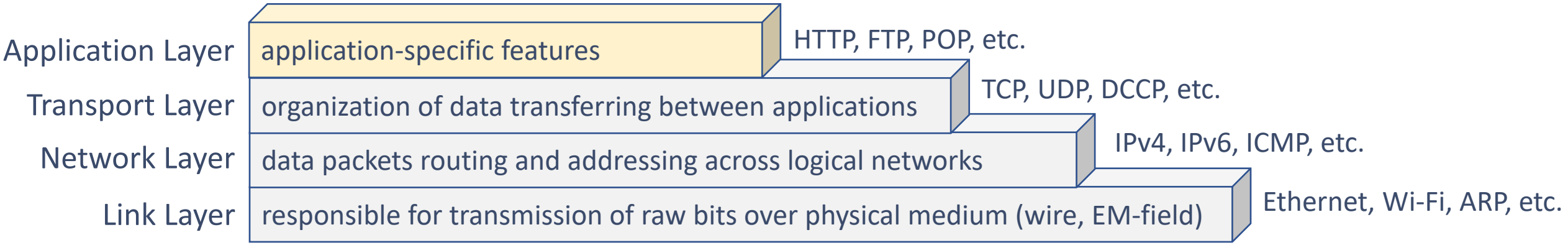
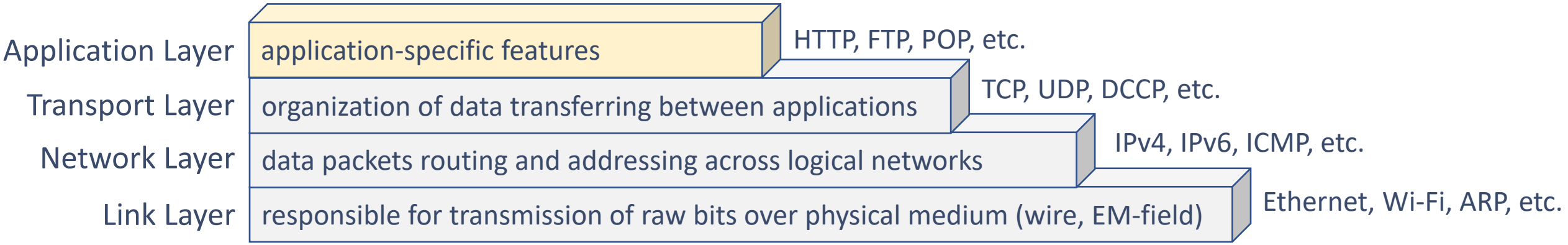
Addressing endpoints – Applications



Addresses in form of numbers
means nothing for an ordinary user.

Addressing endpoints – Hostname



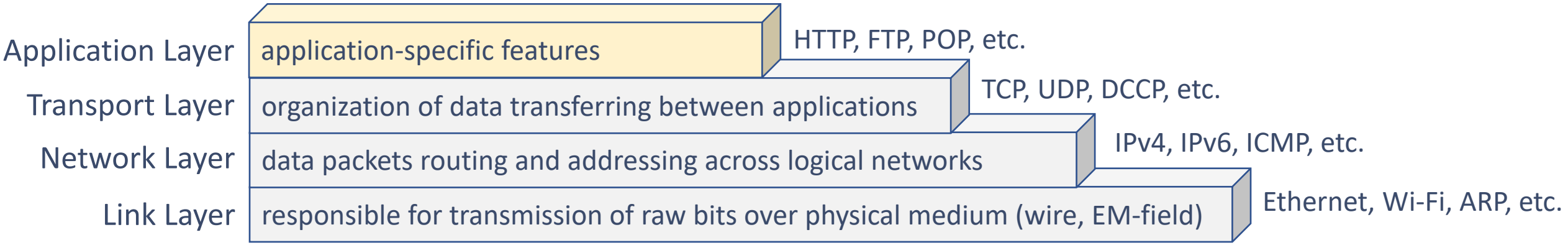
Hostname - is a label that is assigned to a device connected to the network:

www.baidu.com

en.qq.com

www.hznu.edu.cn

Addressing endpoints – DNS



Hostname - is a label that is assigned to a device connected to the network:

www.baidu.com → 103.235.46.39

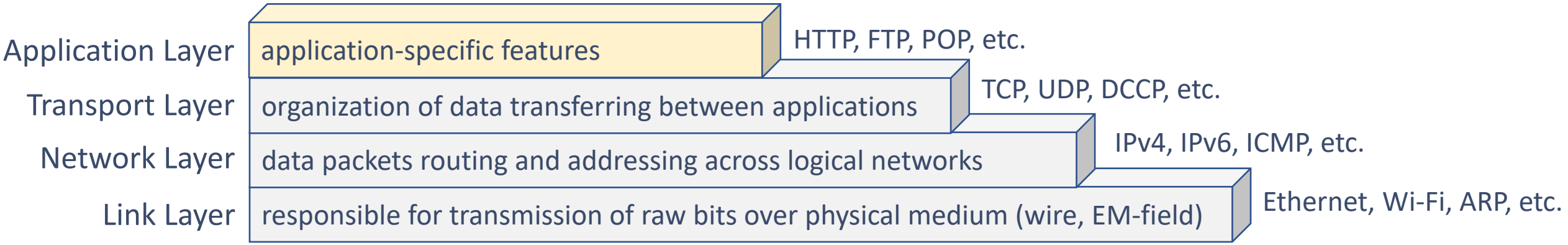
en.qq.com → 203.205.219.231

www.hznu.edu.cn → 124.160.116.201

DNS (Domain Name System) – is a distributed system on the internet solving the task of converting hostnames into IP addresses.

Also DNS – is a name of network protocol implemented over UDP and used by DNS services.

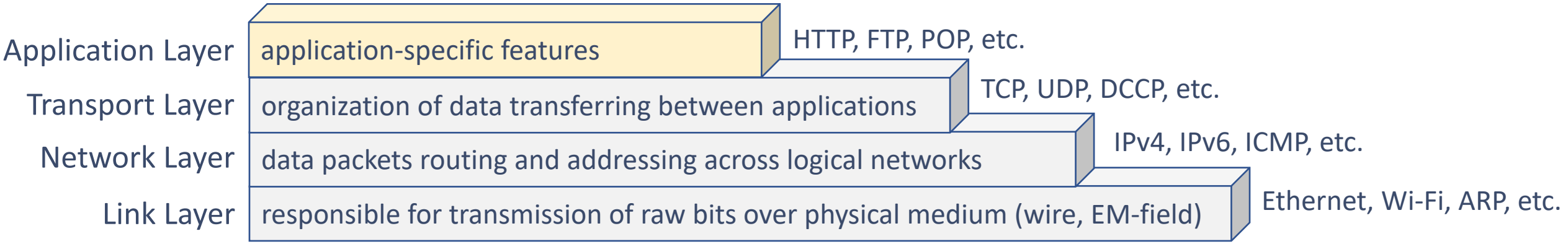
Addressing endpoints – HTTP



HTTP (HyperText Transfer Protocol) – TCP-based application layer protocol intended for different operations with Web-resources, such as:

- retrieve some resource (webpage, picture, music file, etc),
- send some data from the user to the webserver to generate dynamic webpage,
- put some information on the webserver to store (photo in the social network).

Addressing endpoints – URI&URL



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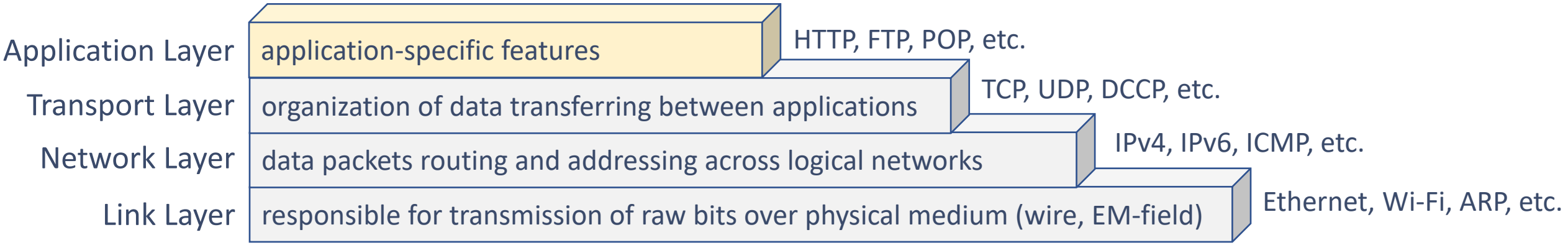
- retrieve some resource (webpage, picture, music file, etc),
- send some data from the user to the webserver to generate dynamic webpage,
- put some information on the webserver to store (photo in the social network).

Web-resource identified by URI – Uniform Resource Identifier – a string of special format.

Web-resource can be located by URL – Uniform Resource Locator – particular case of URI:

<schema>://[//[<login>[:<pwd>]@]<hostname>[:<port>]][/<path>][?<query>][#<anchor>]

Addressing endpoints – URL pattern



Web-resource can be located by URL – Uniform Resource Locator:

<schema>:[//[<login>[:<password>]@]<hostname>[:<port>]][/<path>][?<query>][#<anchor>]

Examples:

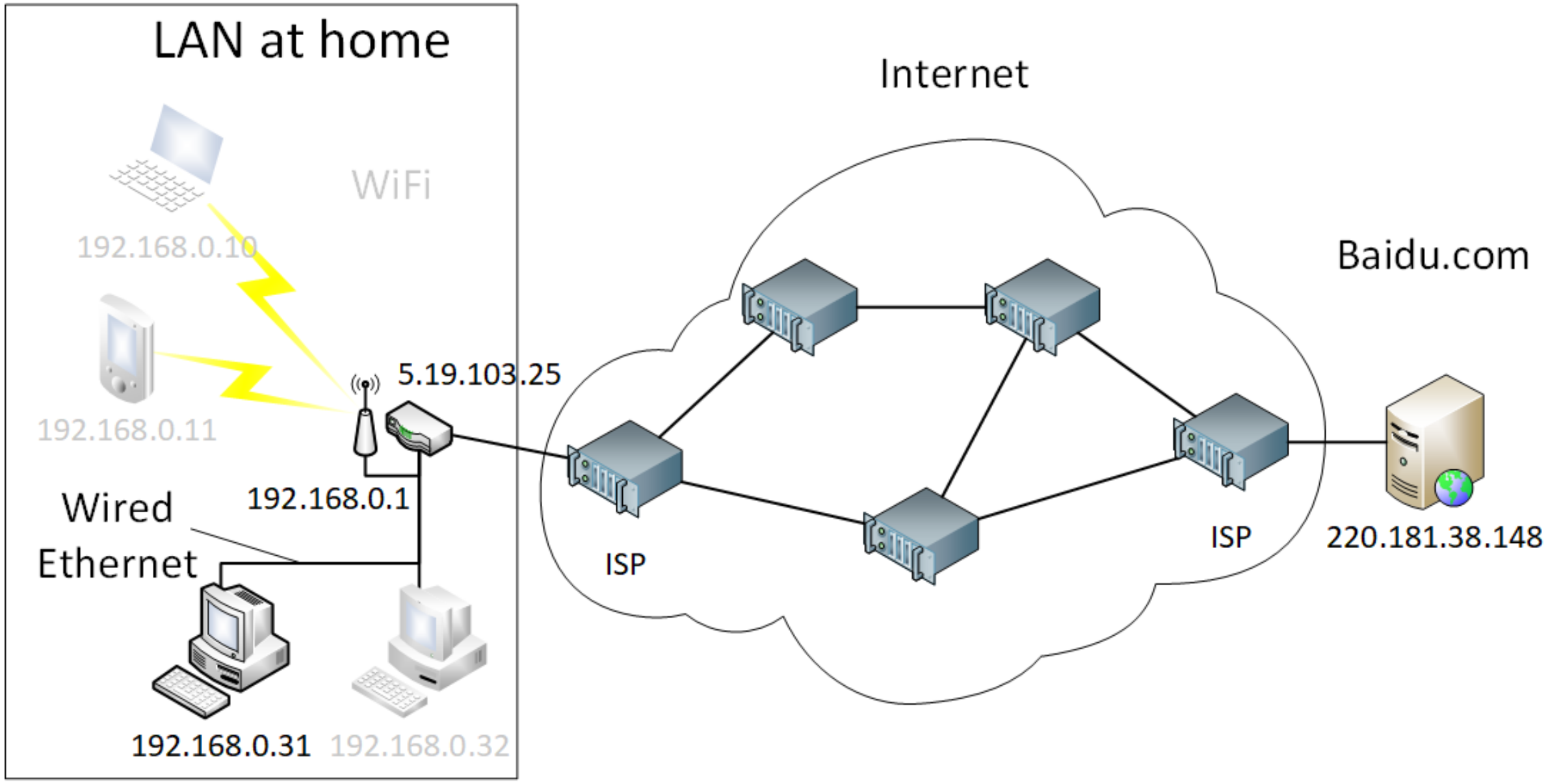
https://english.hznu.edu.cn/

http://www.baidu.com/s?ie=utf-8&wd=php

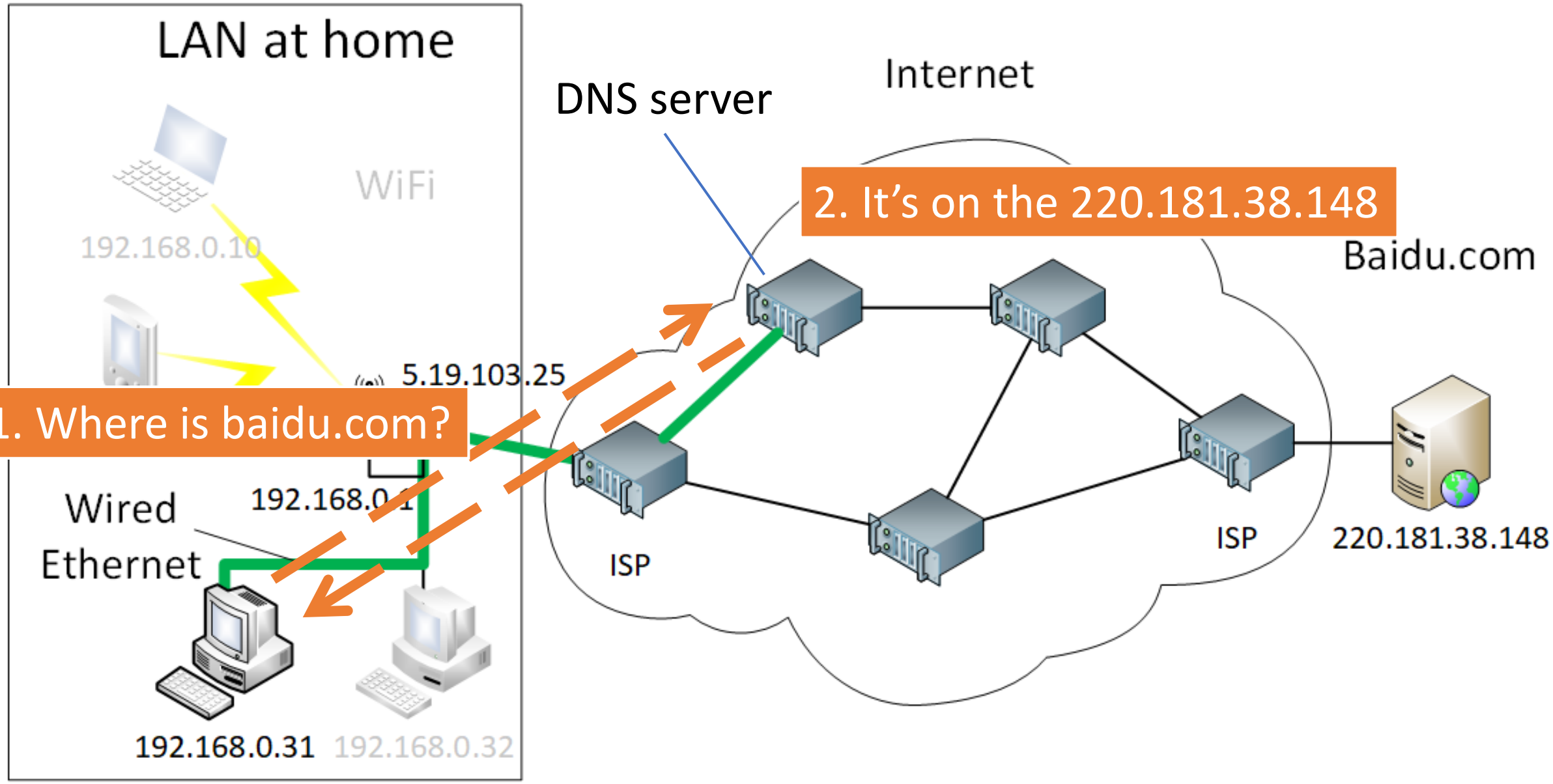
https://en.wikipedia.org/wiki/Hypertext_Transfer_Protocol#Example_session

HTTP protocol uses port 80 if not specified.

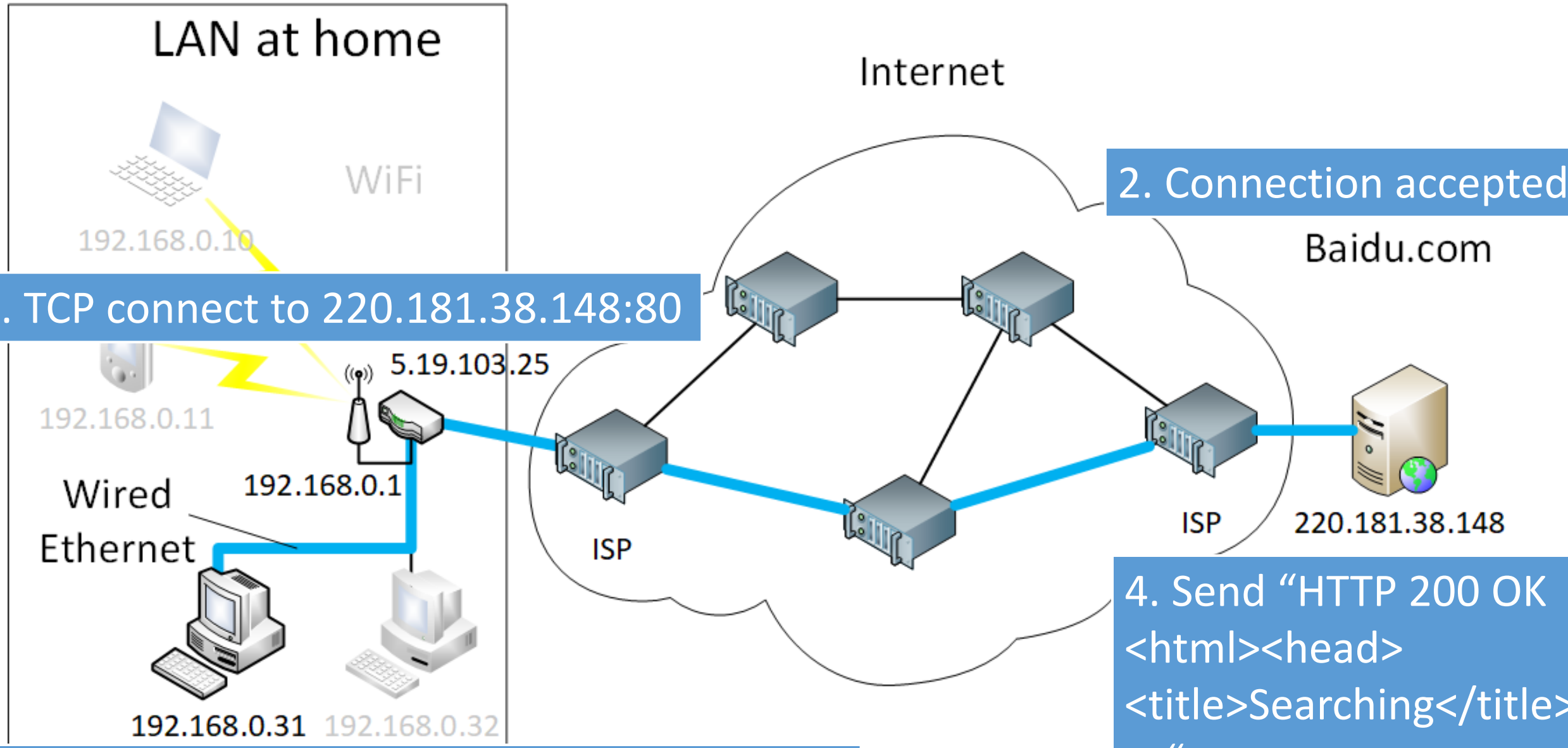
Network example – Connection



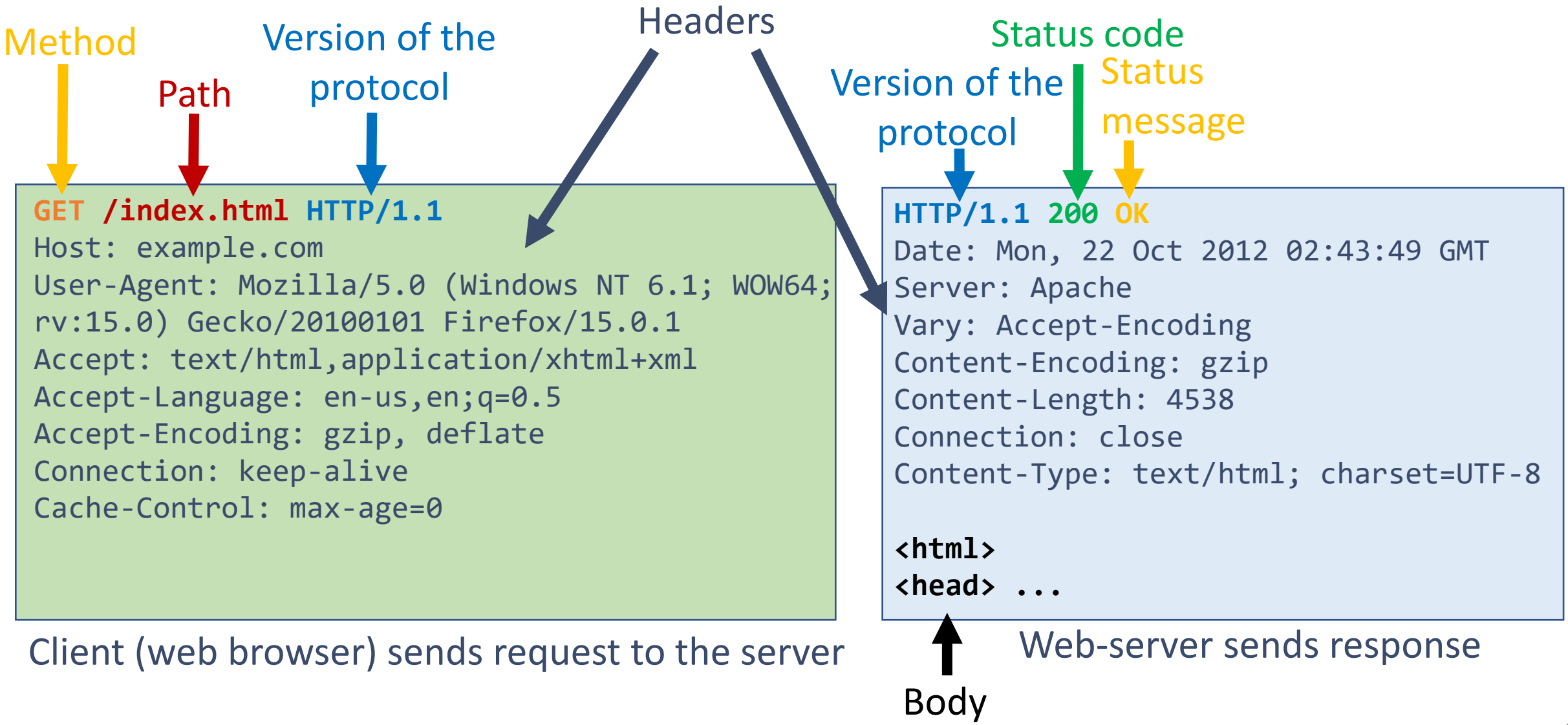
Network example – Connection – DNS



Network example – Connection – HTTP



HTTP – Request-response example



HTTP – Request methods

- ✓ GET – retrieve and request data from a specified resource
- ✓ POST – send data to a server to create or update a resource
- ✓ HEAD – similar to GET, but doesn't have a message-body
- ✓ PUT – updating resource
- ✓ DELETE – delete resources indicated by a specific URL
- ✓ PATCH – apply partial modifications to the resource
- ✓ TRACE – echoes the received request so that a client can see what changes or additions have been made by intermediate servers.
- ✓ CONNECT – establish a "tunnel" to the server defined by the resource
- ✓ OPTIONS – describe parameters for connecting to a resource

HTTP – Response status

Response codes:

- ✓ Informational 1XX
- ✓ Successful 2XX
- ✓ Redirection 3XX
- ✓ Client Error 4XX
- ✓ Server Error 5XX

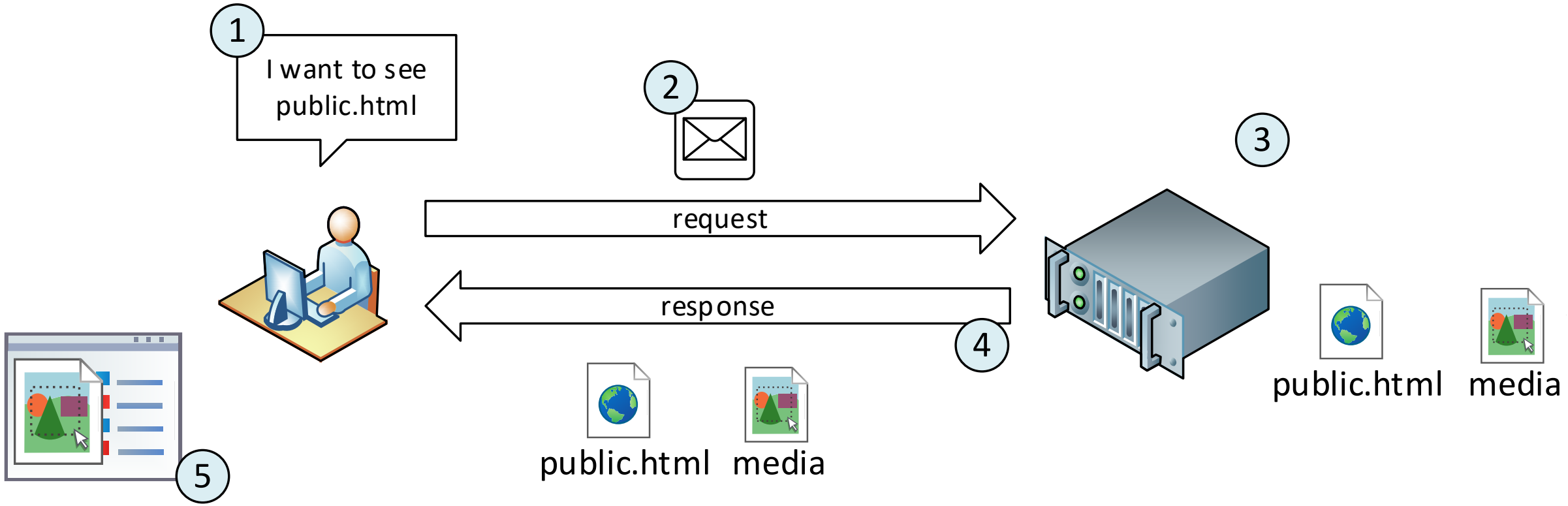
Examples:

200 OK – the request was successful

400 Bad Request - something about the headers or HTTP request in general is not correctly adhering to HTTP protocol

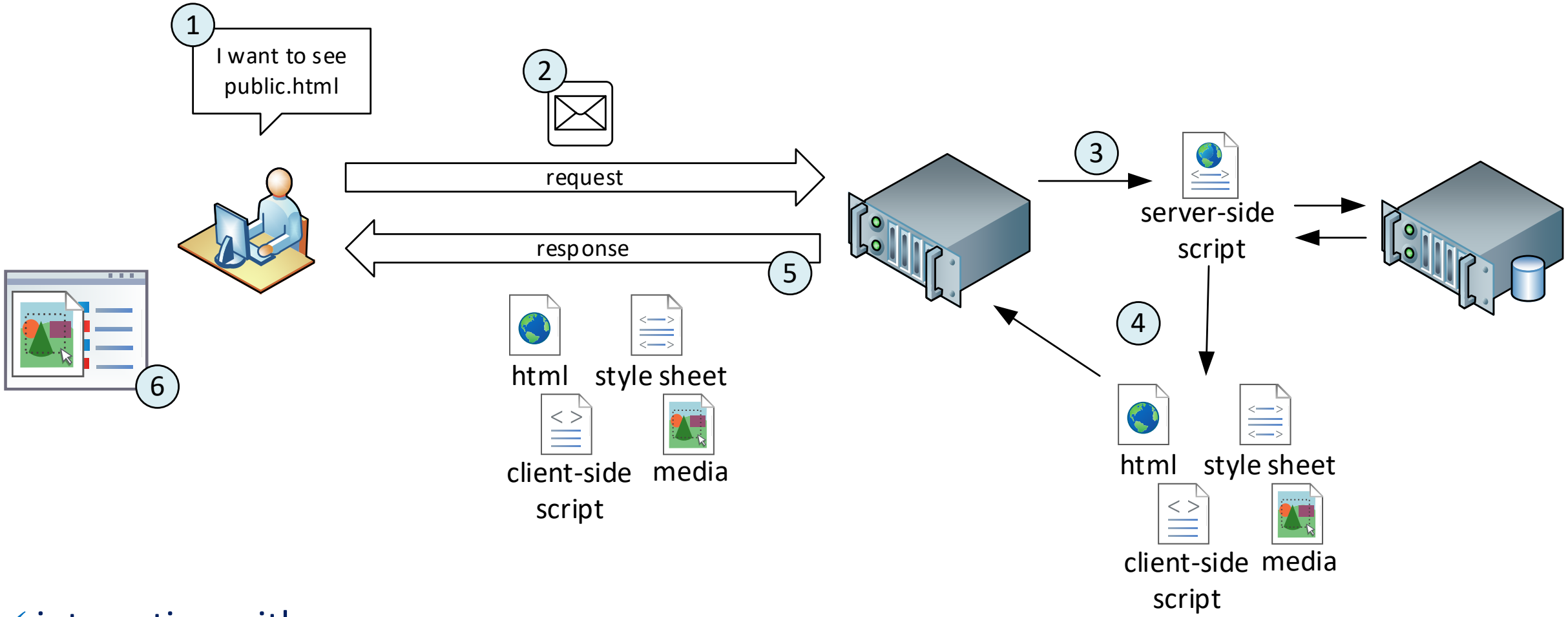
500 Internal server error - say the server has encountered an error

Static web site



- ✓ no interaction
- ✓ fixed content
- ✓ delivered to user on request exactly as stored

Dynamic web site

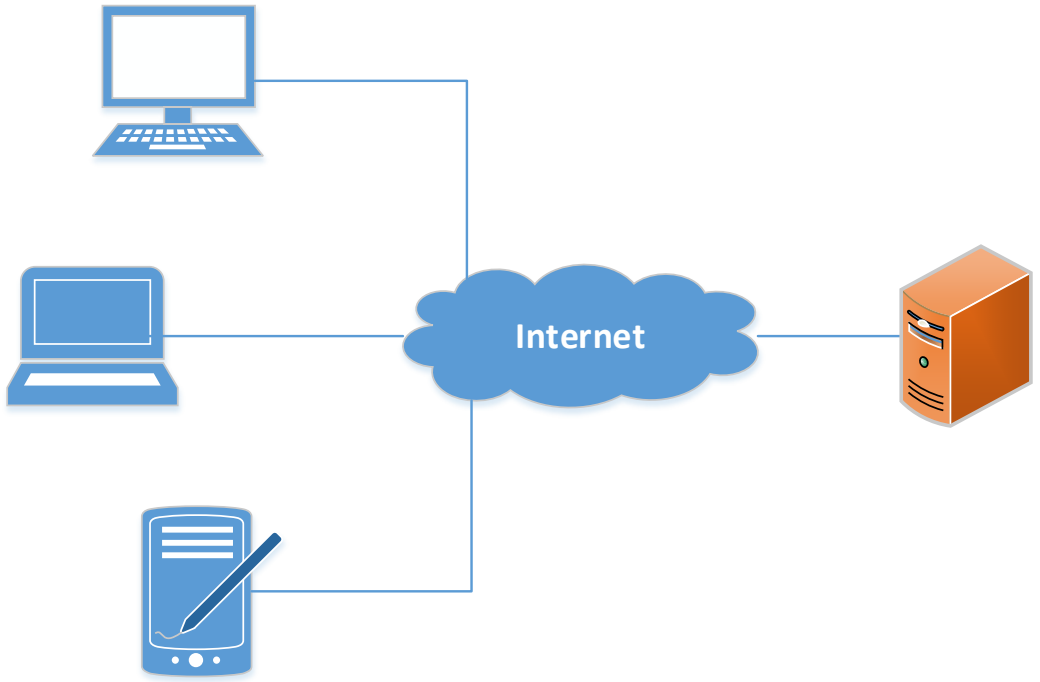


- ✓ interaction with user
- ✓ easier to update
- ✓ computations on server

Client-Server Model

Client:

make requests to particular servers for particular resources using URLs and then wait for the response



Server:

listening for requests, and upon getting one, responds with a message

Communication middleware:
aid the transmission of data and control information between clients and servers

Summary

Data exchange **protocol** - is a formal set of rules, describing organization of data flow between data exchange participants.

TCP/IP suite – set of communication protocols, consists of 4 layers:

1. *Link layer* – transmission of raw bits over physical medium (Ethernet, Wi-Fi): **MAC address**
2. *Network layer* – data routing and addressing across logical networks: **IP address**
3. *Transport layer* – data transferring between applications (UDP, TCP): IP address + **port**
4. *Application layer* – application-specific protocols (DNS, FTP, HTTP, POP3, …)

Hostname - is a label assigned to a device connected to the network.

HTTP – TCP-based protocol operating with Web-resources (GET, PUT, POST, etc)

Web-resource can be located by **URL.**

HTTP interaction organized into **requests** to do something and **responses** carrying results.