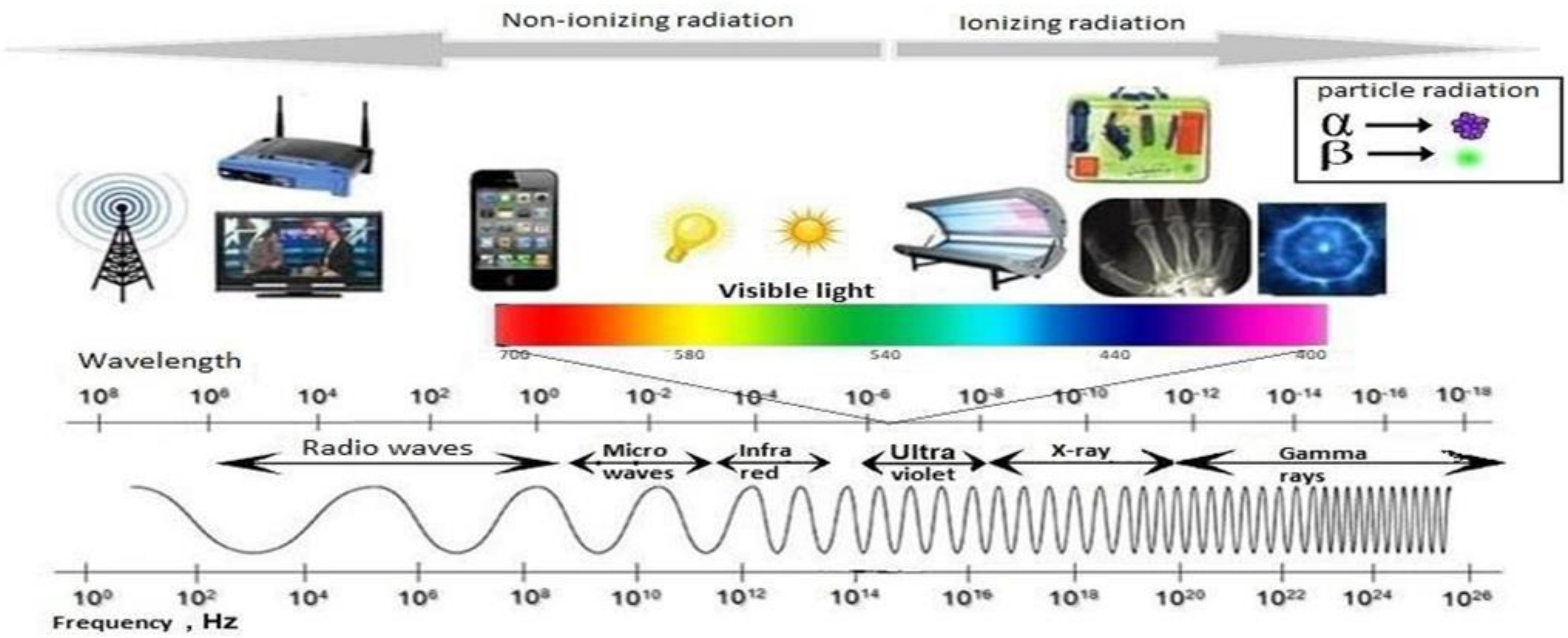
Wireless Networks

Lecture 1: Overview

THE ELECTROMAGNETIC SPECTRUM



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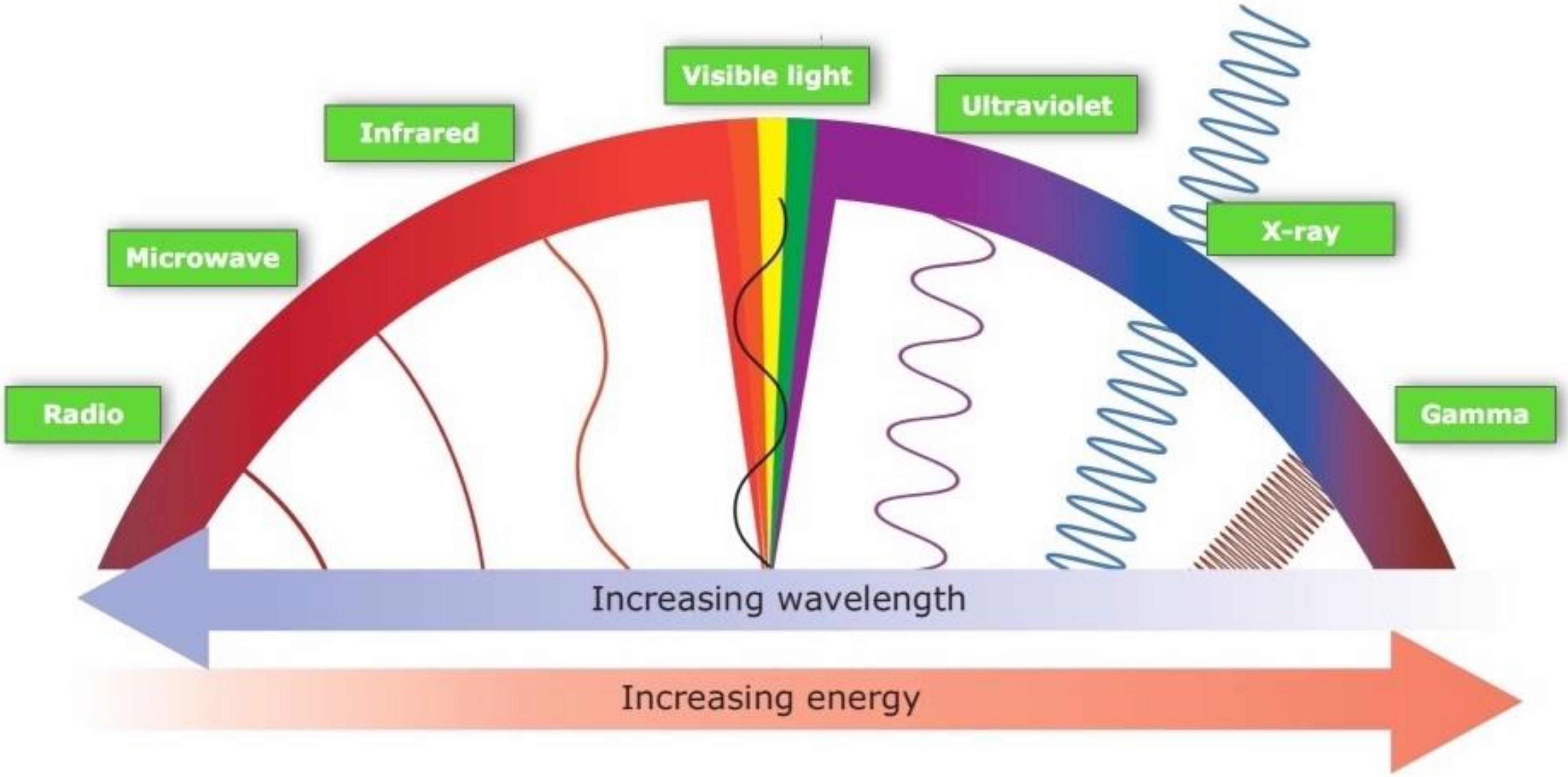
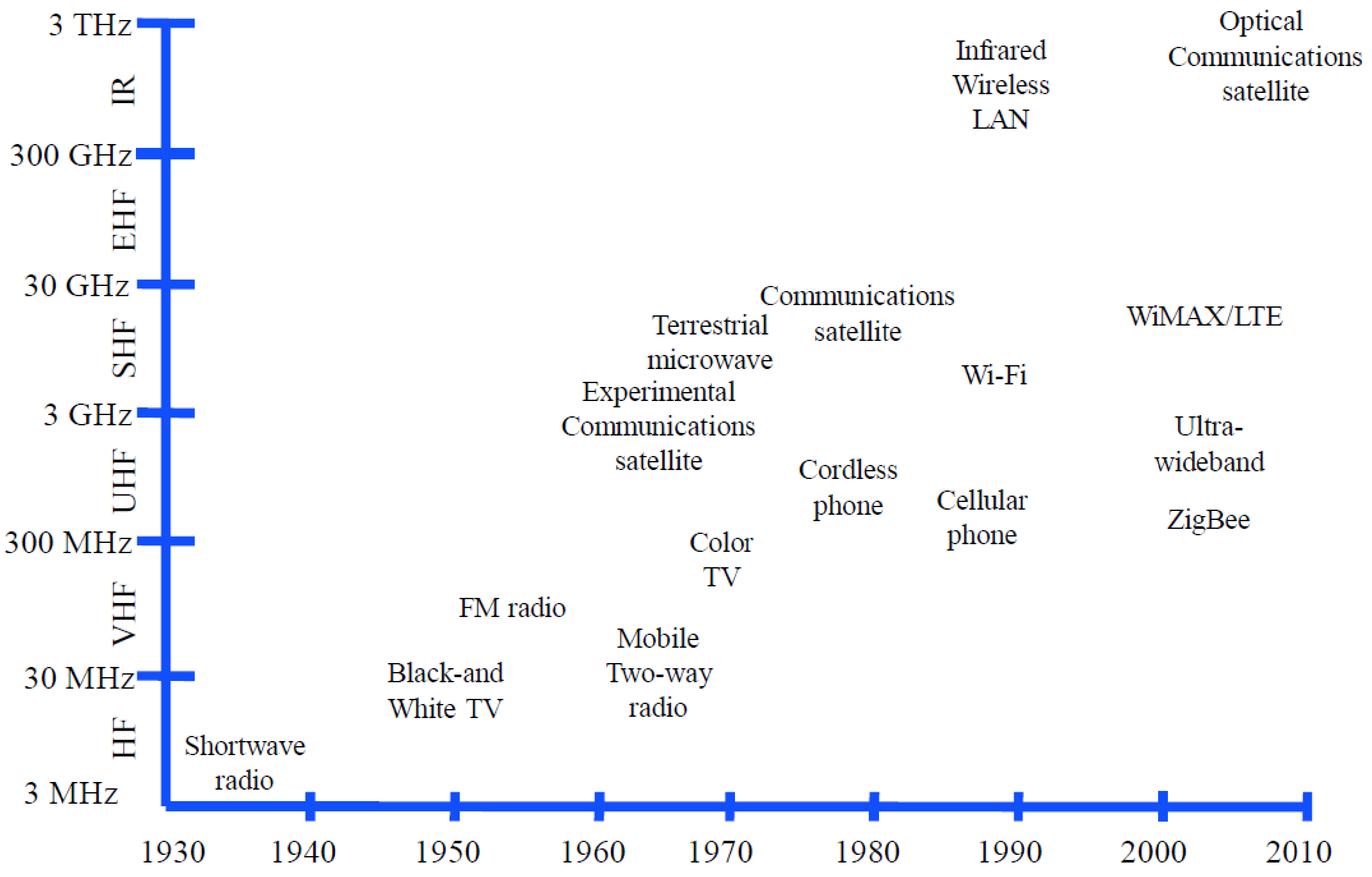


Spectrum Shared by Many Users

- Spectrum allocated by FCC and NTIA
- Two types of spectrum bands:
  1. Licensed spectrum: exclusive access to an organization
     - Federal agencies, broadcast TV, first responders, …
     - Commercial, e.g., cellular operators
  2. Unlicensed spectrum: everyone can use it with appropriate equipment, e.g., WiFi, zigbee, …
- Other trends:
  - » Technology improvements have allowed us to use higher frequency bands over time
  - » Many bands have low utilization
  - » Older bands often use very inefficient technologies

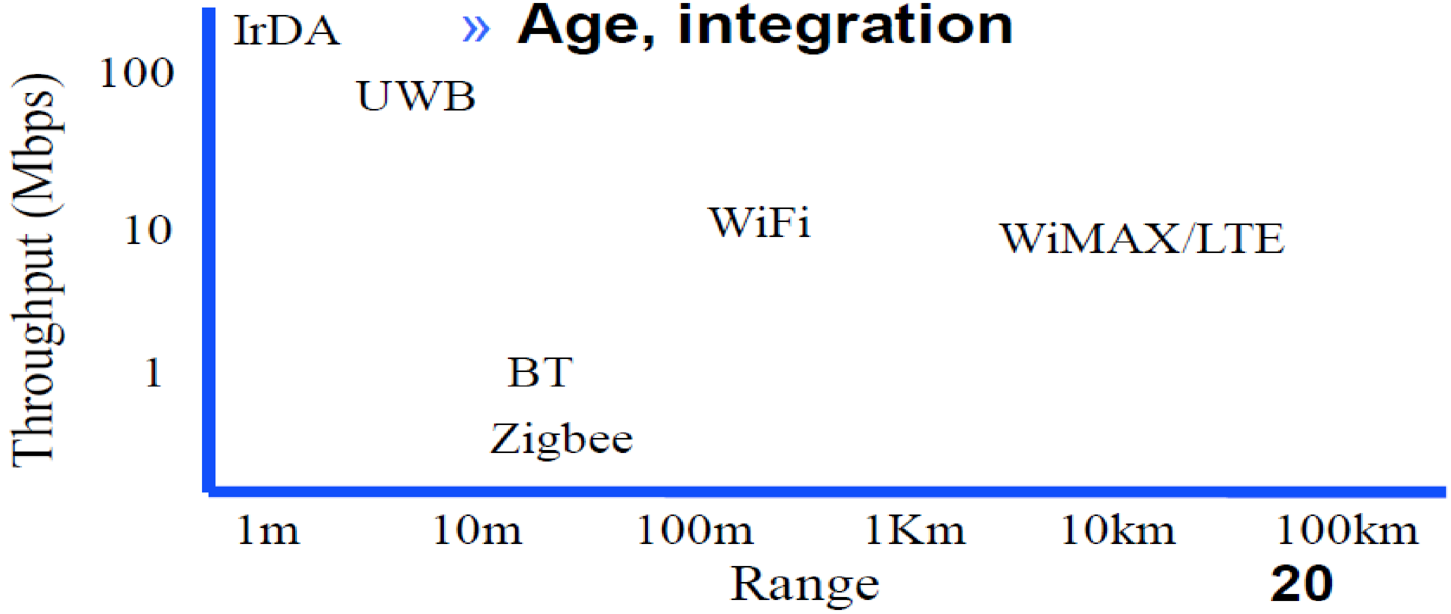
WIRELESS TECHNOLOGIES



WHY SO MANY TECHNOLOGIES?

- Diverse application requirements
  - » Energy consumption
  - » Range
  - » Bandwidth
  - » Mobility
  - » Cost
- Diverse deployments
  - » Licensed versus unlicensed
  - » Provisioned or not

- Technologies have different
  - » Signal penetration
  - » Frequency use
  - » Cost
  - » Market size
  - » Age, integration



APPLICATION TRENDS IN WIRELESS

- Early days: specialized applications
  - Broadcast TV and radio, voice calls, data, ..
  - Holds for wireless and wired
- Today: flexible wireless platforms
  - Phones, tables, and laptops all run similar applications
  - Same trend as for wired networks: everything runs over the Internet
- Wireless is expanding in new domains
  - Sensor networks, body area networks, …
  - Edge of the internet is increasingly wireless
  - Many of these applications are unique to wireless
- Future?

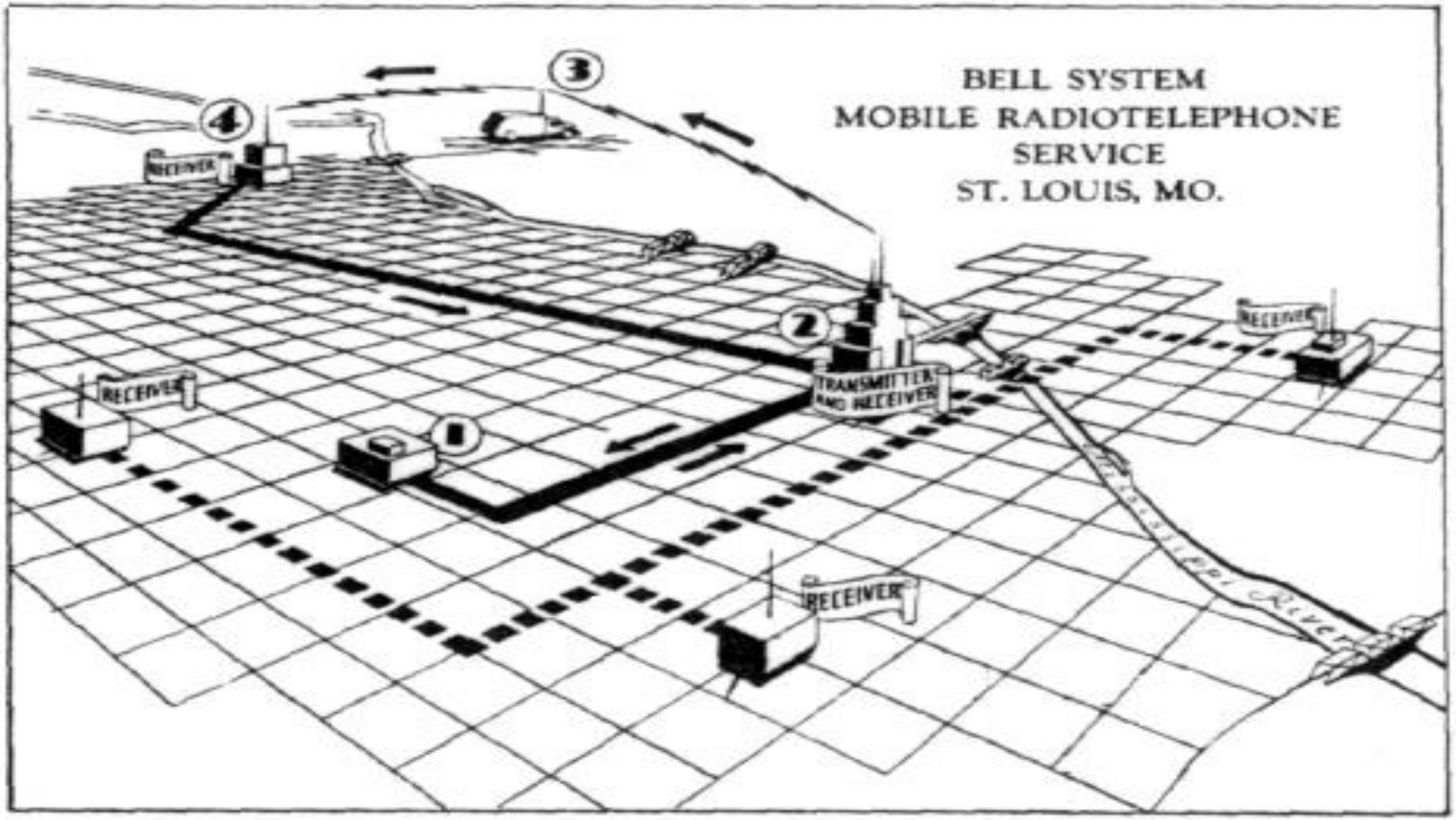
SCOPE OF WIRELESS COVERED IN THE COURSE

- Significant depth on two technologies:
  - Wireless in unlicensed band: WiFi
  - Wireless in licensed spectrum: cellular
  - Focus is on optimizing performance with limited spectrum
  - Sophisticated protocols to fight challenging physical layer
- Other wireless communication technologies
  - RFID/NFC, low-power, satellite, UWB, visible light, …
- Localization and sensing
  - GPS, Wifi for localization and sensing, …
- Wireless deployments
  - Infrastructure WiFi, ad hoc, sensor networks, vehicular, DTN, visible light, ..
  - Some topics covered in the surveys

SOME HISTORY…

- Tesla credited with first radio communication in 1893
- Wireless telegraph invented by Guglielmo Marconi in 1896
- First telegraphic signal traveled across the Atlantic ocean in 1901
- First “cell phone” concept developed in 1946
  - FCC allocated spectrum in the 70s; commercial service in the early 80s
  - Data started only in the 90s
- GPS project started in 1973, complete in 1995
- WiFi technology developed in the mid-1990s

THE MTS NETWORK



THE ORIGIN OF MOBILE PHONE

- America's mobile phone age started in 1946 with MTS
- First mobile phones bulky, expensive and hardly portable, let alone mobile
  - Phones weighed 40 Kg~
- Operator assisted with 250 maximum users

SHORT HISTORY OF WIFI

- In 1985, the FCC opened up the 900 Mhz, 2.4 GHz and 5.8 Ghz bands for unlicensed devices
- NCR and AT&T developed a WiFi predecessor called “Wavelan” starting in 1988
  - NCR wanted to connect cashier registers wirelessly
  - Originally used the 900 MHz band and ran at 1 Mbps
- Standardization started in early 90s and led to 802.11b (1999) and 802.11a (2000)
  - Pre-standard products were available earlier
- Today –many standards!
  - Working on 802.11ba - rates up to several Gps
  - Very sophisticated technology: OFDM, MIMO, multi-user MIMO, ..

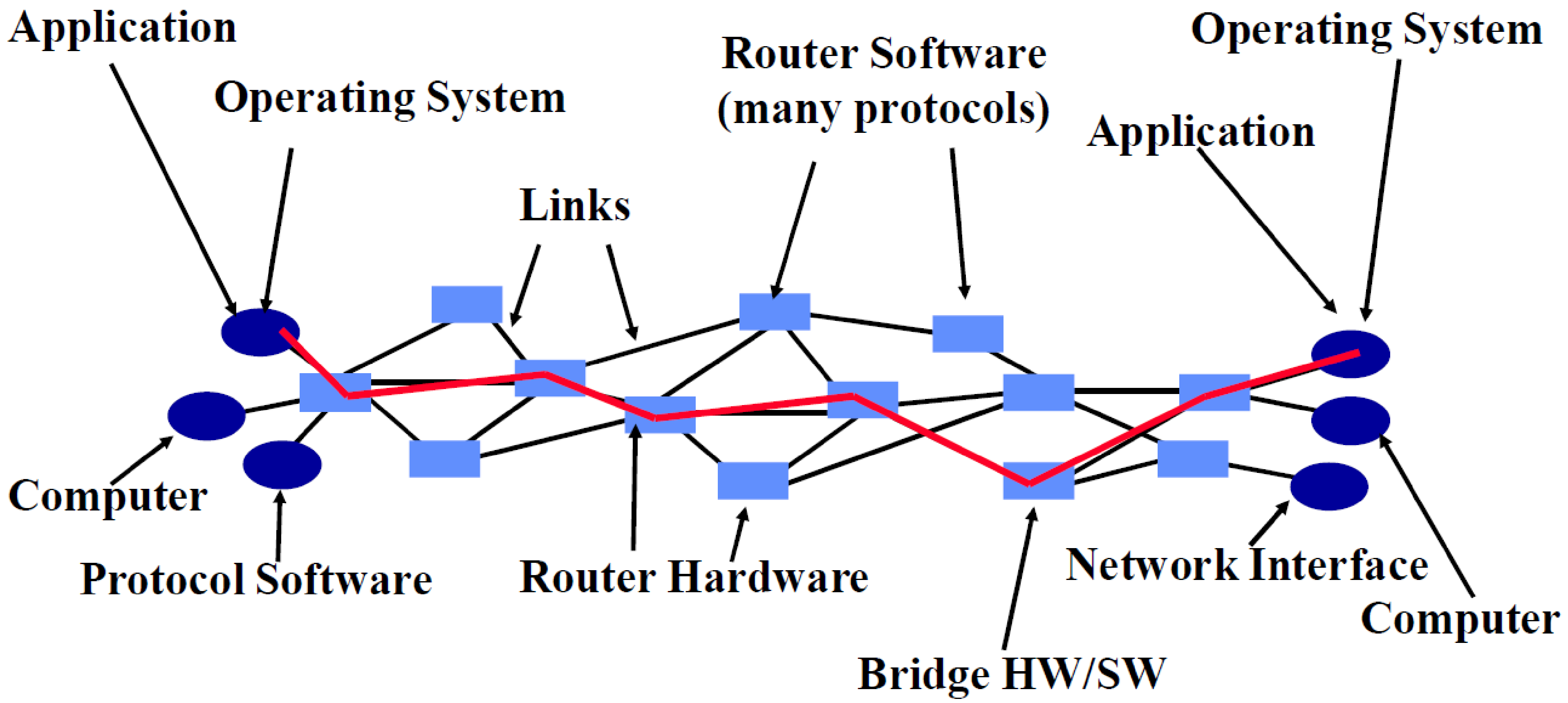
EARLY WIFI INTERFACES

Wavelan at 900MHz
1 Mbps throughput

PCMCIA form factor made Wavelan more portable

THE INTERNET IS BIG AND HAS MANY PIECES

How do you design something this complex?



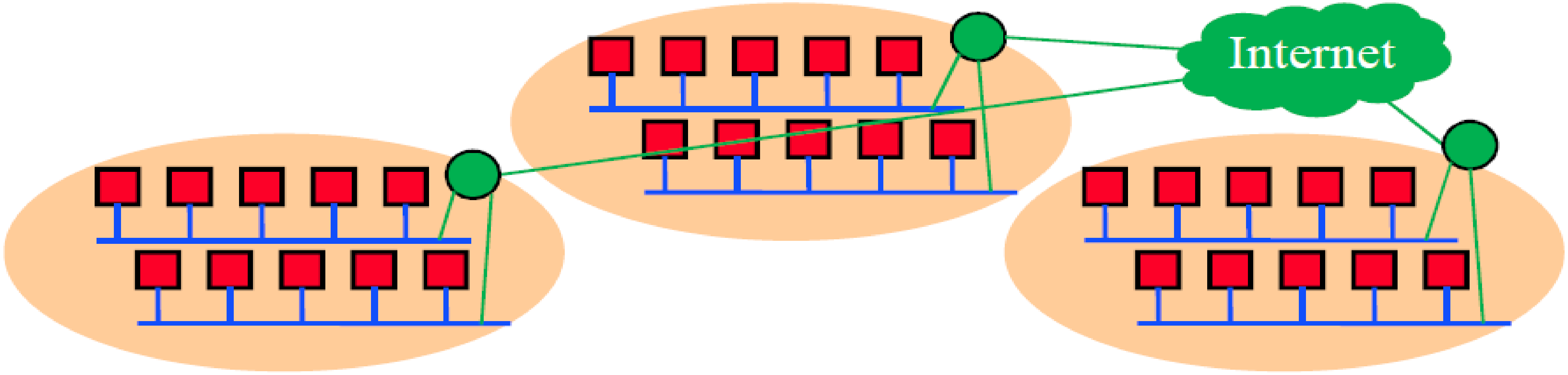
WHAT PIECES DO WE NEED?

	Module:
• We need to be able to send bits	
» Over wired and wireless links	Physical
» Based on analog signals	
• We really want to send packets	Datalink
» Statistical multiplexing: users can share link	Network
» Need addresses to deliver packets correctly	
• But network may not be reliable	
» Bit errors, lost packets, …	Transport
» Must recover from these errors end-to-end	
• You need applications and services	Application
» Otherwise: who cares?	

HOSTS EXCHANGING PACKETS CAN BE EASY OR HARD

Scaling up

- Two or more hosts talk over a wire (bits) — Physical
- Groups of hosts can talk at two levels
  - » Hosts talk in a network is homogeneous in terms of administration and technology — Datalink
  - » Hosts talk across networks that have different administrators and technologies — Internet
- Differ in physical and admin properties, scale

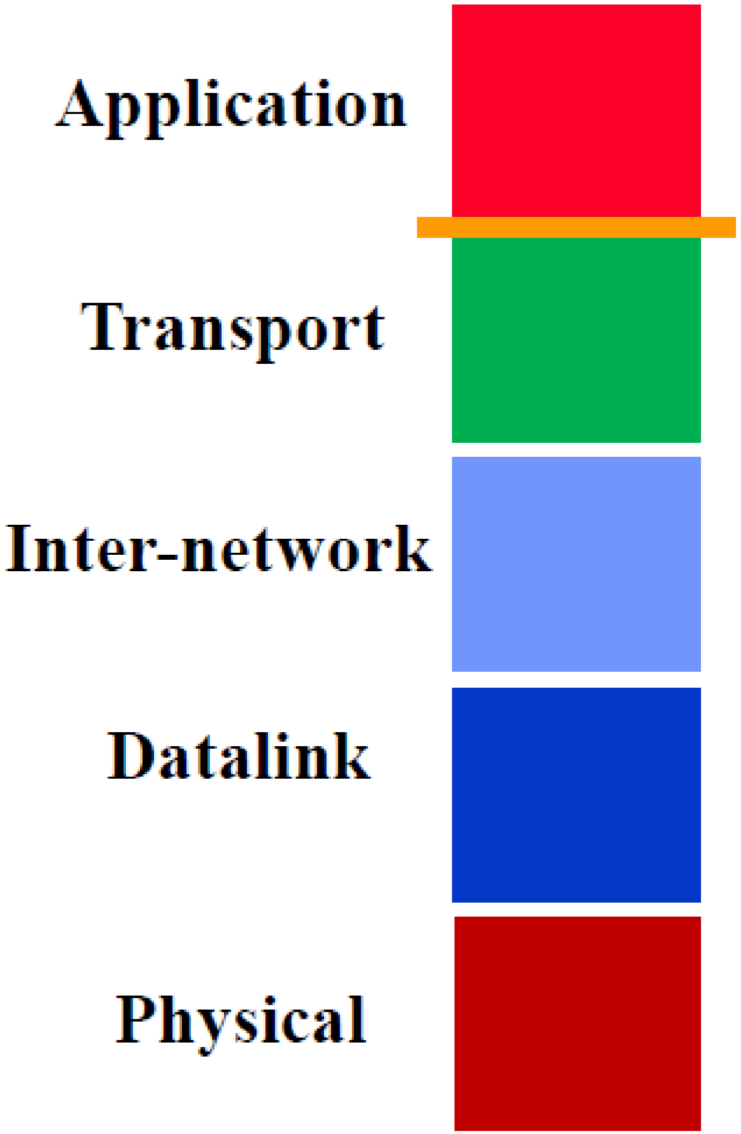


A BIT MORE DETAIL

- Physical layer delivers bits between the two endpoints of a “link”
  - Copper, fiber, wireless, visible light, …
- Datalink layer delivers packets between two hosts in a local area network
  - Ethernet, WiFi, cellular, …
  - Best effort service: should expect a modest loss rate
  - “Boxes” that connect links are called bridges or switches
- Network layer connects multiple networks
  - The Inter-net protocol (IP)
  - Also offers best effort service
  - Boxes that forward packets are called routers

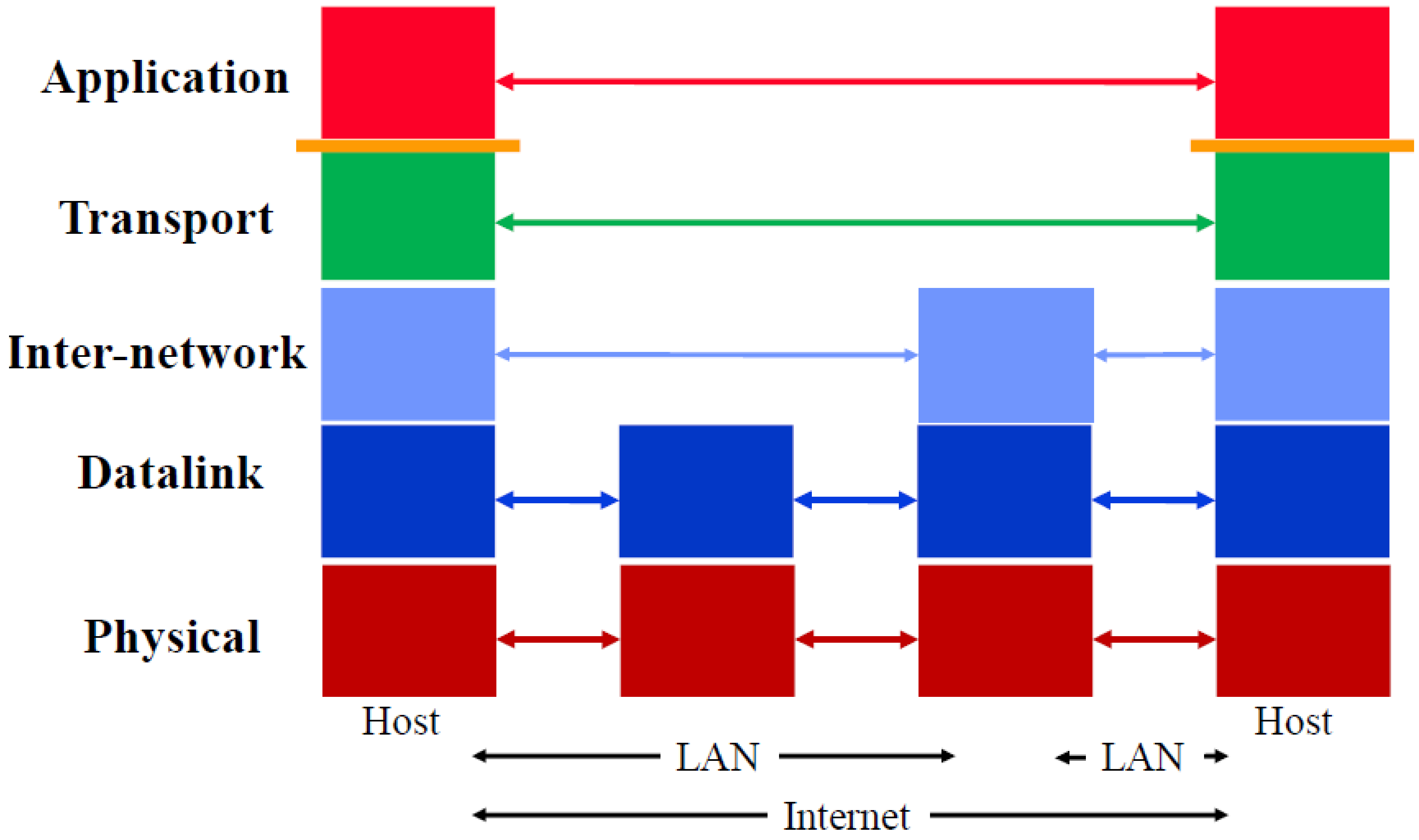
Scaling up the network

OUR INTERNET SO FAR



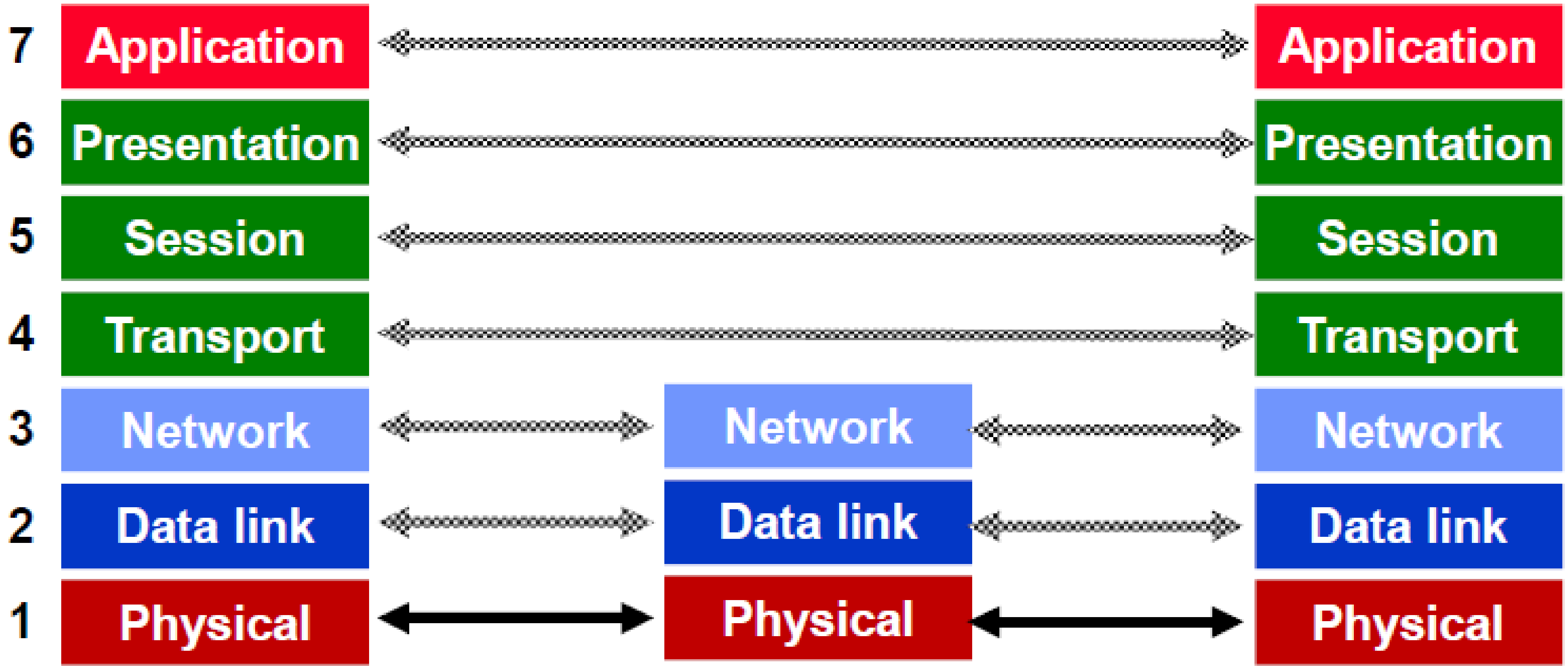
- The Internet as five modules that are stacked as a set of layers
  - » More on this later
- Five layers is nice, but …
  - » Each module is still huge!
  - » What about communication?
- We need protocols!
- Protocol modules within each layer on different devices allow the devices communicate

PROTOCOL AND SERVICE LEVELS



THE ISO LAYERED NETWORK MODEL

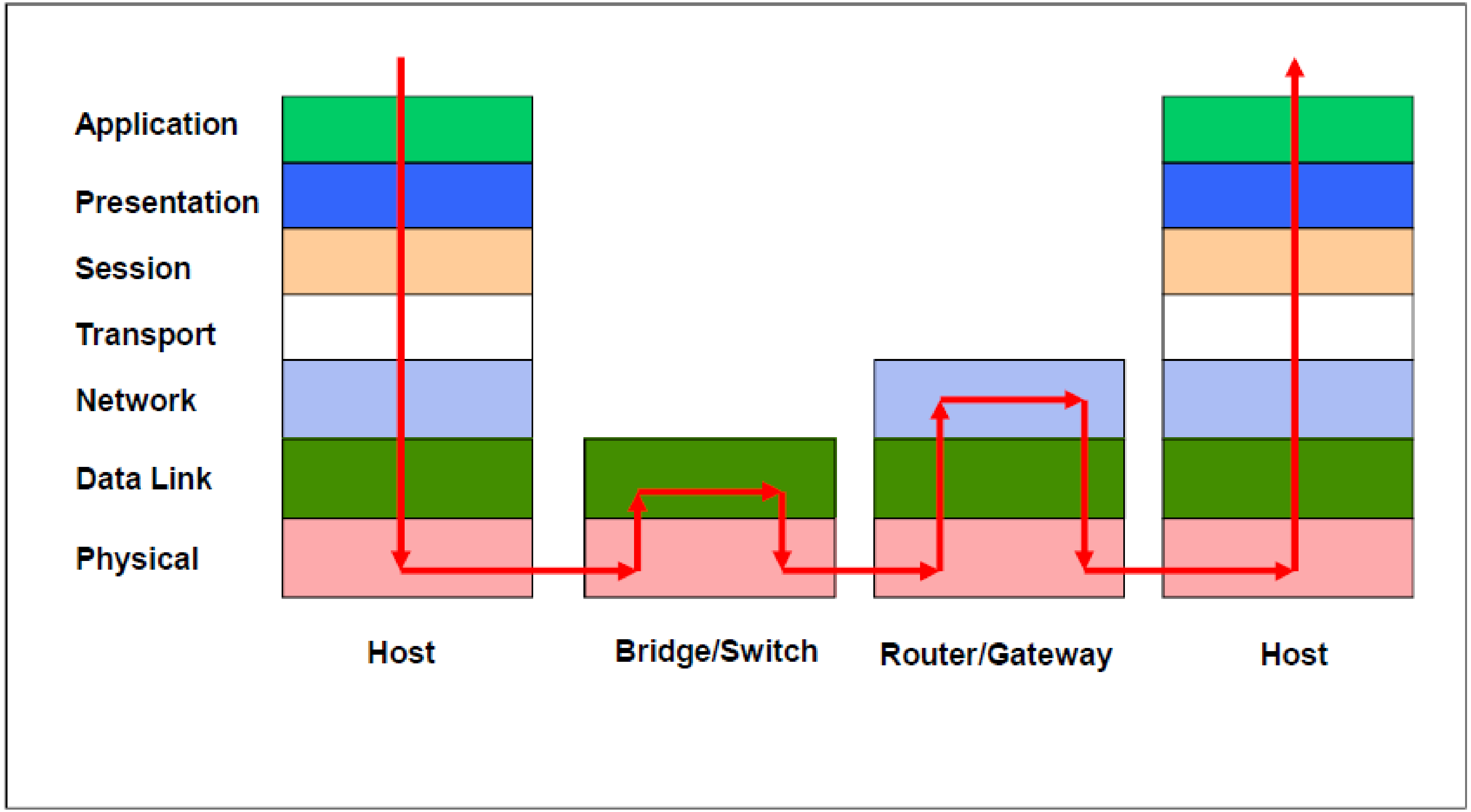
The Open Systems Interconnection (OSI) Model.



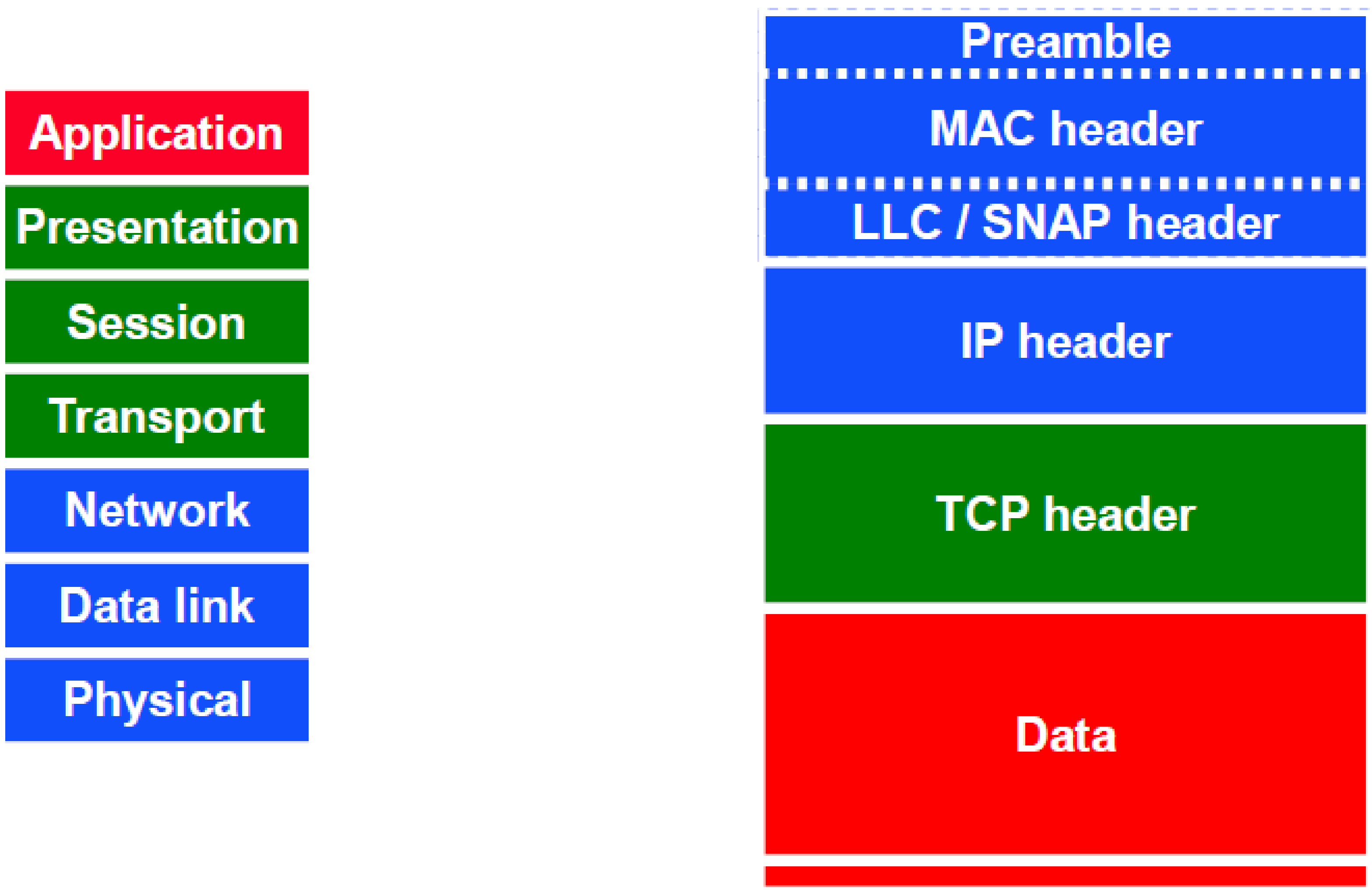
OSI FUNCTIONS

- (1) Physical: transmission of a bit stream.
- (2) Data link: flow control, framing, error detection.
- (3) Network: switching and routing.
- (4) Transport: reliable end to end delivery.
- (5) Session: managing logical connections.
- (6) Presentation: data transformations.
- (7) Application: specific uses, e.g. mail, file transfer, telnet, network management.

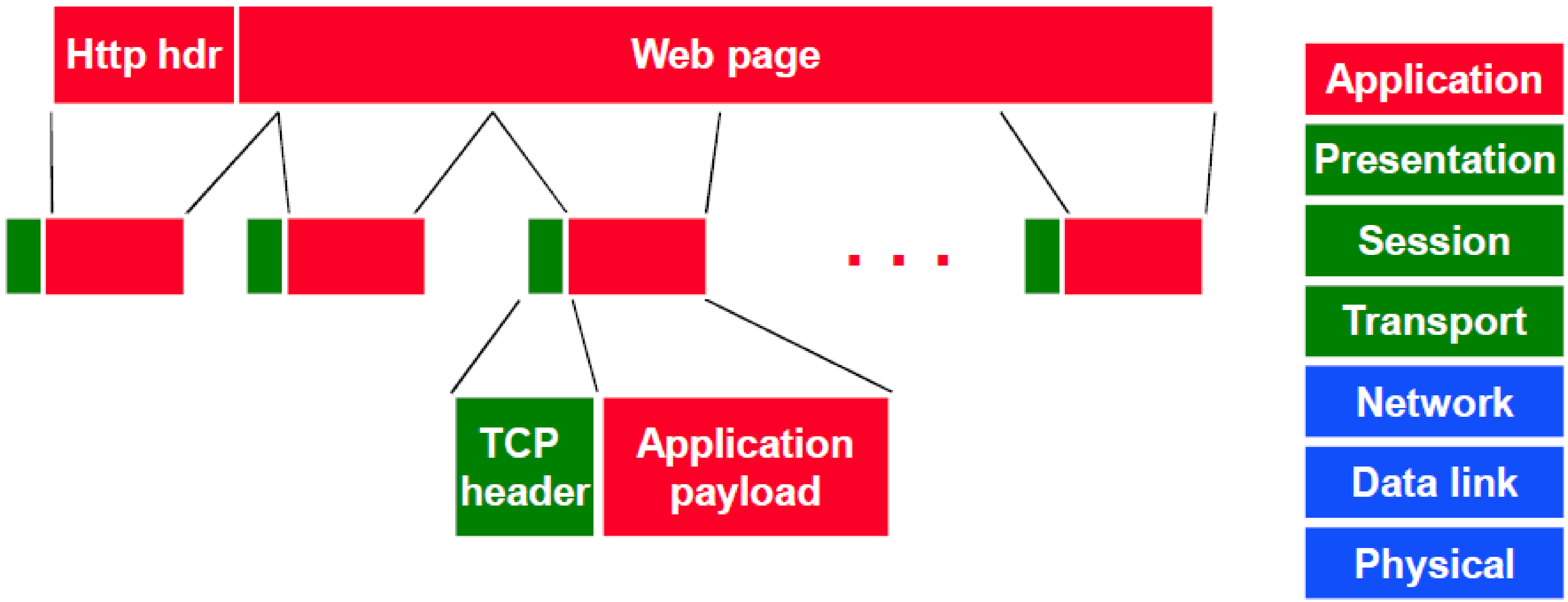
LIFE OF PACKET



A TCP / IP / 802.11 PACKET



EXAMPLE: SENDING A WEB PAGE



BENEFITS OF LAYERED ARCHITECTURE

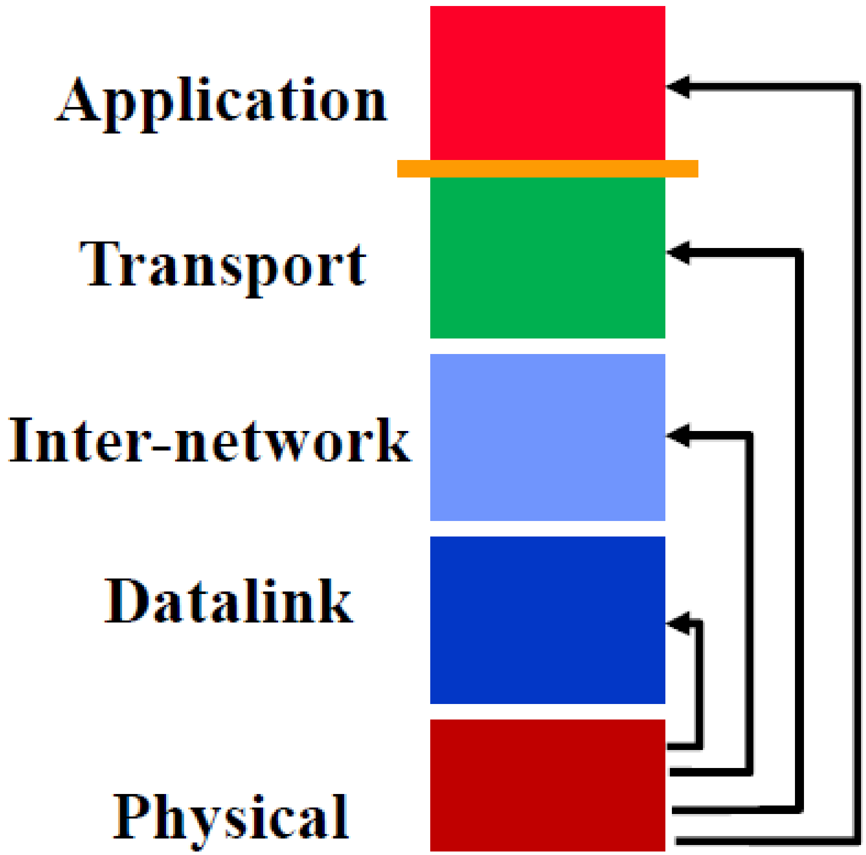
- Significantly reduces the complexity of building and maintaining the system.
  - » Effort is 7 x N instead of N^7 for N versions per layer
- The implementation of a layer can be replaced easily as long as its interfaces are respected
  - » Does not impact the other components in the system
  - » Different implementation versus different protocols

True For Wireless?

- In practice: most significant evolution and diversity at the top and bottom:
  - » Applications: web, peer-to-peer, video streaming, ..
  - » Physical layers: optical, wireless, new types of copper
  - » Only the Internet Protocol in the "middle" layer

IMPACT OF THE PHYSICAL LAYER

Wires: reliable and predictable ⟷ **Wireless:** error prone and variable



- Packet losses and variable delay and bandwidth
- Disconnections
- Mobility: IP addresses change
- Must manage complex PHY to perform error control
- Sophisticated modulation & coding, bit rate adaptation