ECS404U: Computer Systems & Networks

Introduction to Computer Networks

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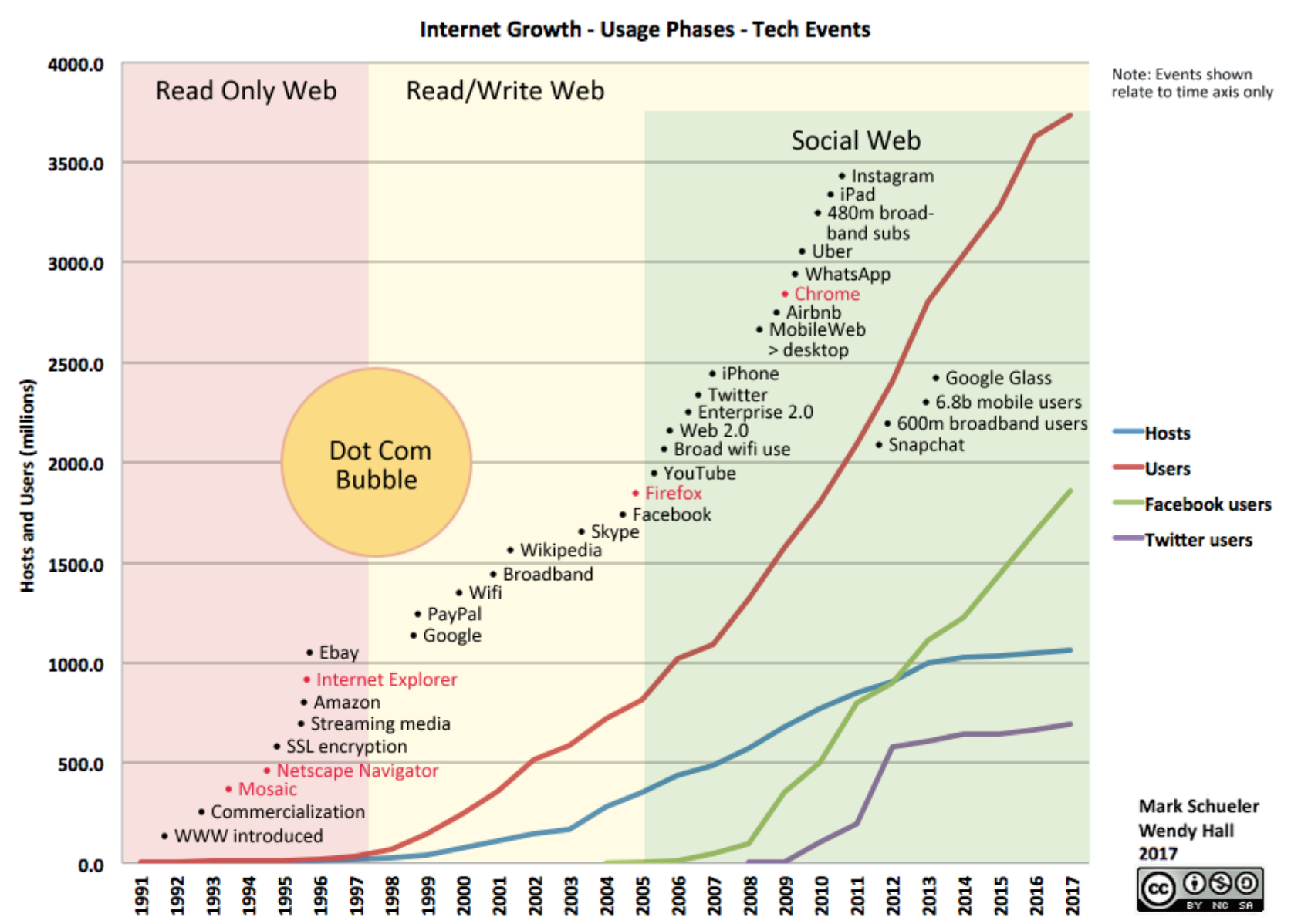
EECS, QMUL

Learning Objectives

- The concept of the Layered network model
- The 5-layer model of TCP/IP:
  - Application Layer (HTTP, FTP, SMTP, IMAP)
  - Transport Layer (TCP, UDP)
  - Internet Layer (IP)
  - Data Link Layer (Ethernet)
  - Physical layer (Ethernet Cables, Optical Fibre, Wireless Channel)
- What are the essential roles of each layer, and hence their corresponding “headers”
- The process of encapsulation/decapsulation

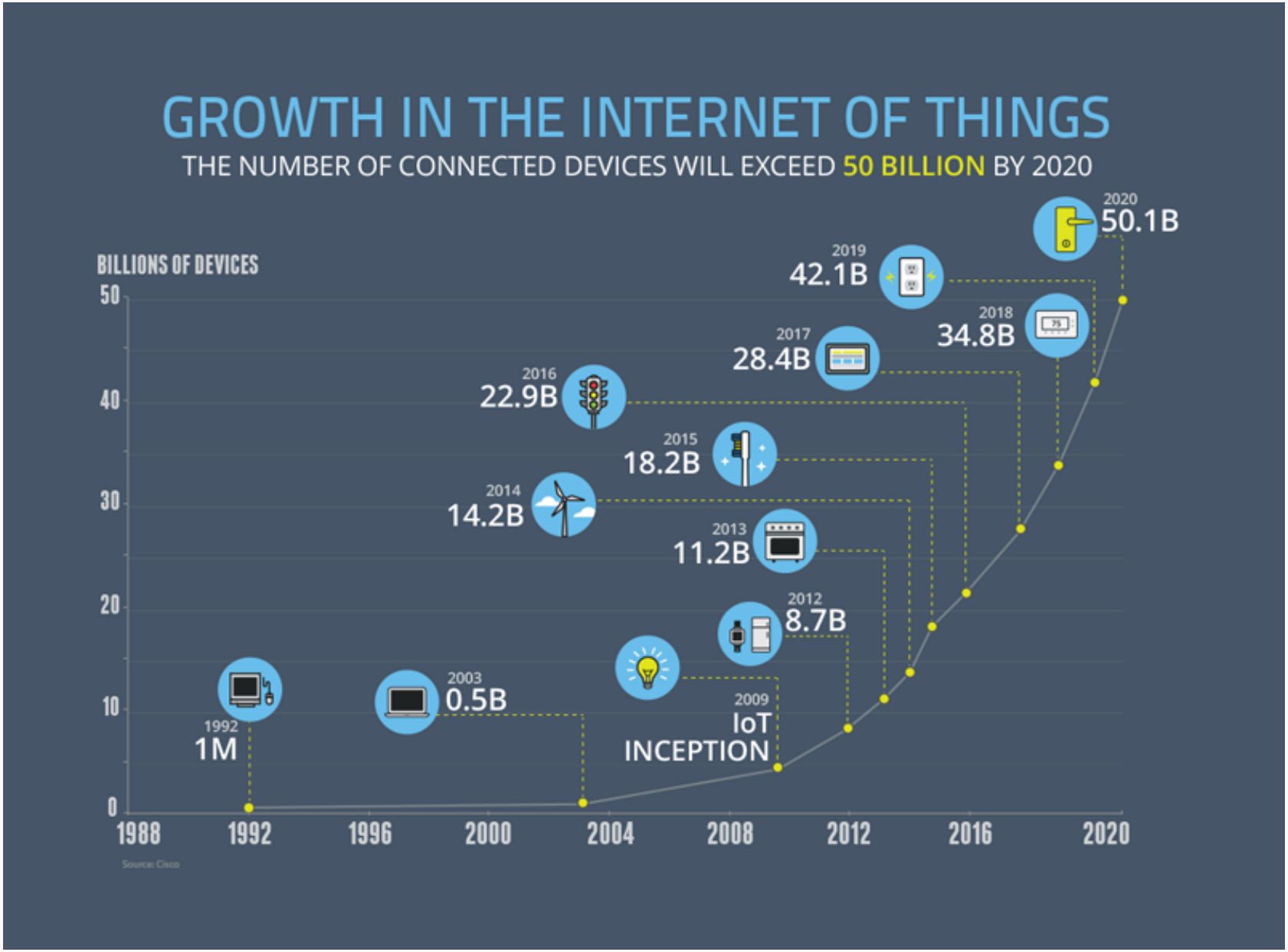
Motivation



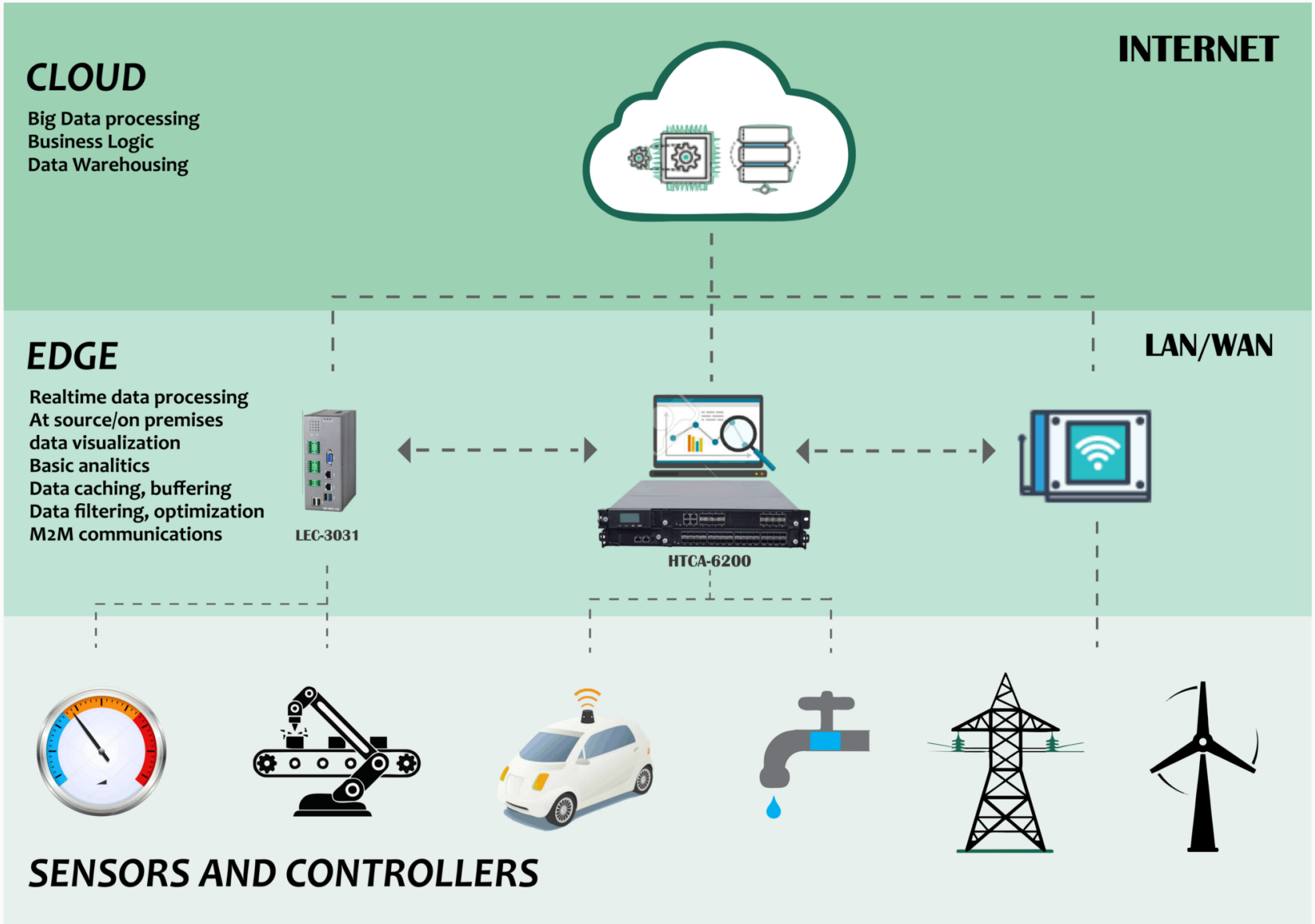
http://growthchart.weebly.com/

https://www.smartinsights.com/internet-marketing-statistics/happens-online-60-seconds/

Cloud Computing



https://www.ncta.com/whats-new/behind-the-numbers-growth-in-the-internet-of-things-2

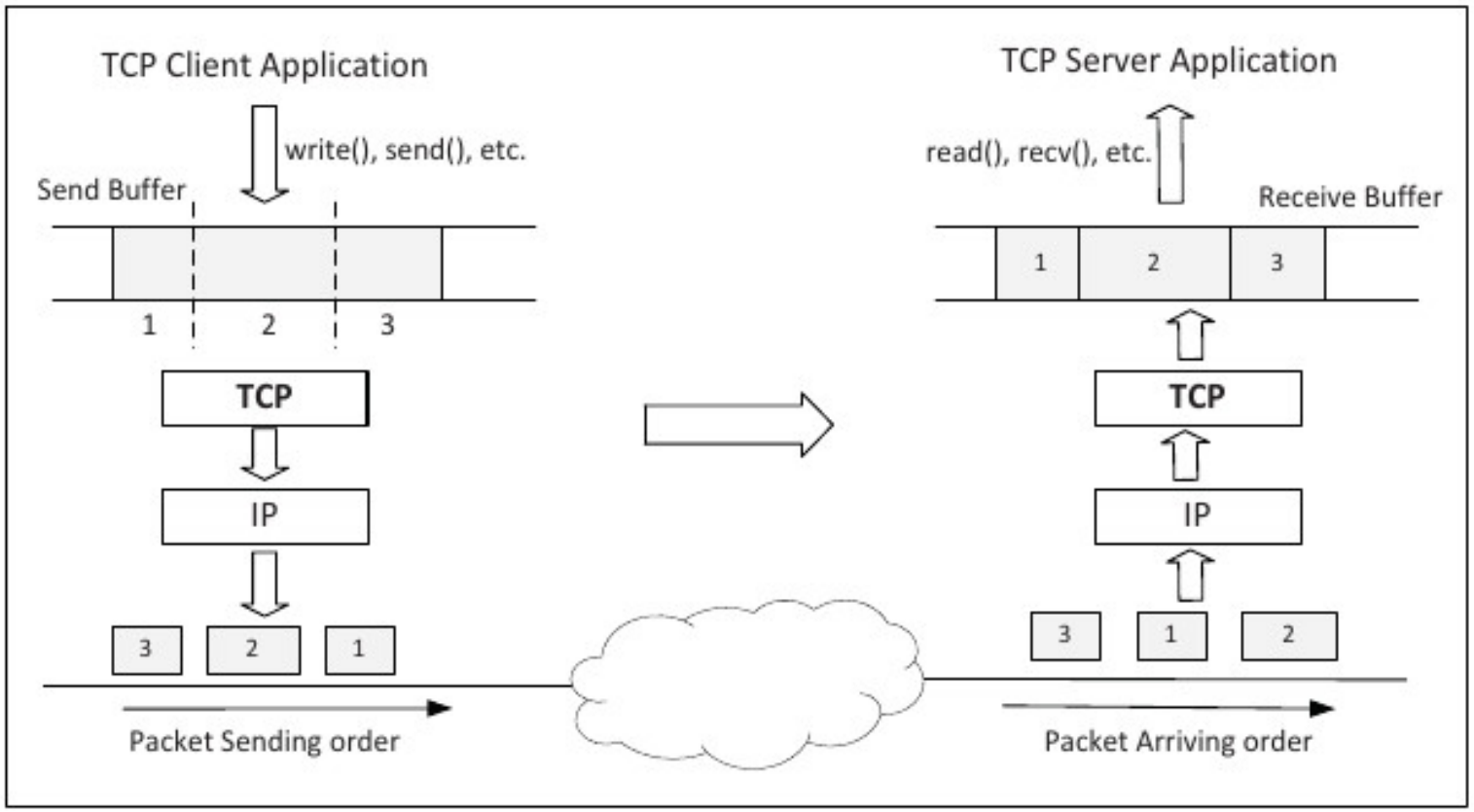


https://www.lanner-america.com/blog/4-edge-computing-technologies-enabling-iot-ready-network-infrastructure/

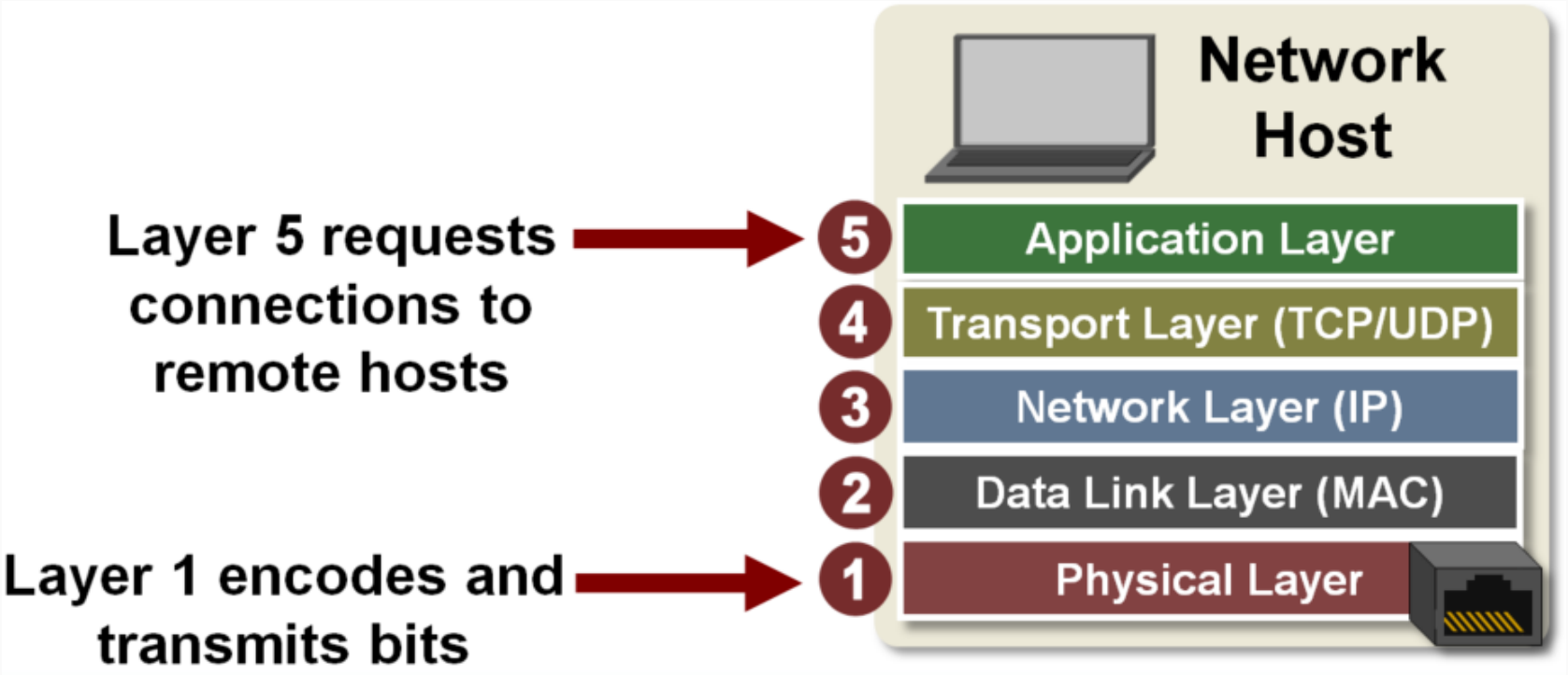
Introduction to TCP/IP

TCP/IP

- TCP/IP collection of communication protocols, originally developed as part of ARPANET in 1980s.



Networking Layers



Ref: http://microchipdeveloper.com/tcpip:tcp-ip-five-layer-model

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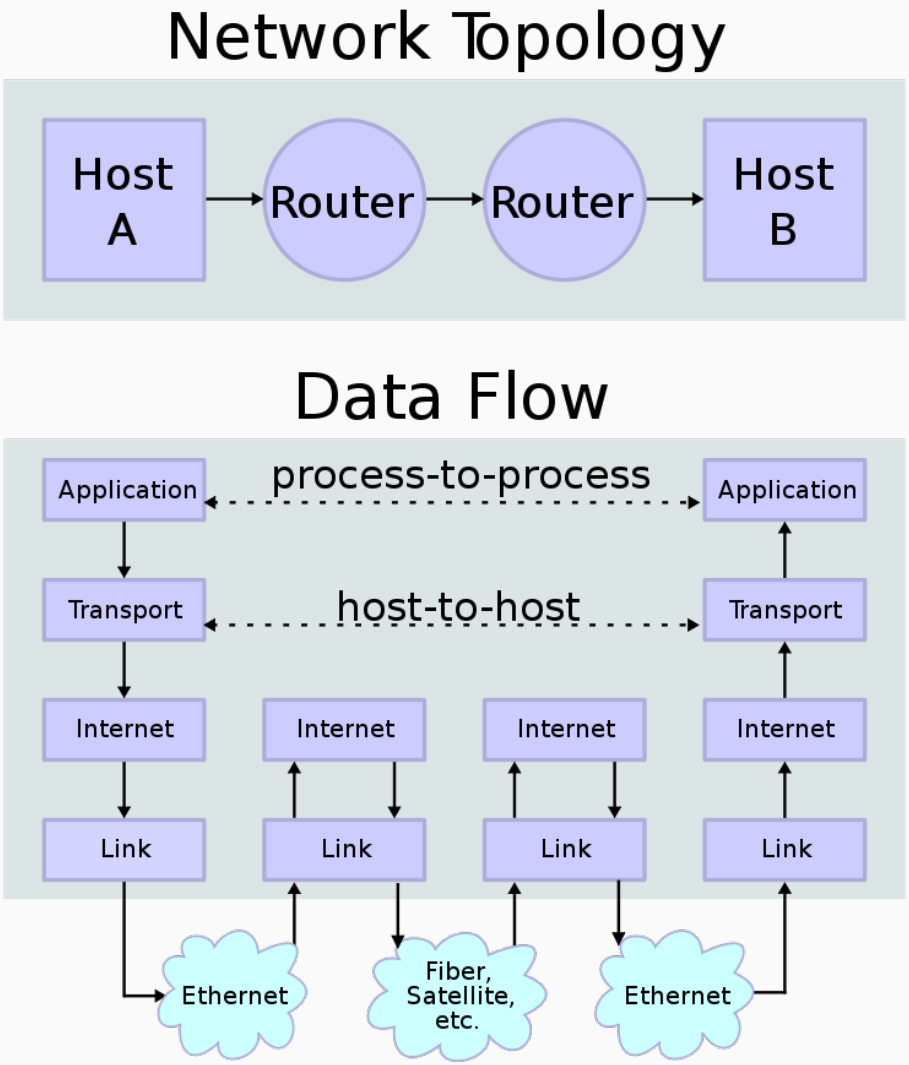

Ref: https://en.wikipedia.org/wiki/Internet_protocol_suite#Key_architectural_principles

Network Layering Model

- Each layer provides services for the layer above it, and “abstracts” the lower levels.

For example, a web browser, or a mail client (in the application layer) use the TCP layer to send requests to a remote host. In particular, they do not have to worry about “how” it does it!

- The promise of TCP is that the application data will be delivered “reliably” to the destination.
- The promise of UDP is that the application data will be delivered to its destination in the lowest latency but no guarantee.

An application chooses one based on its needs (e.g.?)

Network Layering Model

- TCP or UDP (transport layer protocols) in turn relies on the services of the IP layer: for instance, it first establishes a notion of connection between the source host (where it resides) and the TCP layer of the destination hosts, but does not have to worry about the detail of how the requests are actually routed between intermediate hops. That's IP layer's business!
- IP on the other hand relies on the link layer to do its service: for instance, it does not have to worry about the physical medium of transmission, the capacity of the channel, the frequency it runs on, synchronisation, avoiding collisions, etc.

Network Layering Model

This not having to worry goes both-ways:

- IP layer does not have to worry about who are the two ends of the communication.
- TCP/UDP does not have to be concerned with the content of the data, or the detail of the application

Physical Layer

- The process of transforming bits of data to electric/electromagnetic signals to be transmitted over a physical channel is called **modulation**
  - ▷ e.g., 0 $\rightarrow$ light off, 1 $\rightarrow$ light on in optical fibre.

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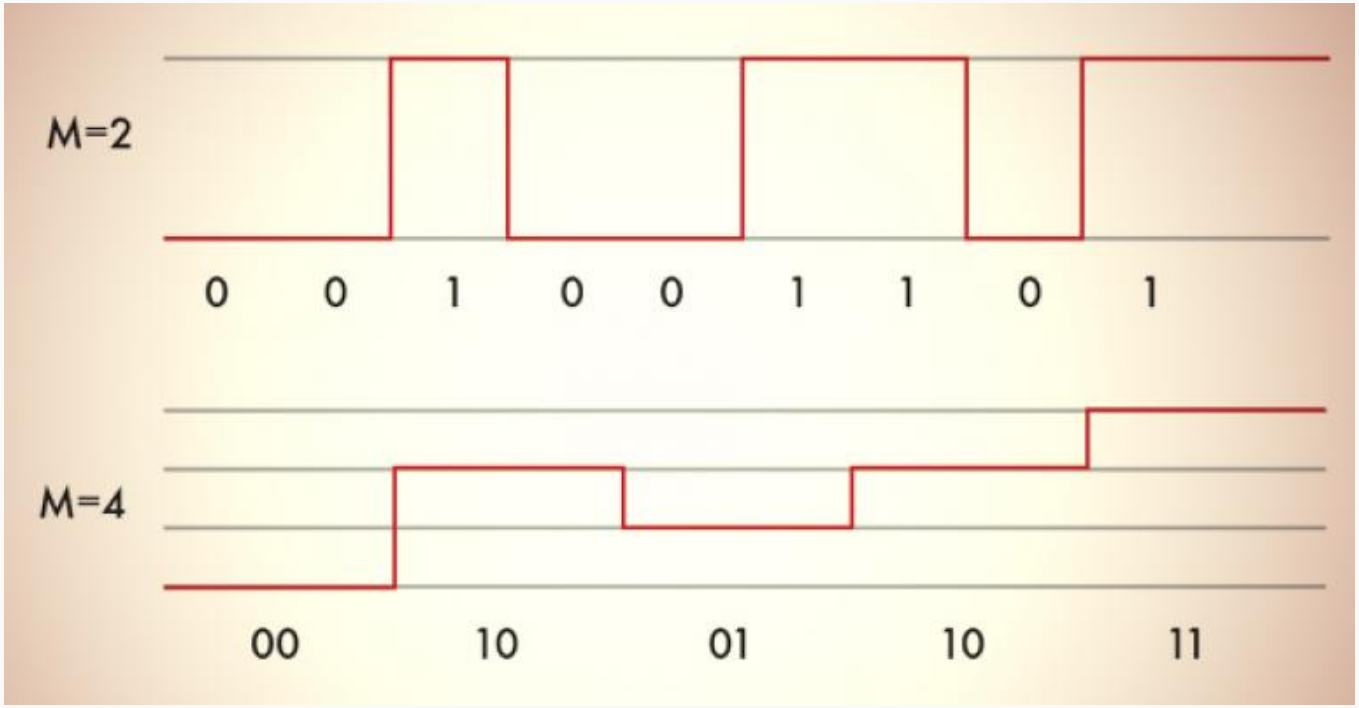
▷ The device responsible for modulation and demodulation is called *modem*

Physical Layer: Examples of modulations

- Information can be carried in the magnitude of the signal (Pulse Amplitude Modulation (PAM)):



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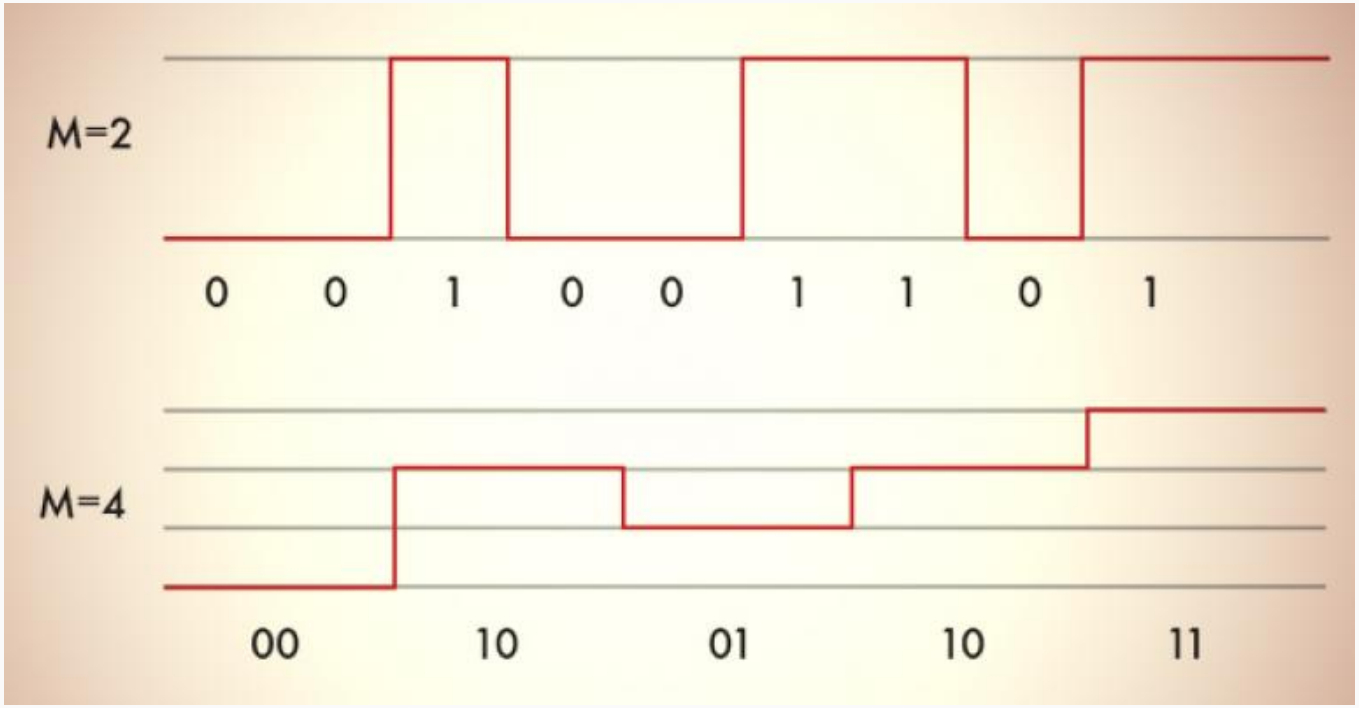
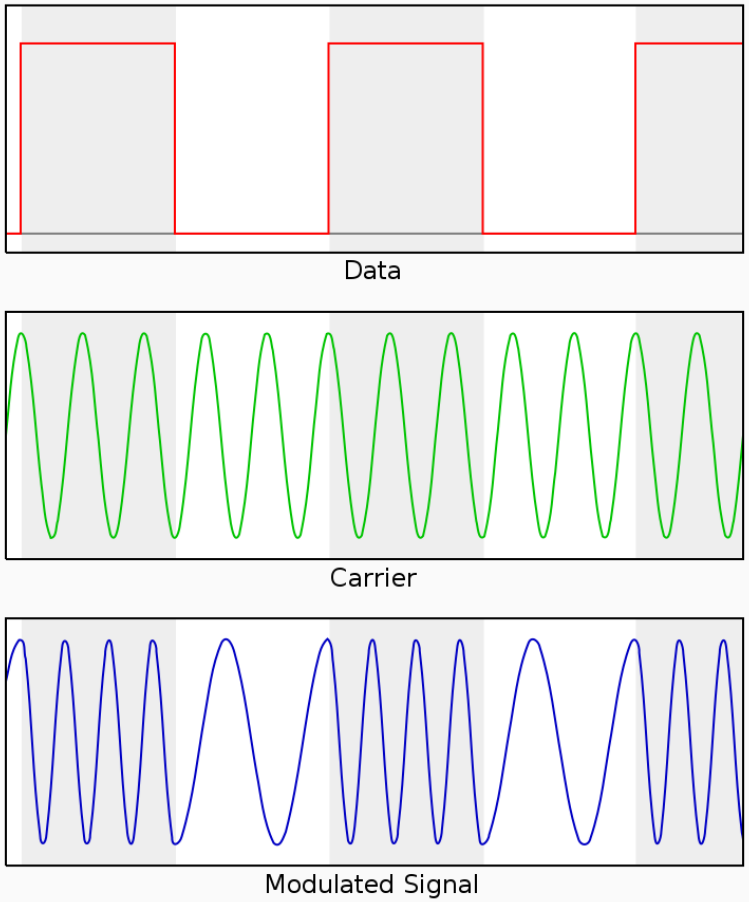


  - As the second figure shows, each “symbol” can represent more than one bit.

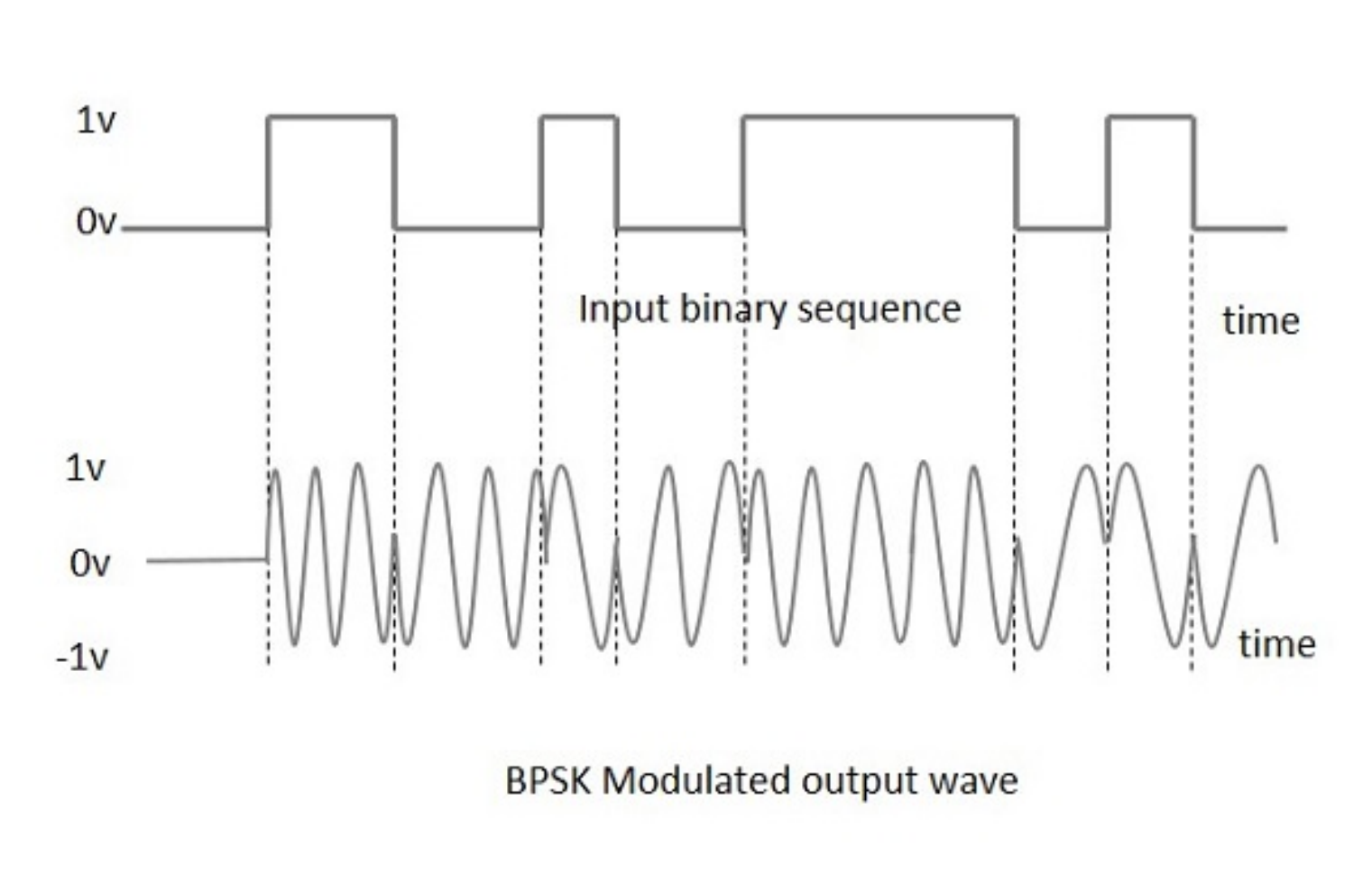
Physical Layer: Examples of modulations

- or the changes in the “carrier” wave’s frequency (Frequency Shift Keying (FSK))



Physical Layer: Examples of modulations

- or in the “phase” of the carrier: (Phase Shift Keying (PSK))

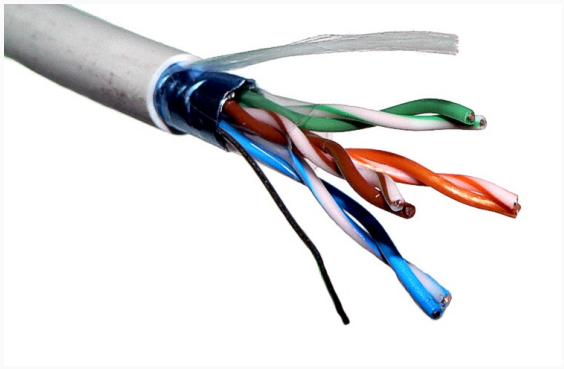


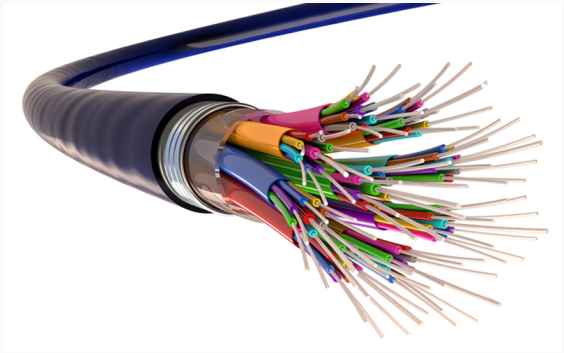
Physical Layer: Transmission Media

Two types of transmission media (medium: where the electric/electromagnetic waves propagate from one device to the next)

- **Guided**
  - Ether cable (Twister Pair Cable), Coaxial Cable, Fibre-Optic Cable
- **Unguided**
  - air, atmosphere, space (microwave links, Infrared, wifi links, wimax links, cellular/mobile communication)

Physical Layer: Guided Media





Link Layer (a.k.a. Data Link Layer)

- **Link layer**: includes the protocol necessary to send information between two hosts that are connected immediately to the same media (for example, a coaxial cable or over the air via radio waves).
  - Takes care of frame synchronisation, flow control, error correction, and addressing.
  - It also includes the mechanisms for replication over several links by “switches” (a.k.a. “bridges”).
- main protocols: HDLC (implemented by CISCO and called *Ethernet*), PPP
  - At link layer, the message unit is called a *frame*.
  - To differentiate the devices that are immediately connected to the same link we use **MAC addresses**

Internet Layer (a.k.a. Network Layer)

- Not all devices can be immediately connected to each other! so there is a need to transmit data across multiple devices, hence the **Internet Layer**
  - Each host is **assigned** an Internet Protocol (IP) address upon connection
  - Each router transmits the data to the next best router to reach the destination IP address (“routing”), based on (a prefix of) the IP address of the destination
    - At the Internet layer, the message unit is called a *packet*.

Transport Layer

- How can the sending host know whether its data successfully made it to the destination? This is the main job of the **transport layer**.
  - For example, it detects whether any part of the information is delivered out of order (how?) or went missing (how?) or any part is delivered with errors (again, how?)

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  - At this layer, the message unit is called a *segment*.

Application Layer

- e.g.: Simple Message Transfer Protocol (SMTP) is used to handle sending of emails, the Hypertext Transfer Protocol (HTTP) is used to request a web page within a browser, File Transfer Protocol for file transfer, etc.
- The protocols are not concerned with how the information will reach the destination, but only work on defining the content of the information being transmitted.

Layer Terminology

Layer #	Layer Name	Protocol	Protocol Data Unit	Addressing
5	Application	HTTP, SMTP, etc…	Messages	n/a
4	Transport	TCP/UDP	Segments/ Datagrams	Port #s
3	Network or Internet	IP	Packets	IP Address
2	Data Link	Ethernet, Wi-Fi	Frames	MAC Address
1	Physical	10 Base T, 802.11	Bits	n/a

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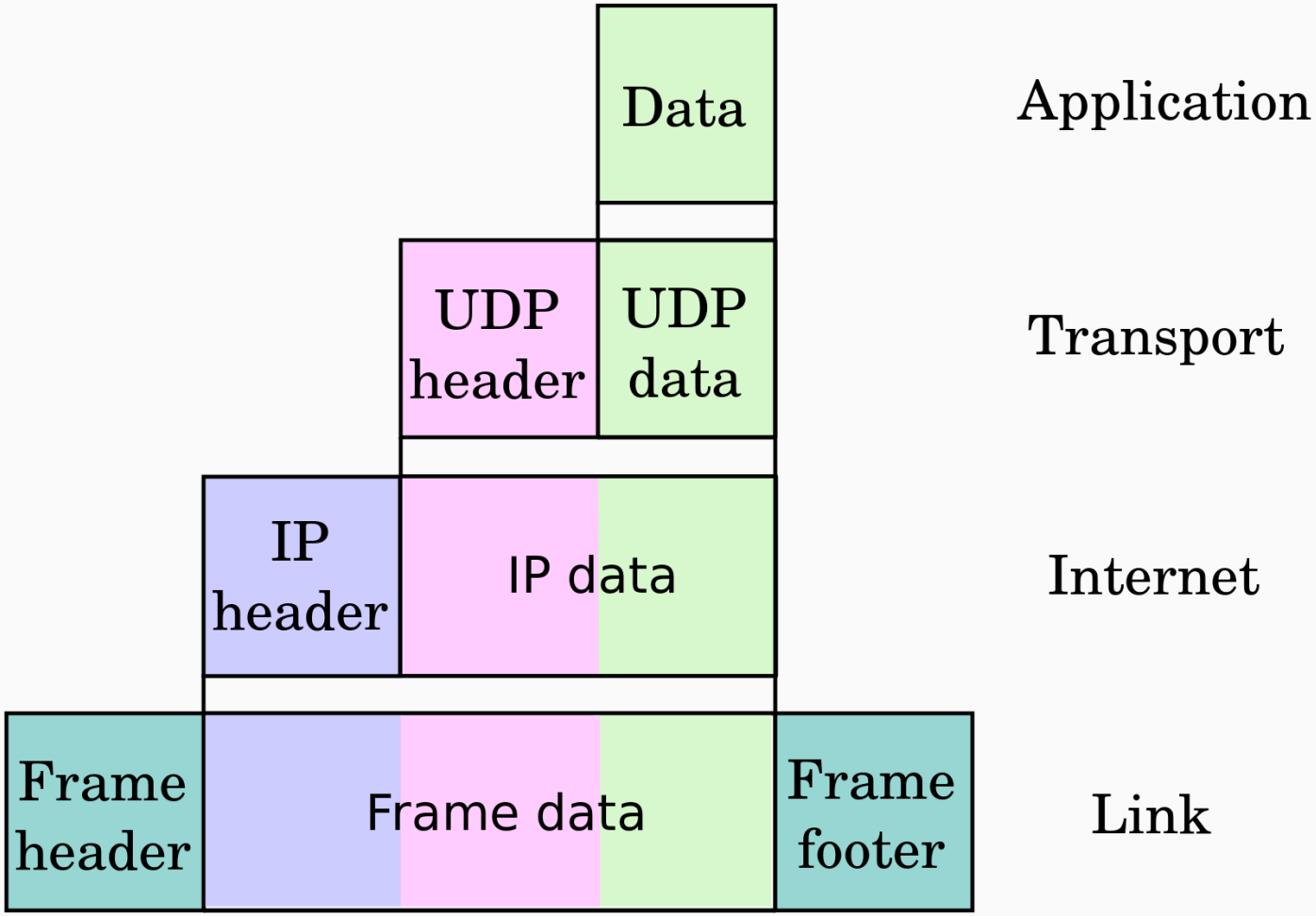
Encapsulation



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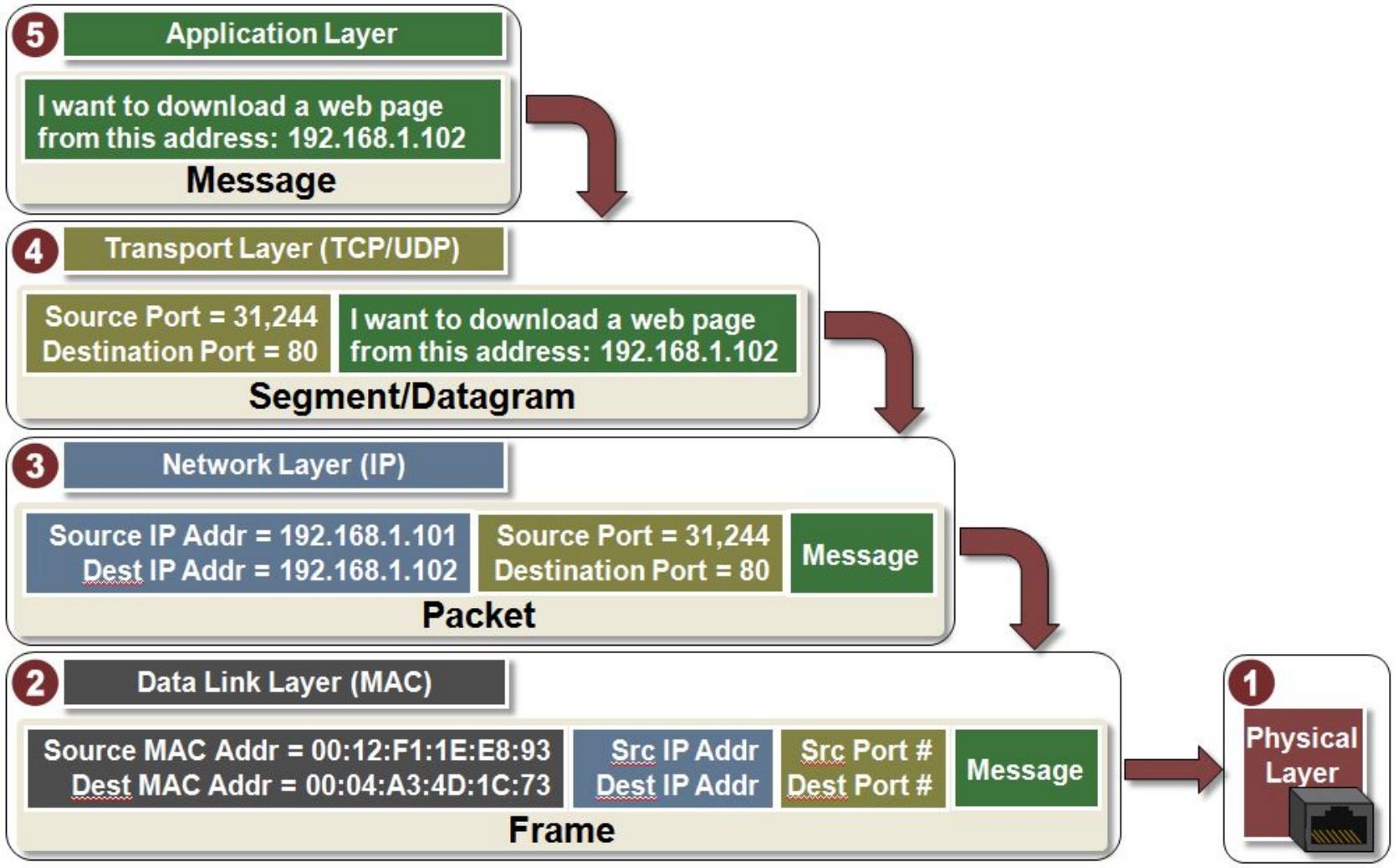
Encapsulation

- Example items in the **TCP** header:
  - Source port – why?
  - Destination port – why?
  - “Checksum” – why?
  - Sequence number – why?
- Example items in a **IP** header:
  - Destination IP address – why?
  - Source IP address – why?
  - Time to live (TTL) – why?
- Example items in a **Link** layer protocol header:
  - Destination MAC address **Note: Destination here means the next immediate node!**
  - Source MAC address **Note: Source here means the current node!**

Encapsulation: Example



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TCP/IP

The Open System Interconnection Standard (OSI) Model:

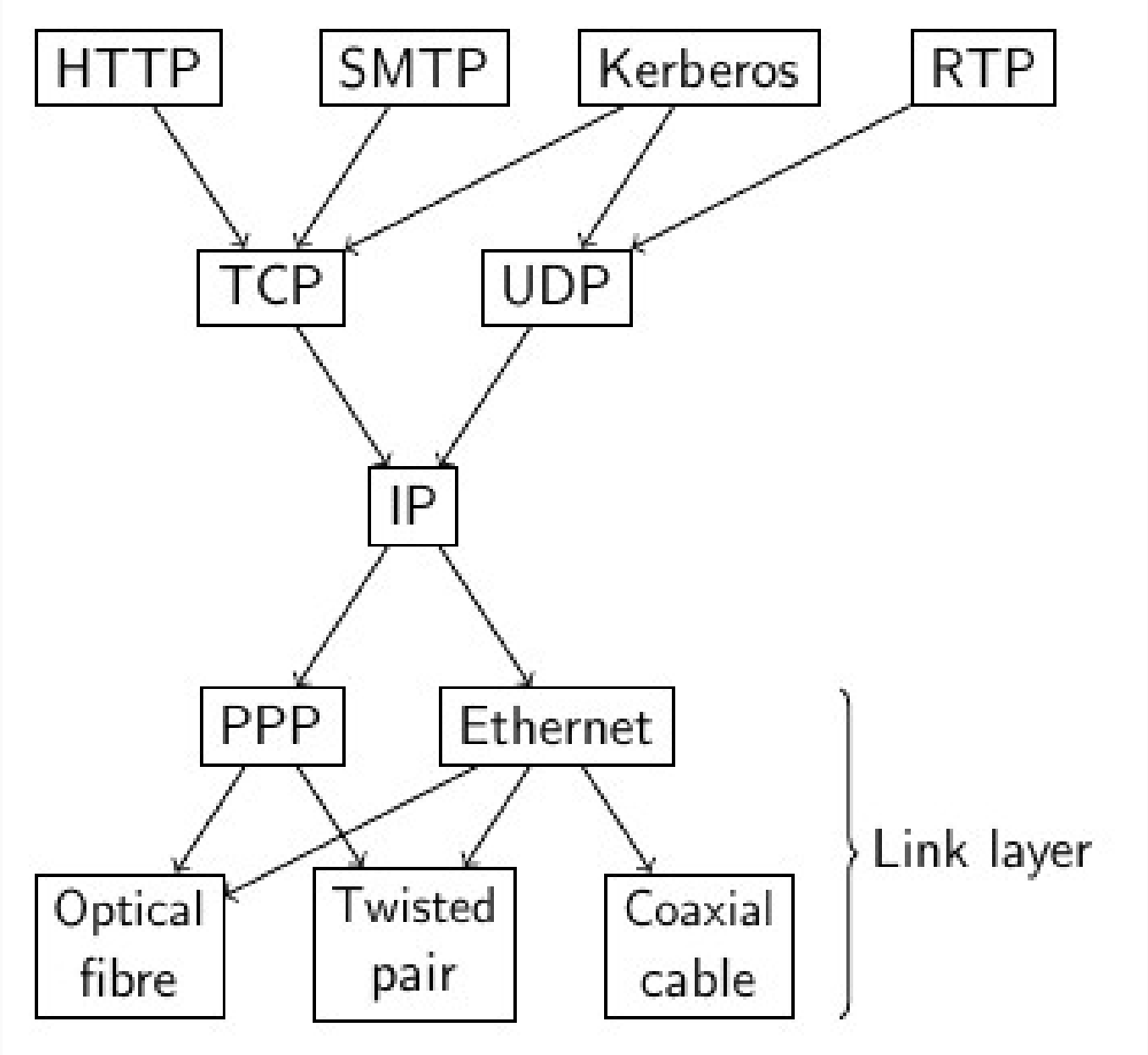
Layer	Unit	Purpose	Examples
1 Physical	Bit	Representation and transmission of data over network medium	Ethernet, Bluetooth
2 Data link	Frame	Conversion of data to network-specific frame format; error detection	ATM, PPP, Ethernet
3 Network	Packet	Provides host-to-host communication channels; congestion control	IP, IPsec
4 Transport	Segment	Provides application-to-application communication channels	TCP, UDP
5 Session	Data	Controls connection-oriented communications between hosts	NetBIOS, TLS/SSL
6 Presentation	Data	Conversion between different data formats; compression; encryption	MIME
7 Application	Data	Specifies application interaction with network	HTTP, DNS, BGP, SNMP, IKE

TCP/IP

OSI model vs TCP/IP:

OSI Model	TCP/IP		
	RFC 871	RFC 1122	Stallings
Application	Application	Application	Application
Presentation			
Session			
Transport	Host-to-host	Transport	Transport
Network		Internet	Internet
Data link	Network interface	Link	Network access
Physical			Physical

TCP/IP


HTTP
SMTP
Kerberos
RTP
TCP
UDP
IP
PPP
Ethernet
Optical fibre
Twisted pair
Coaxial cable
Link layer

TCP/IP: an example

- Web server and web browser communicate using an application layer protocol.
- In this case, the protocol is Hypertext Transfer Protocol (HTTP).
- Users invoke applications which “speak” using application protocol.
- Applications interact with a transport protocol to send or receive data.

TCP/IP: an example

HTTP outline:

GET /directory/dirsearch.html HTTP/1.1

Host: www.company.com.co.uk

TCP/IP: an example

TCP outline:

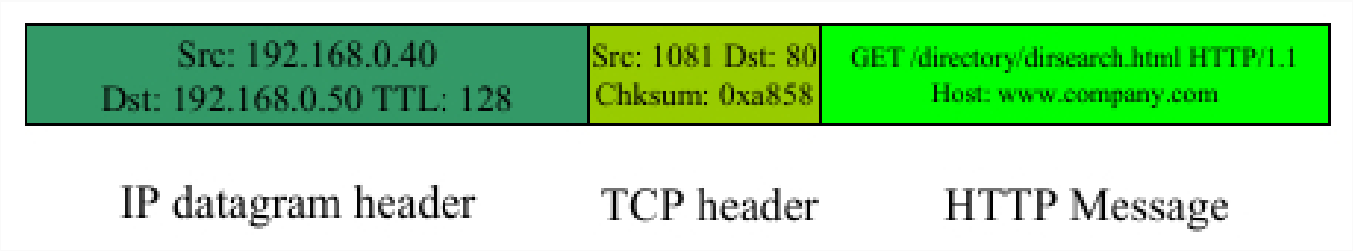
- ▷ Source Port: 1081
- ▷ Destination Port: 80
- ▷ Checksum: 0xa858

- ► Ports allow identification of applications.
- ► Checksum for error detection.

TCP/IP: an example

IP outline:

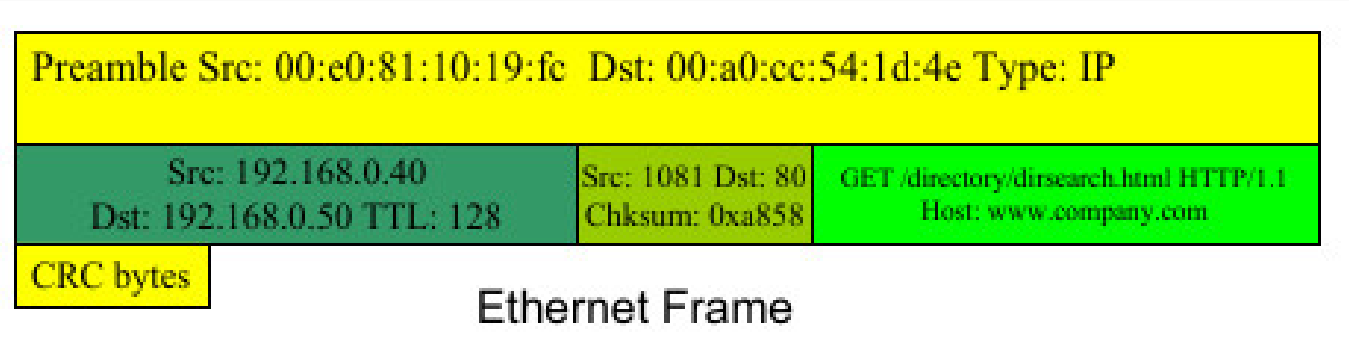
- Time to live: 128
- Header checksum: 0x57d1
- Source: pelican (192.168.0.40)
- Destination: www.company.co.uk (192.168.0.50)



TCP/IP: an example

In this example, say Ethernet is used.

- Ethernet outline:
  - Synchronisation preamble.
  - Destination: 00:a0:cc:54:1d:4e.
  - Source: 00:e0:81:10:19:fc.
  - Type: IP.
  - Data in frame.
  - Cyclic Redundancy Check (CRC).



TCP/IP: an example

- The network interface card of all the machines that are on the same Ethernet wire (including the router/switch) keep inspecting the header of all the ethernet data-frames, and if the ethernet address, i.e., the destination MAC (Media Access Control) address of a data-frame matches theirs, they will pick it up for processing;

TCP/IP: an example

- A router looks at (a prefix of the) IP address of the destination, then based on its “routing table” and routing rules, decides what is the next immediate link, so it replaces the source ethernet address with its own ethernet address (which was the destination ethernet address of previous step), and replaces the destination ethernet address (the next hop router);

TCP/IP: an example

- This process goes on till the packet reaches the machine with destination IP address. At that point, the IP datagrams, the TCP messages and eventually, the HTTP message is reconstructed at the IP, TCP and the application layer of the destination machine, respectively.

Questions?