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ISO/OSI protocol stack

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Introduction and Fundamentals
Basic and terminology of terrestrial networks

ISO/OSI MODEL

Body and soul of a tlc network

- The Bones of a TLC network are
  - ✓ **Terminal Devices**
    - E.g., PC, phones, screens, speakers, mics, storing unit…
  - ✓ **Switching unit**
    - Routers for data networks
    - Switches for telephone networks
  - ✓ **Links**
    - Fibre optic, copper, twisted pairs, radio, …
- The "soul" of a TLC net are
  - ✓ Communication rules
    - **Protocols and interfaces**

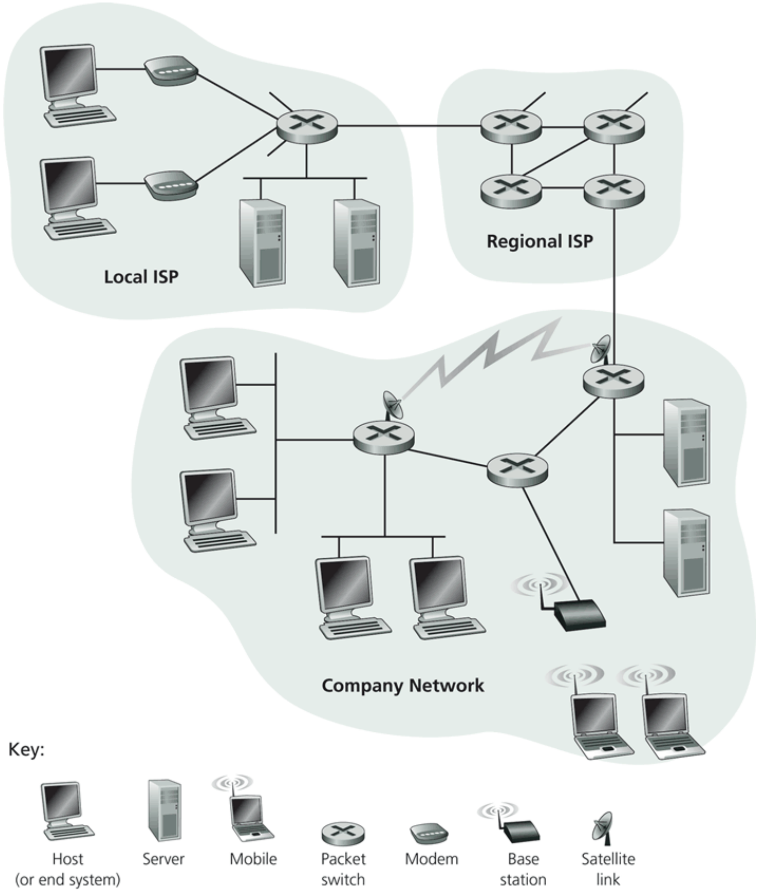
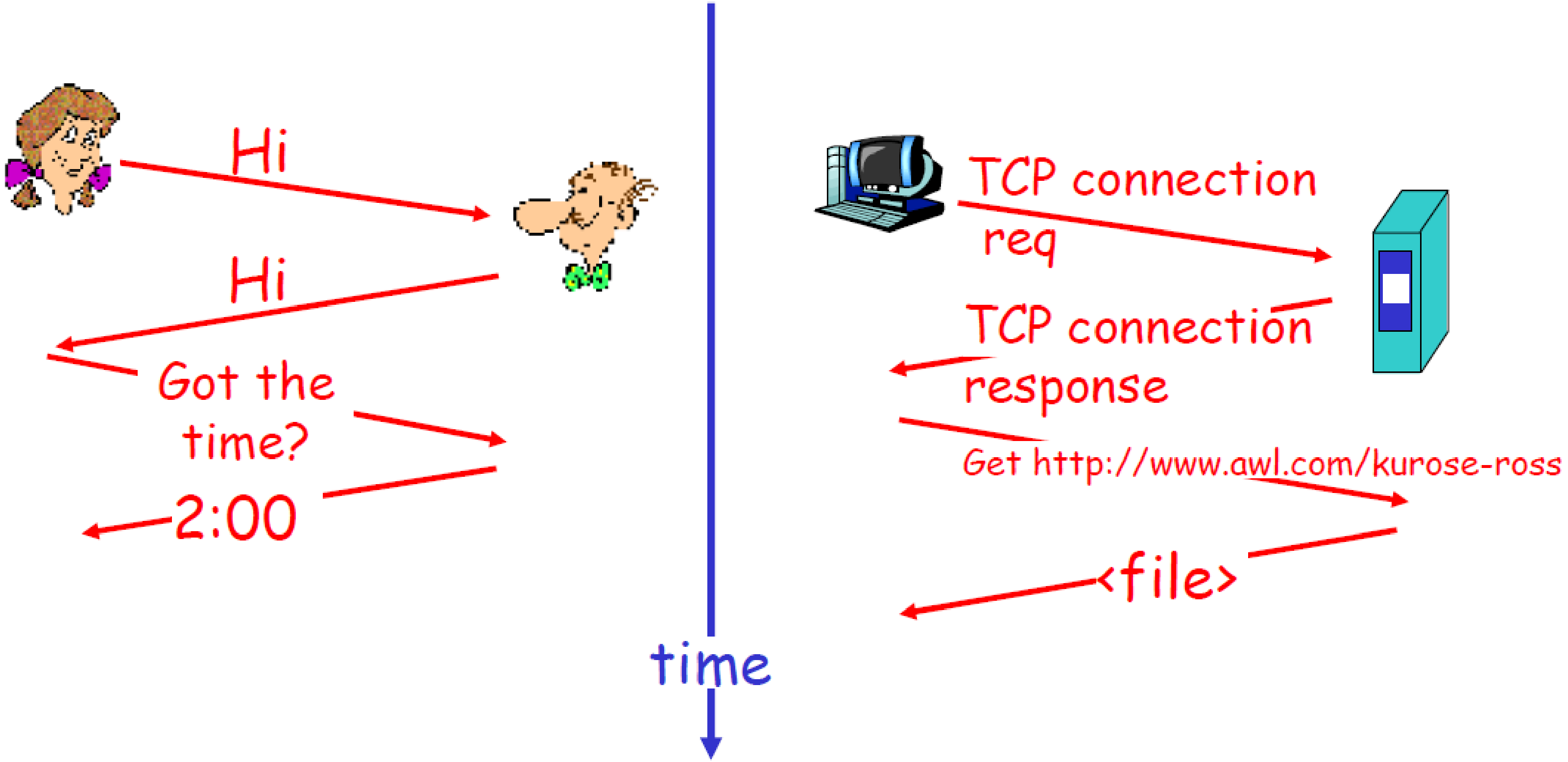


Figure 1.1 ♦ Some pieces of the Internet

Protocol

a human protocol and a computer network protocol:



Protocol

- A protocol is a **series of steps**, involving two or more parties, designed to accomplish a task
- Everyone in the network must know the protocol and agree to follow it
- The protocol must be **unambiguous** (no chance of a misunderstanding)
- The protocol must be **complete** (specified action for each situation)

Protocol Model

Address:
- how to name a partner

Format:
- specify the message formats

Rules:
- specify the behaviors of the protocol
- what should be done when something happens

Can a single protocol do it all?

Computer communications deal with all sorts of problems…

- Electrical/optical signals/noise
- Error detection & recovery
- Medium Access Control (MAC)
- Message boundary
- Routing, fragmentation
- Flow control (network congestion)
- Loss and duplicated messages
- Synchronization
- Representation (information sources)
- Application specific constraints / QoS requirements

Yes, it can be done but …

- Development cost, complexity, energy, delay, etc.

Layered Approach

Divide and conquer

- Partition into multiple **layers** of software
- Each layer has clear programming interfaces
- Each layer solves a limited set of problems
  - Each layer provides a service to adjacent layers (one for error control, one for medium access control, one for flow control, one for synchronization, etc.)
- Each layer **encapsulates** the related details (so that other layers simply do not have to care about what that layer is in charge of)

Pros

- Reduce complexity, isolate changes, promote manageability
- Each layer is in charge for a class of functionalities, no confusion
- Allows for **encapsulation** *(protocol messages in upper layers is data to layer below)*

Cons

- Efficiency, but still…

ISO/OSI Model (late '70s)

ISO – International Organization for Standardization

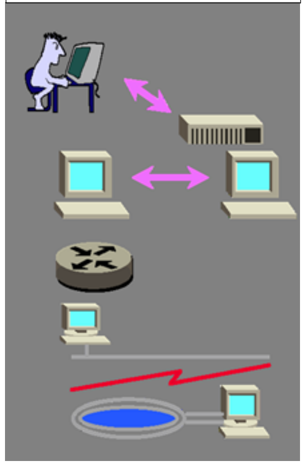
- International body dedicated to worldwide agreement on standards

OSI - Open System Interconnection

- Seven layers altogether
- Each layer performs a unique function and has its own protocol

Layer Name	Description	Examples
Application	User Level Processing	Telnet, FTP, Mail
Presentation	Data Representation & Syntax	ISO Presentation
Session	Sync Points and Dialogs	ISO Session
Transport	Reliable End to End	TCP
Network	Unreliable Thru Multi-Node Network	X.25 Pkt, IP
Link	Reliable Across Physical Line	LAPB, HDLC
Physical	Unreliable Wire, Telco Line	RS232, T1, 802.x

Graphical



Interfaces vs Protocols

Interface: vertical communication

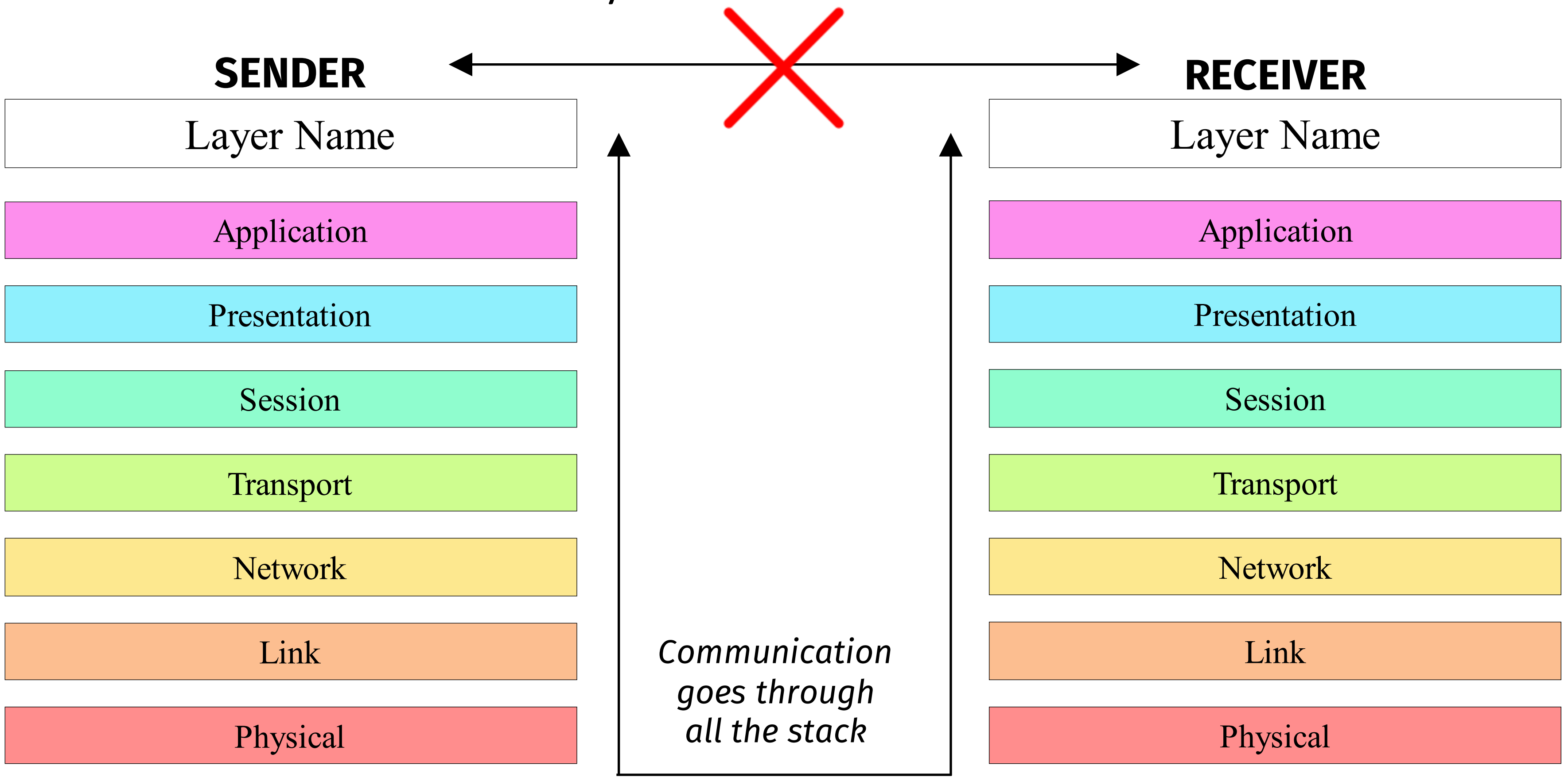
- defines the format and the meaning of the command primitives that can be exchanged between the entities of adjacent layers in the same device
- Protocol Data Unit (PDU) of upper layer is the Service Data Unit (SDU) of lower layer

Protocol: horizontal communication

- Defines the format and the meaning of the language talked by peer entities (i.e., entity of the same layer) of different devices

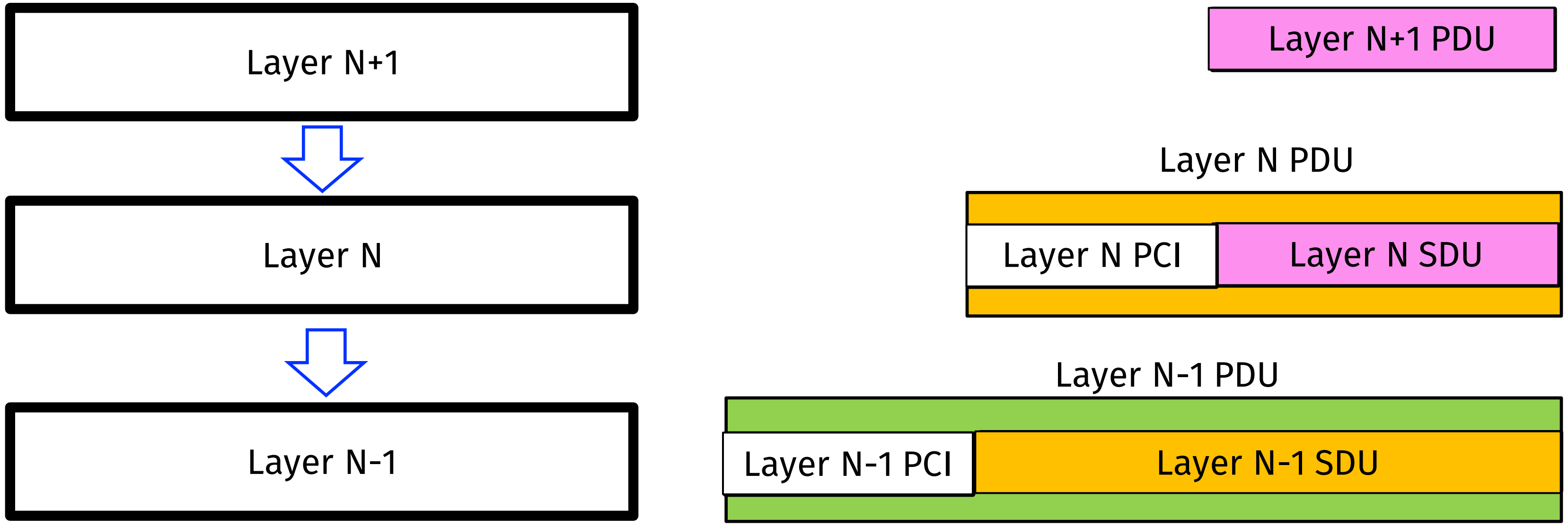
Layered Approach — Terminology

- Each layer-(N-1) entity provides a service to the layer-(N) entity
- Dialogue only between two entities of same layer



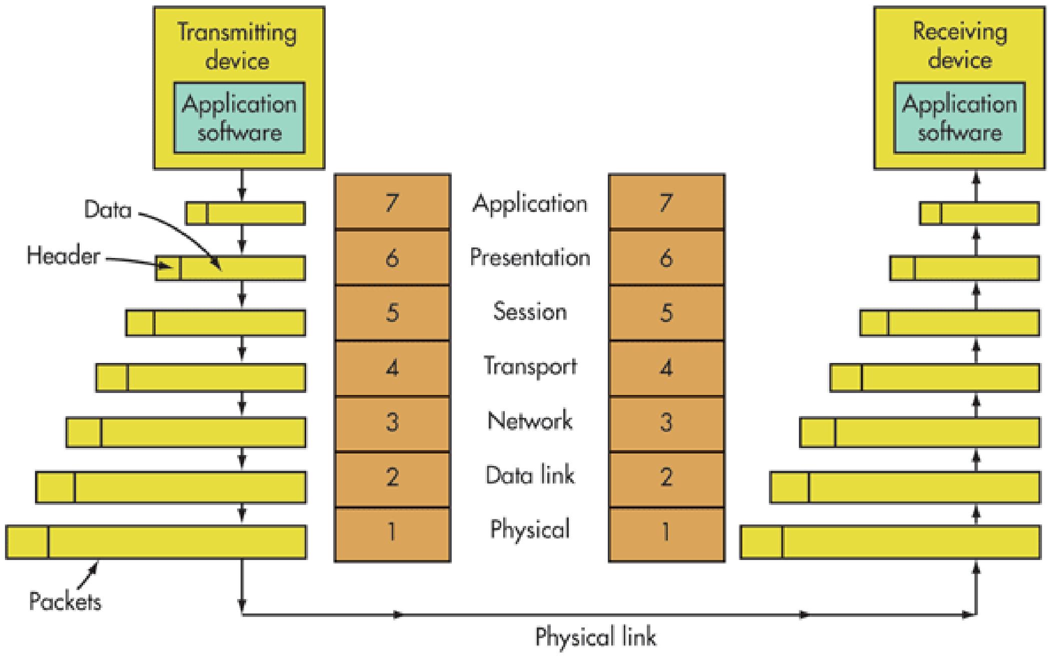
Layered Approach — Terminology

- Dialogue only between two entities of same layer (**peer entities**) via **Protocol Data Units** (PDUs)
- The PDU of a layer is called **Service Data Unit (SDU)** at the lower layers
- Underlying layers add their own **Protocol Control Information (PCI)** ***(header)***, which is necessary to implement their own communication protocol and make the new PDU, which is then transmitted to the lower layer or to the next-hop PHY later entity



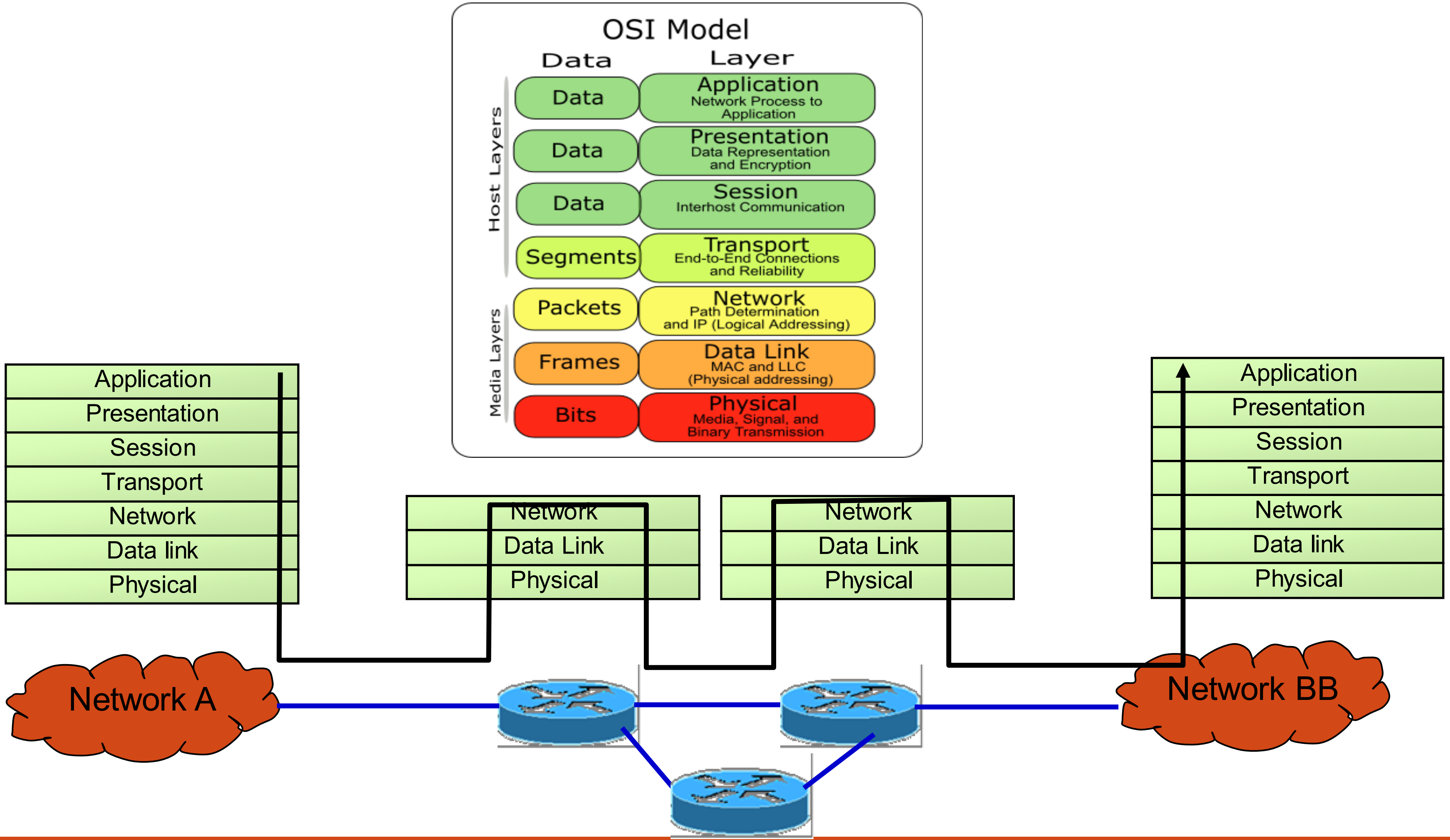
Layered Approach – Encapsulation

Encapsulation: packing of upper-later data and its own control data – occurs at the source



Decapsulation: separation of upper-later data from its own control data – occurs at the destination

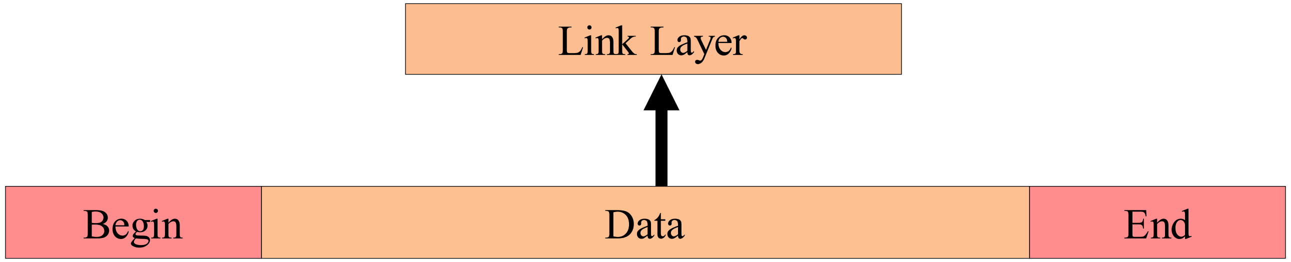
Protocols across network elements



Physical (PHY) Layer

Physical layer: Responsible for actual delivery of data over physical medium (channel)

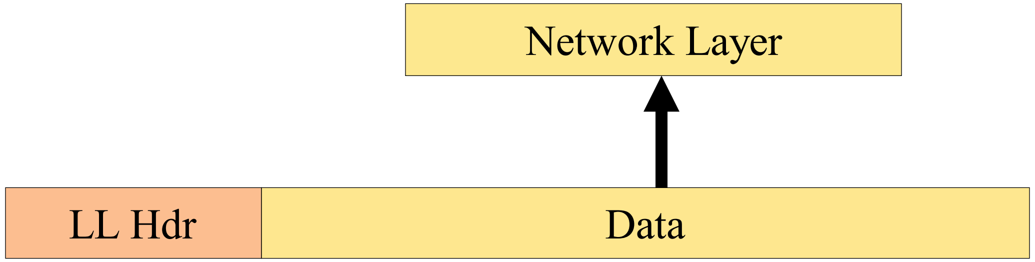
- The PHY takes the 1’s and 0’s coming from the **link layer** (above of it) and turns them into *some kind of signal* that can go over the physical layer (electrical current, light pulses, etc.) It also takes this signal and turns it back into 1’s and 0’s to pass up the stack on the receiving end
- Typical problems: wavaforms shape and duration to represent bits, hardware characteristics, synchronization etc
- Message has beginning (header) and end (tail)
- Data in between passed up to link layer



(Data) Link Layer

<u>Link layer:</u> Responsible for the delivery of a packet from one node to physically adjacent node over a link

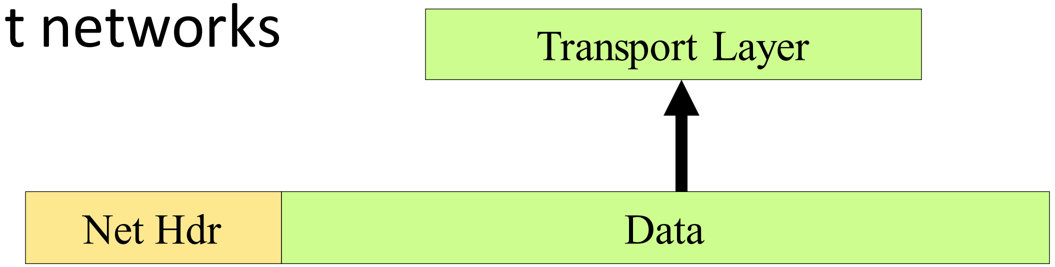
- It is limited to **local** link (single hop)
- It is divided into <u>two sublayers</u>
  - **Medium Access Control (MAC) →** manages presence of multiple users on the same transmission medium (to avoid collisions)
  - **Logical Link Control (LLC) →** performs *flow* and *error* control on a local basis
    Flow control: adapt sender and receiver speeds; Error control: avoid sending erroneous data to the next layer



Network Layer

Network layer: Responsible for the host-to-host routing and delivery (forwarding) of datagrams

- **Routing** means finding the most desirable path for the data to follow
  - Can be fixed or dynamic
- Move data across multi-node network (multi-hop)
- Whereas the link layer is concerned with local communication exchanges, the network layer has a **global** view
- No error recovery – data can be lost (unreliable)
- It can perform flow control, is in charge of QoS (delay, jitter, etc.)
- Must deal with different networks



Addressing at the network layer

Network layer offers global exchange → Network packets **can be routed** (they pass from one local network to another)

- *Data layer packets can't be routed, they're local only. Your computer can only get data layer packets on its data layer interface*

To achieve **routing**, the network layer is responsible for **host addressing** in a unique manner → **IP** addresses(*)

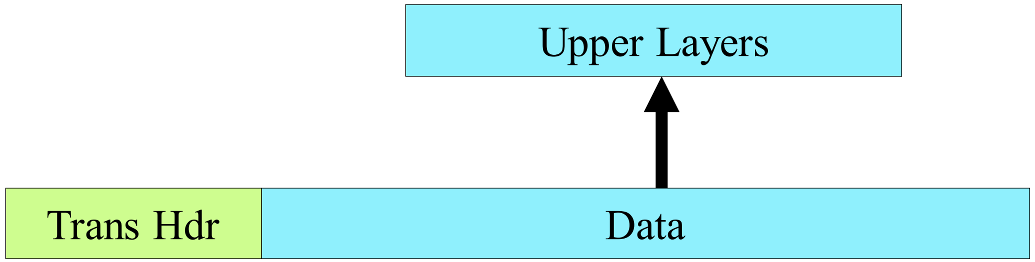
- Are *unique* (each address defines only one connection to the Internet)
- Are *universal* (are accepted by any host connecting to the Internet)

IP ADDRESS: 131.175.21.1

(*) **Not to be confused with MAC addresses,** used to identify devices, NOT connections

Transport Layer: Responsible for creating a one-to-one transparent virtual pipe between two ends of the communication flow

- It does not care about the actual topology: it offers flow control mechanisms as though **only two entities** existed in the network
- It can offer reliability and try to achieve **error-free communication**
  - Services include error control, retransmissions (if packet is corrupted), and flow control (prevents transport layer from sending information faster than the rate at which the receiver can handle)



Upper Layers

Session Layer

- Managing communication sessions, i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes

Presentation Layer

- Translation of data between a networking service and an application; e.g., character encoding, data compression and encryption / decryption

Application Layer

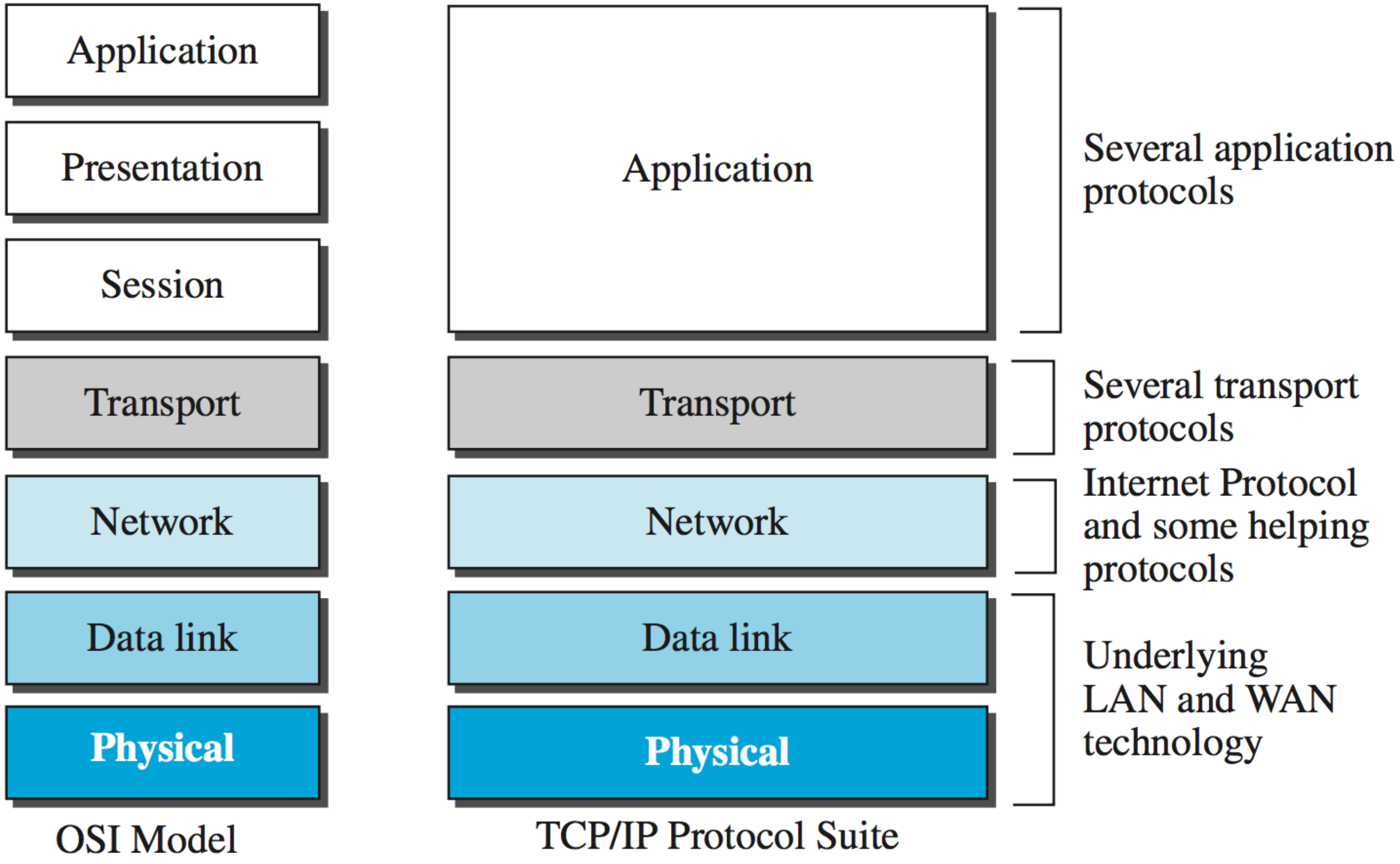
- High-level APIs / application functionalities

The complete picture: TX through encapsulation

(Application, presentation & session omitted)

PHY PCI	Link PCI	Network PCI	Transport PCI	Data generated at the application

ISO/OSI stack *vs* TCP/IP stack



ISO/OSI: theoretical
TCP/IP: description of the existing

ISO/OSI: L3 offers CO and CL services, L4 only CO. This is bad because L4 is what is seen by users
TCP/IP: IP is CL, but L4 has 2 protocols, TCP offering a CO service, and UDP offering a CL service

TCP/IP hasn't the rarely used L5 and L6: their functionalities are left to applications

OSI: good for model description
TC/IP: effective protocols

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PERFORMANCE METRICS

Throughput

DEF: throughput = total quantity of data, in bits per second, correctly transferred through the network (i.e., correctly received at destination)

- Normalized throughput = number of packets received per timeslot

- Network throughput = total throughput of the whole network

- Throughput per node (or average throughput) = number of bits per second each node can correctly transmit to the final destination

- Goodput = total data transferred through the network minus the overhead data

NOTE: in literature many uses throughput to refer to the goodput. This is not a problem as soon as the metrics is univocally defined in the paper

Packet Delivery Ratio (PDR) and Packet Error Rate (PER)

DEF: PDR = #received_packets/#transmitted packets

- PDR can be observed at different layers

- In general, PDR at upper layers > PDR at lower layers (retransmissiom occurs)

E.g., PDR at MAC > PDR at APP (unless APP drops out of order)

- Packer Error Rate (PER) = 1-PDR

NOTE: in your work always tell where you are observing the PDR (application, MAC, etc.)

Packet Delivery Delay (PDD) and Propagation Time

DEF: PDD = time spent from the packet from its generation to reach the final destination = reception_time – generation_time

- PDD depends by many factors: number of hops, bitrate of the modem, propagation delay, collisions and retransmissions, network load, queuing time, MAC protocol, etc.

- PDD of a single hop network = Qt + Tpkt + prop_delay

- Qt = queuing time due to network congestion and the MAC protocol used

- Tpkt = #bits/bitrate

- prop_delay = distanceTxRx/media_spead

- media_spead = speed of sound if acoustic, light if optical or EM/MI

Age of Information (AoI)

- Age of Information (AoI): metrics to assess the freshness of data from the receiver perspective. It is equal to the age of the last correctly peace of information received (current_time – generation time). Do not confound it with PDD, as it AoI keeps increasing until the next update is received.

  - Very relevant to vehicular monitoring systems