Mobile and Wireless Networks

Introduction

Scope of this course

- Study of the architecture and operations of mobile and wireless networks.
- This area is huge and cannot be covered in one course.
- Divided in two parts
  - Wireless/mobile Internet access
  - Mobile networks

http://eclass.uoa.gr/courses/D211/

Parts of this course

Wireless/mobile Internet access

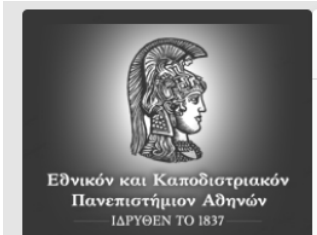
- History, general principles of mobile communications
- Problems of IP over wireless networks
- Wireless communications – Modulation, transmission
- Wireless networks – WLANs
- Mobility support

Mobile Networks

- 4G networks – LTE - LTE-A
- 5G architecture
- Quality of Service – Quality of Experience
- Radio resource management
- Interference management
- Mobility support

Assignment

- **Students that will attend this course, will have to prepare a 15-minute presentation on a subject related to the course.**
- **A list of subjects will be proposed by mid-November, while the students will be allowed to propose a subject of their own choice.**
- **The presentations will be recorded and uploaded through eclass by the end of January 2022.**
- **The grade of the presentation will be 30% of the final grade.**
- **70% of the grade will be through the final examinations (language of your choice).**



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Κινητά και Ασύρματα Δίκτυα (M121 - EN23/IC1)

Νίκος Πασσάς

Description

The rapid development of wireless and mobile communications, that started in the 80's, mainly through WiFi and GSM, continues in our days with 4G and now with 5G mobile networks. The aim of this course is to describe the principles and architecture of modern wireless and mobile networks, focusing on their main functionalities. The course will cover:

Wireless/mobile Internet access:

- History, general principles of mobile communications
- Problems of Internet Protocol (IP) over wireless networks
- Wireless communications – Modulation, transmission
- Wireless networks – WLANS
- IP mobility support

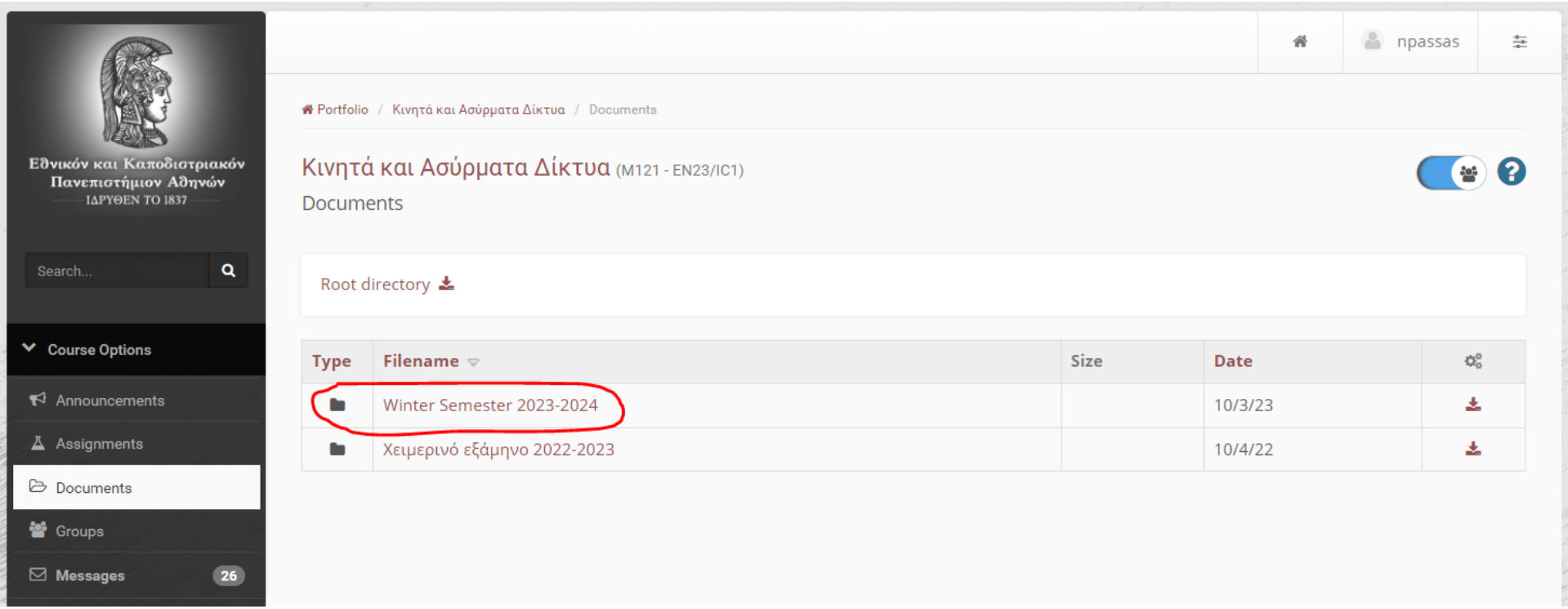
Mobile Networks:

- 4G networks – Architecture and operation
- 5G architecture
- Quality of Service / Quality of Experience support in modern networks
- Radio resource management
- Interference mitigation/management
- Mobility support in mobile networks

The course also includes an individual assignment for the students, in the form of a 15-minute presentation on a relevant subject. A list of

More

Course Description +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Announcement	Date
Πρώτη διάλεξη Τετάρτη 04/10/2023 στις 14:15 - First lecture Wednesday 04/10/2023 at 14:15 Η πρώτη διάλεξη του μεταπτυχιακού μαθήματος "Κινητά και Ασύρματα Δίκτυα" θα πραγματοποιηθεί την **Τετάρτη 4 Οκτωβρίου 2023 στις 14:15** στην αίθουσα Ε. Οι φοιτητές παρακαλούνται να εγγραφούν στη σελίδα του μαθήματος στο eclass για να ενημερώνονται από τ... More	today at 3:39 PM
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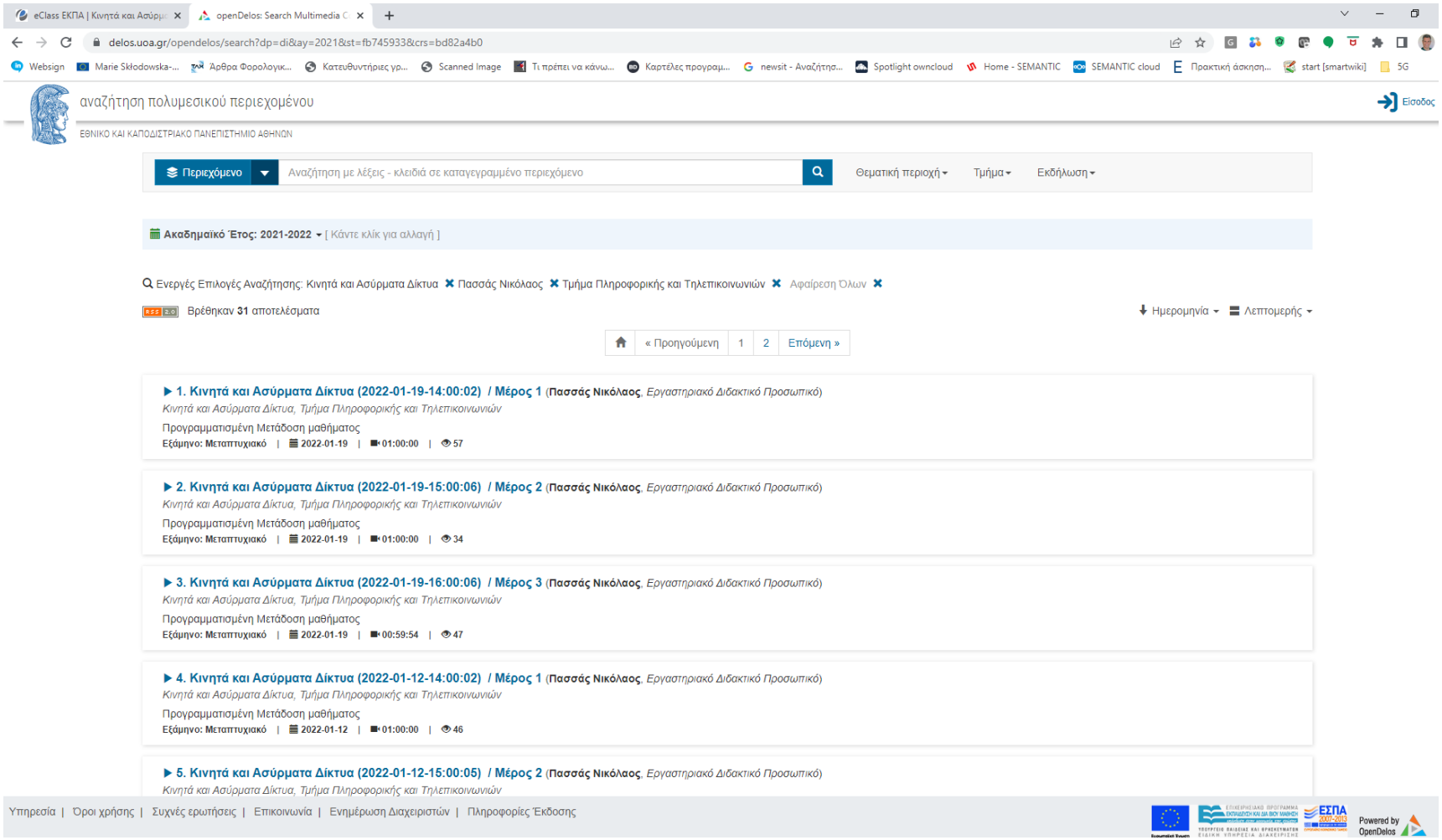
Αναβολή αυριανής εξέτασης https://www.di.uoa.gr/announcements/1914 More	Tuesday, February 7, 2023 at 7:08 PM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Θεματική περιοχή
Τμήμα
Εκδήλωση
Ακαδημαϊκό Έτος: 2021-2022 [Κάντε κλίκ για αλλαγή]
Ενεργές Επιλογές Αναζήτησης: Κινητά και Ασύρματα Δίκτυα Πασσάς Νικόλαος Τμήμα Πληροφορικής και Τηλεπικοινωνιών Αφαίρεση Όλων
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▶ 5. Κινητά και Ασύρματα Δίκτυα (2022-01-12-15:00:05) / Μέρος 2 (Πασσάς Νικόλαος, Εργαστηριακό Διδακτικό Προσωπικό)
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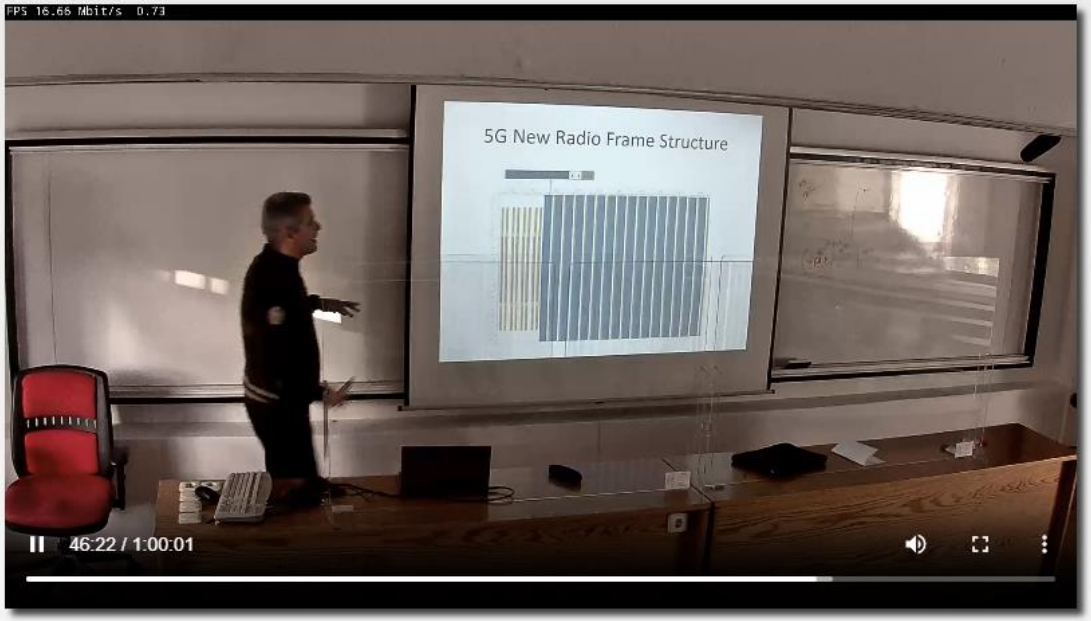

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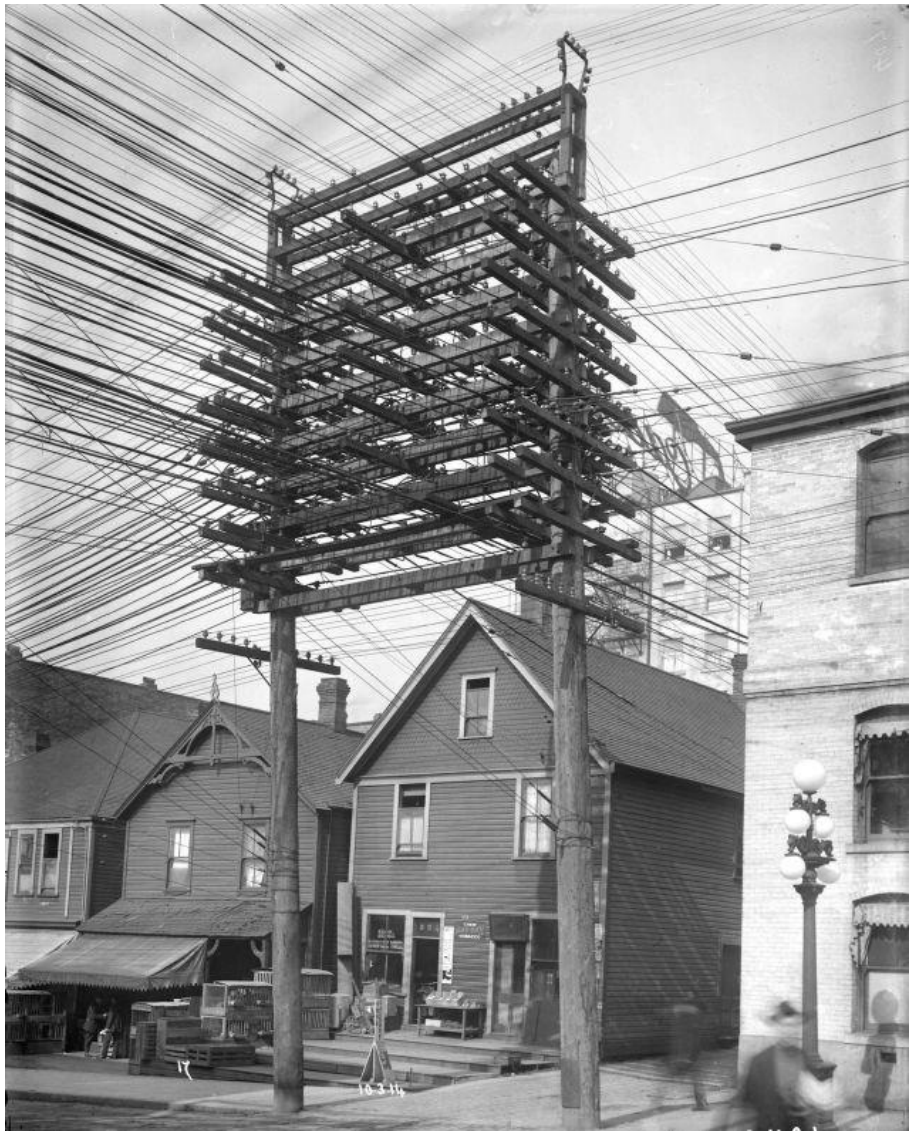
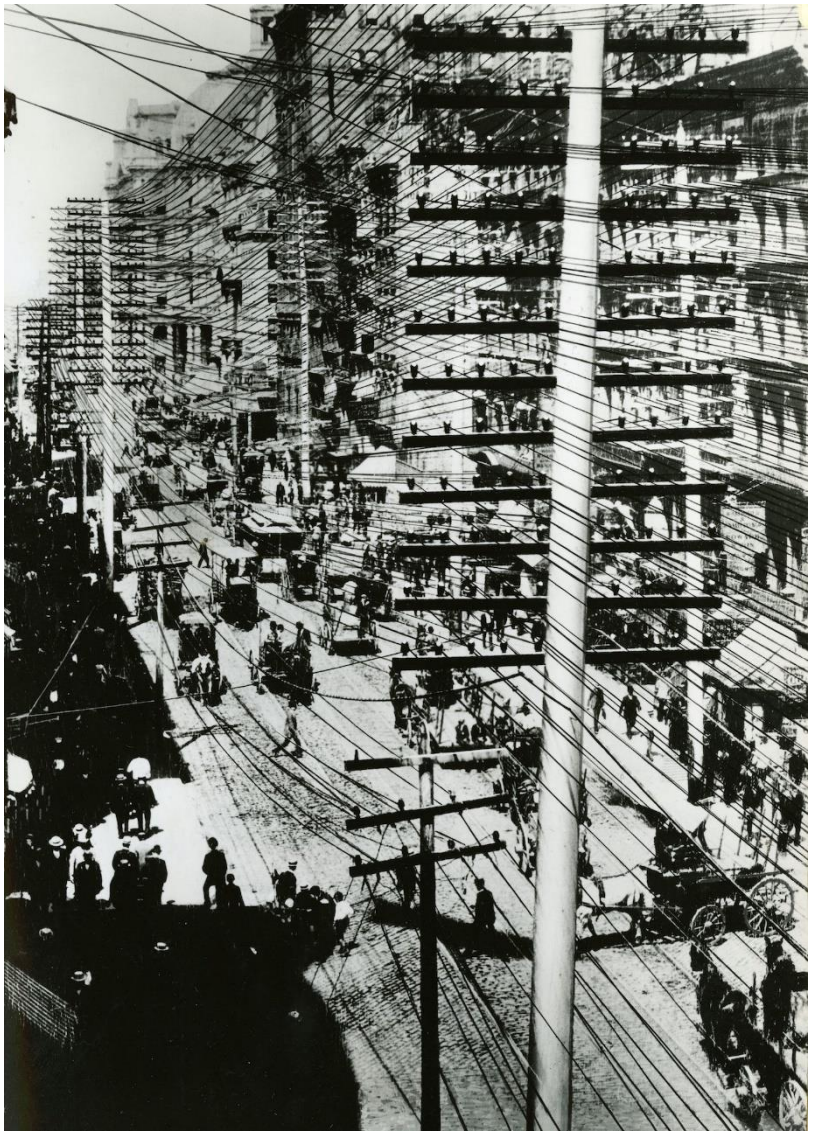
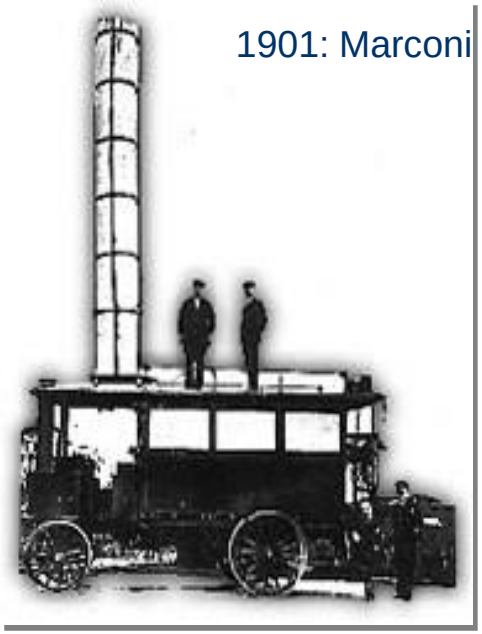
Before wireless communications





Mobile communications start

1901: Marconi

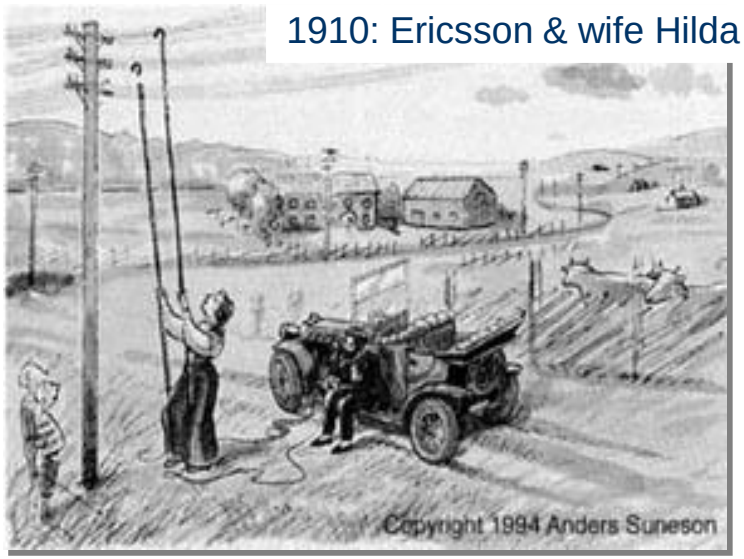


"Are you ready"

"S"

Mobile Communications at the beginning of the 20th century

1910: Ericsson & wife Hilda



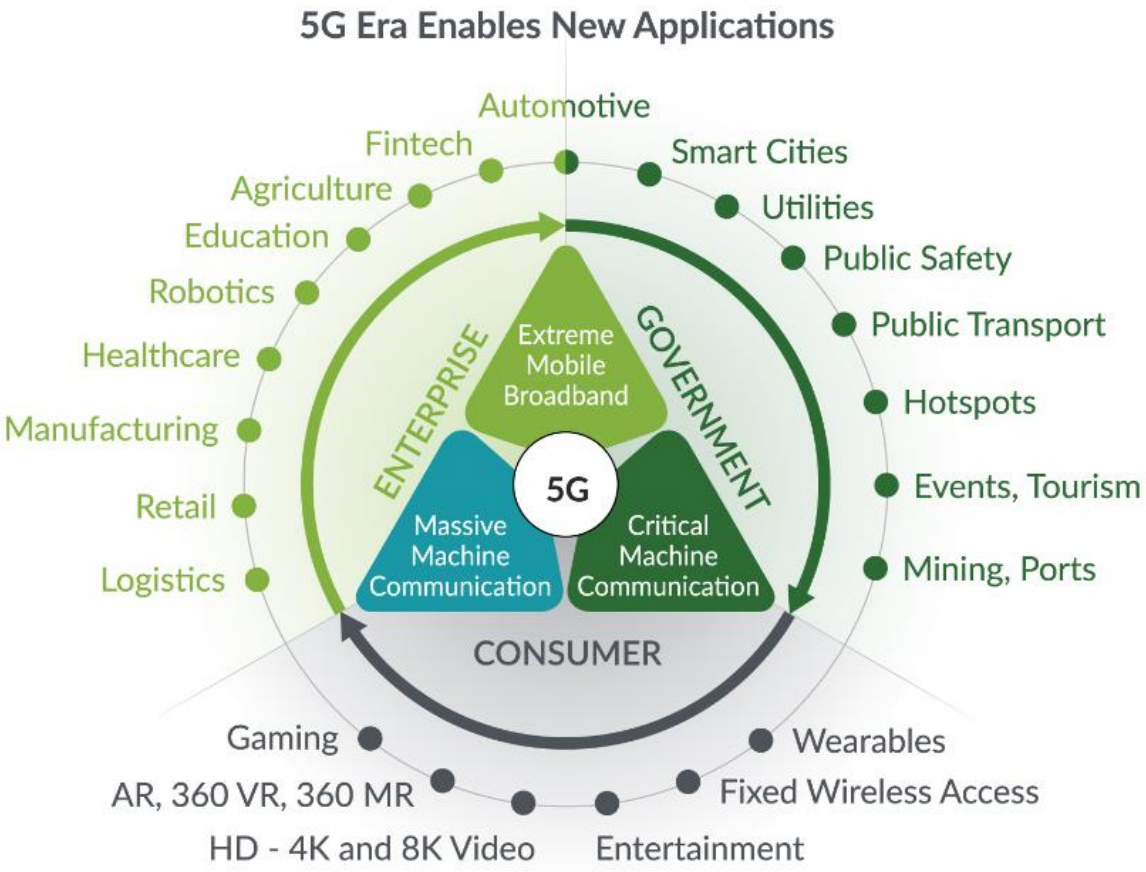
1924: First mobile radio telephone

Courtesy of Rich Howard

Generations of Mobile Networks

- 0G: Briefcase-size mobile radio telephones
- 1G: *Analog* cellular telephony (end ‘70s)
- 2G: *Digital* cellular telephony (beg ’90’s)
- 3G: *High-speed* digital cellular telephony (including *video telephony*) (beg ’00)
- 4G: IP-based “anytime, anywhere” voice, data, and multimedia telephony at *faster* data rates than 3G (beg ’10)
- 5G: 10-times faster data rates, much more flexible in mobility, Internet of Things (IoT) support (cheap, low energy, massive number of devices) (beg ’20)

New applications



Through the years

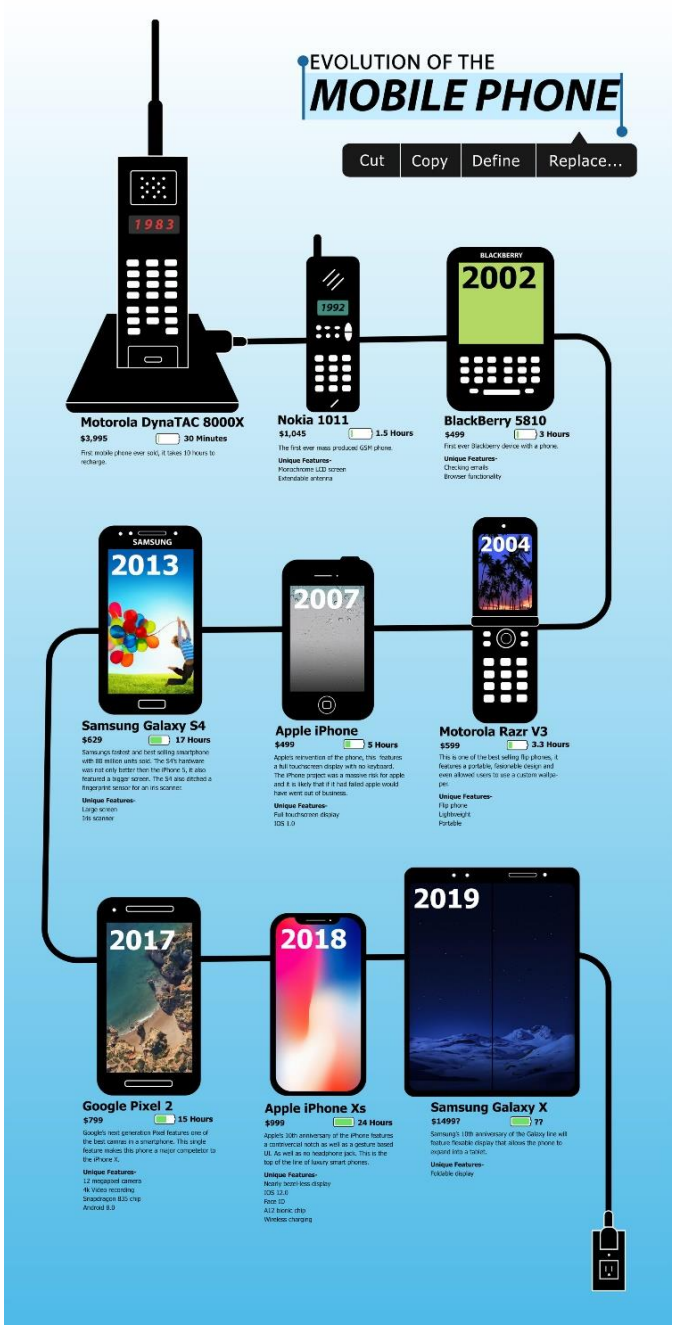
- The first official mobile phone used in Sweden by the Swedish police in 1946; could make 6 phone calls before car's battery was drained

- development of first cell phone (creation of towers/cells at Bell Labs in 1947

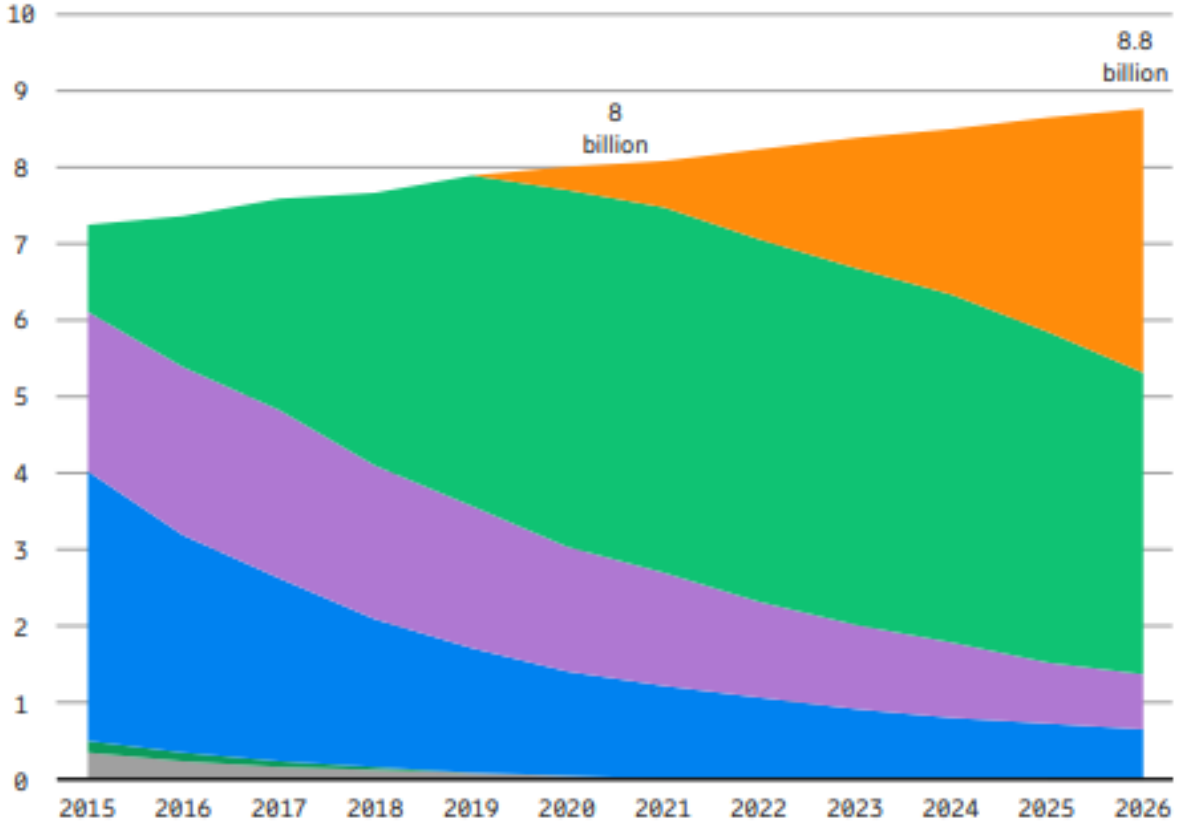
- 1983 Motorola DynaTAC 8000X made commercially available: 2 lbs (900gr), $3,500

- 1991 Motorola MicroTac Lite (350gr) the lightest phone: $1,000

Through the years



Mobile Subscriptions



3.5bn

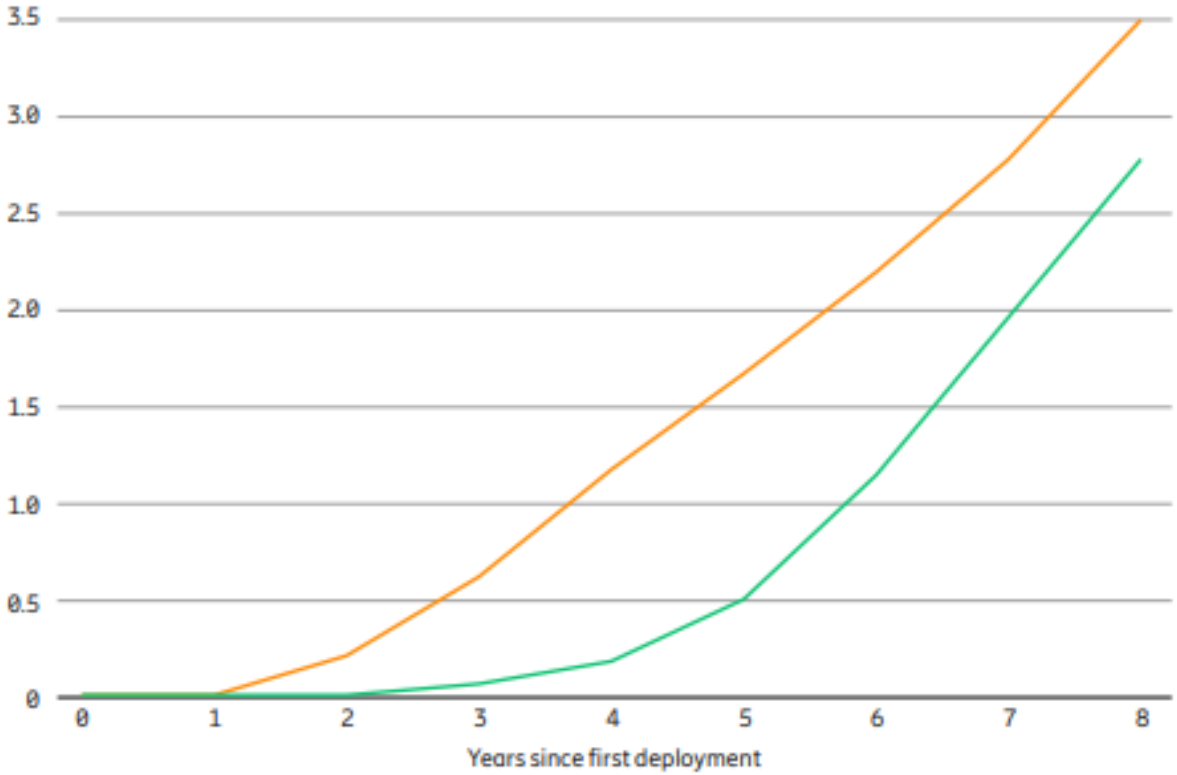
In 2026, 3.5 billion 5G subscriptions are forecast.

- 5G
- LTE (4G)
- WCDMA/HSPA (3G)
- GSM/EDGE-only (2G)
- TD-SCDMA (3G)
- CDMA-only (2G/3G)

Note: IoT connections are not included in this graph. Fixed wireless access (FWA) connections are included.

[1] GSA (April 2021).
[2] A 5G subscription is counted as such when associated with a device that supports New Radio (NR), as specified in 3GPP Release 15, and is connected to a 5G-enabled network.

4G/5G subscribers

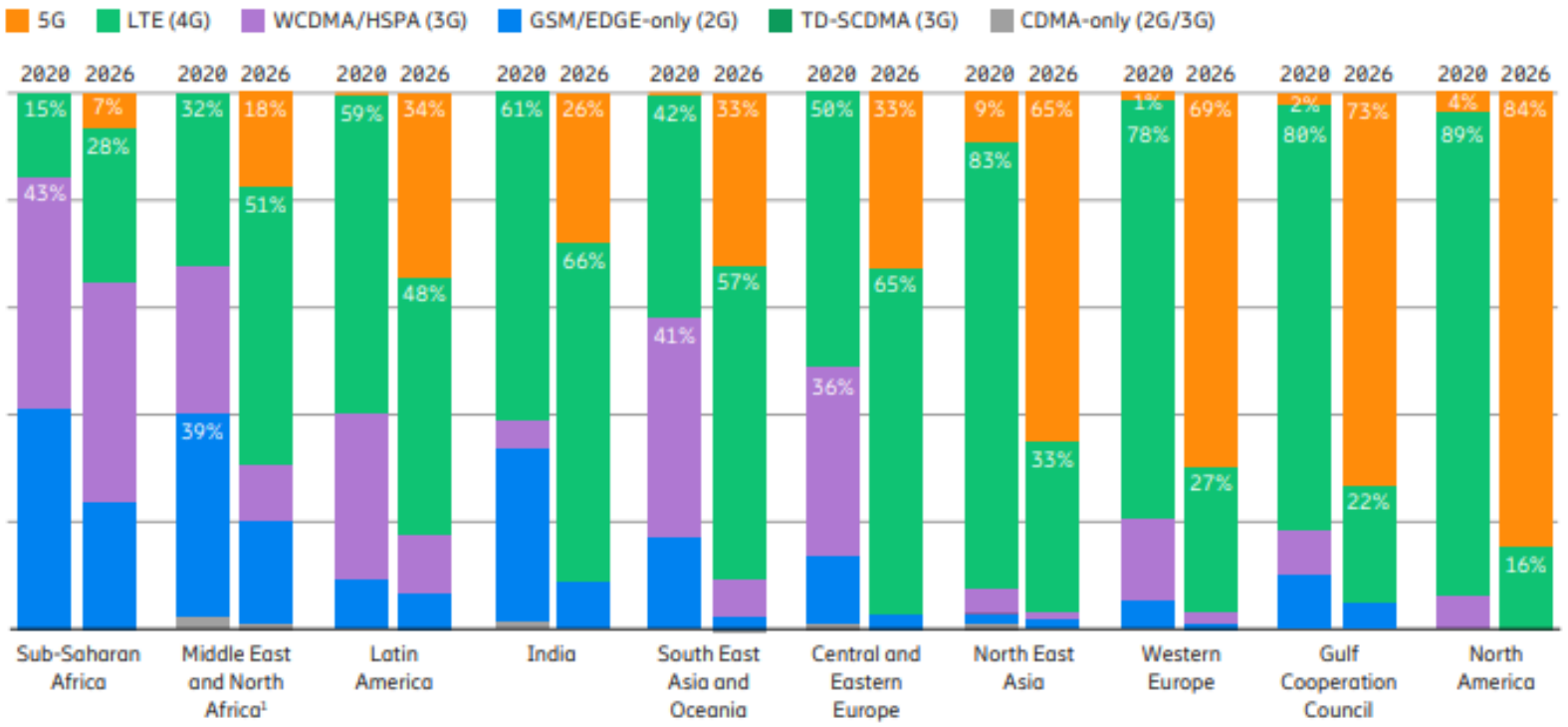


5G subscription uptake is expected to be faster than for 4G.

5G (2018–2026)

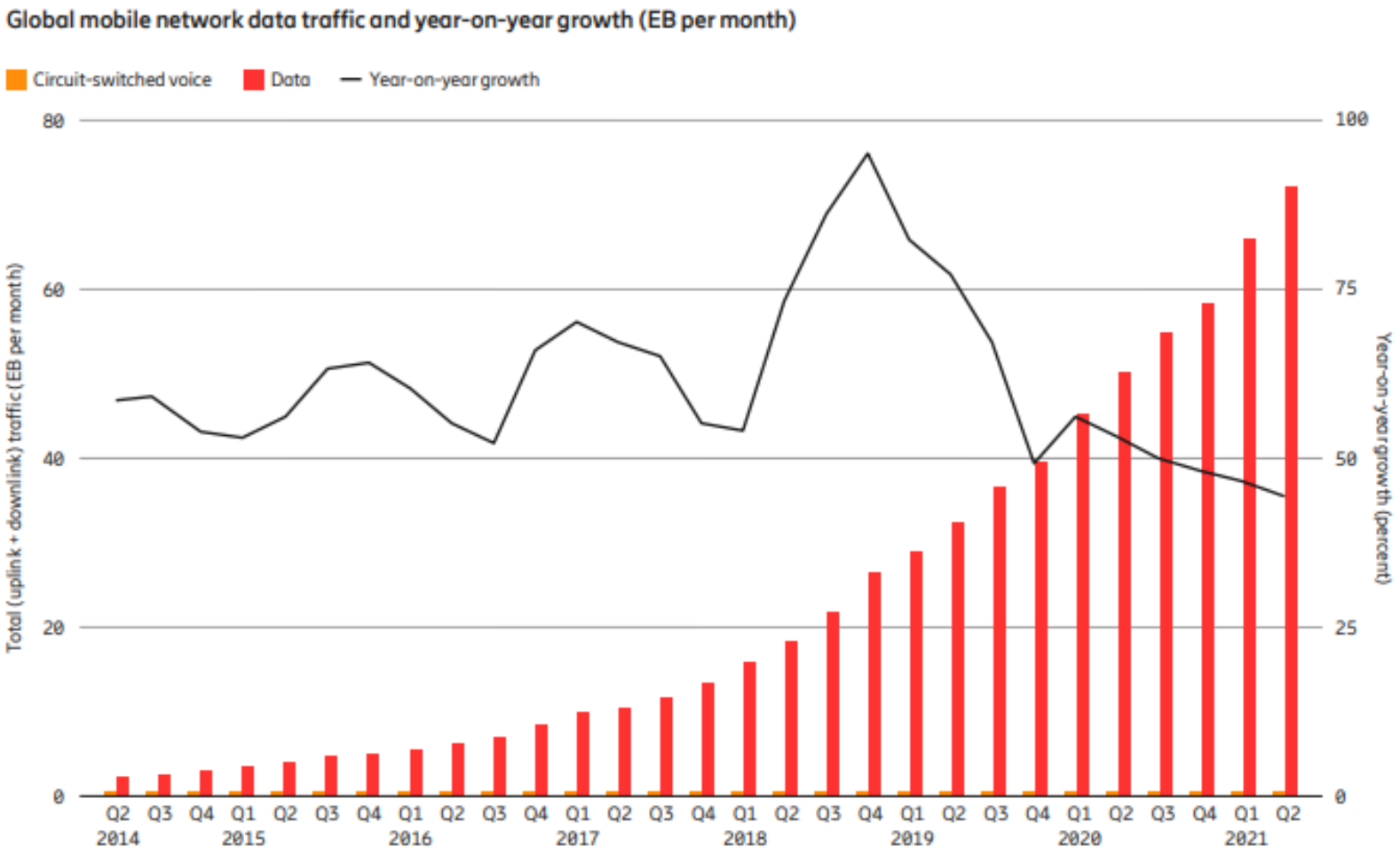
4G (2009–2017)

Subscriptions per area

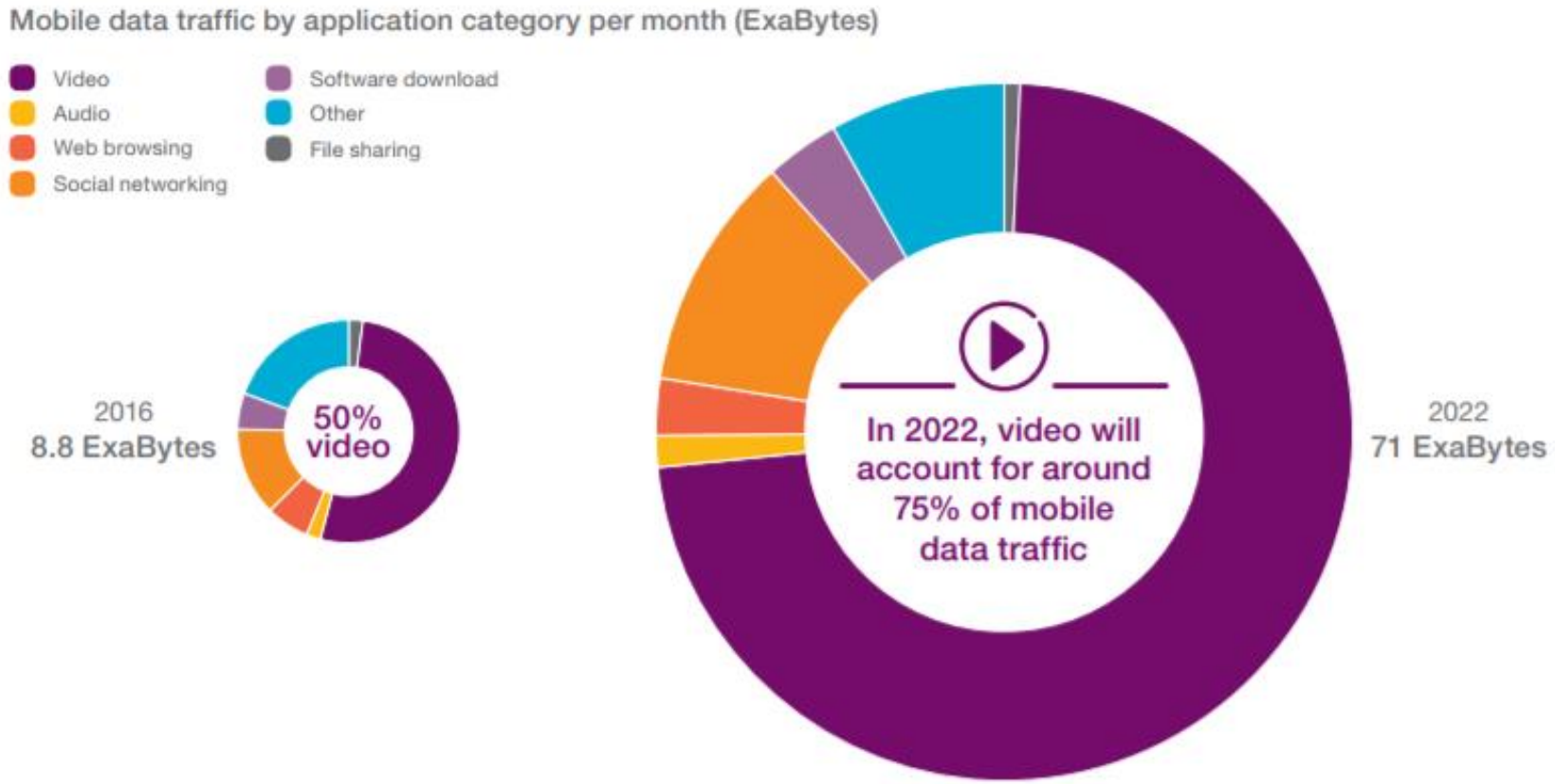


Note: Except for 5G, technologies with less than 1 percent of subscriptions are not shown on the graph.

Mobile data traffic

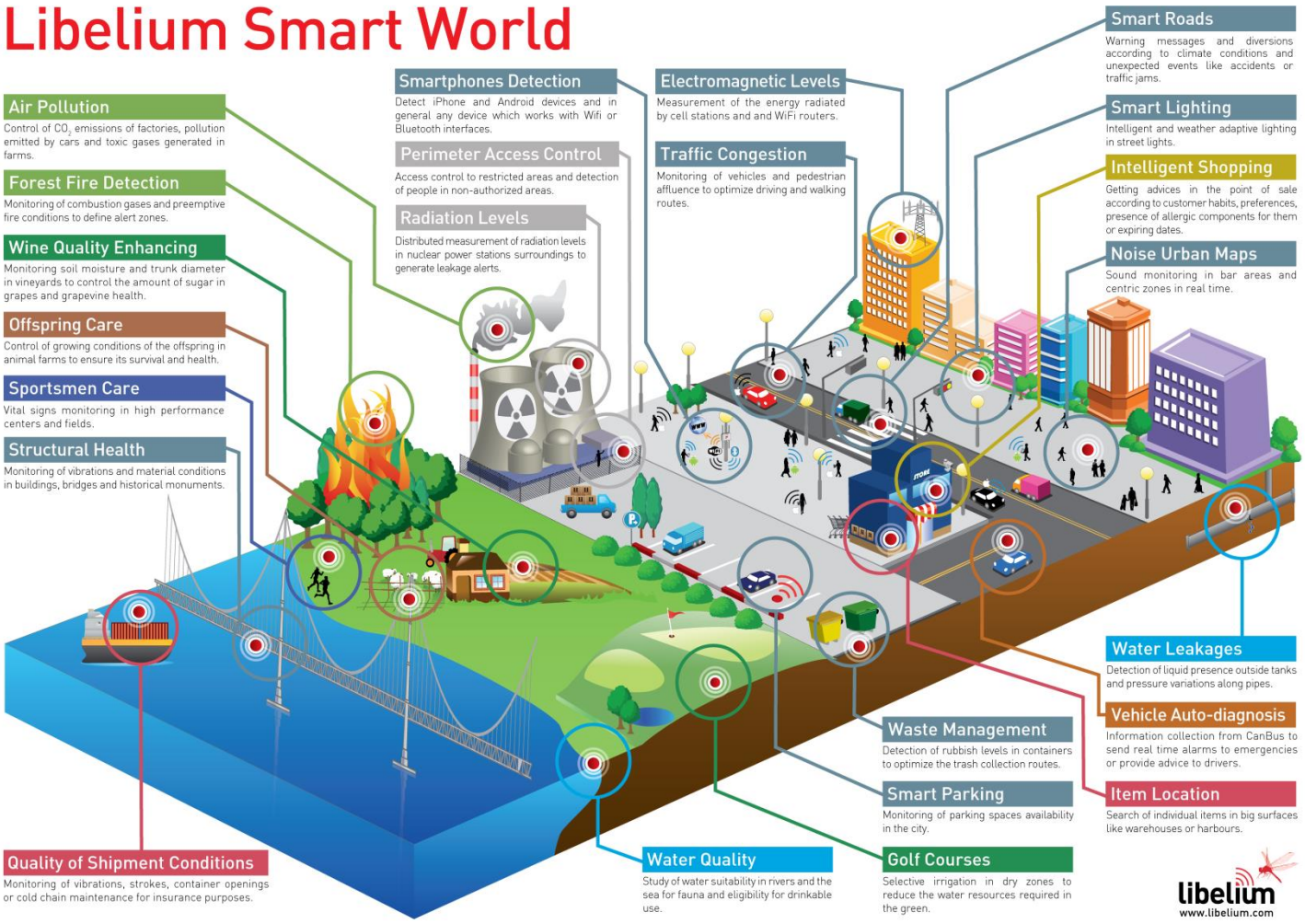


Mobile data traffic

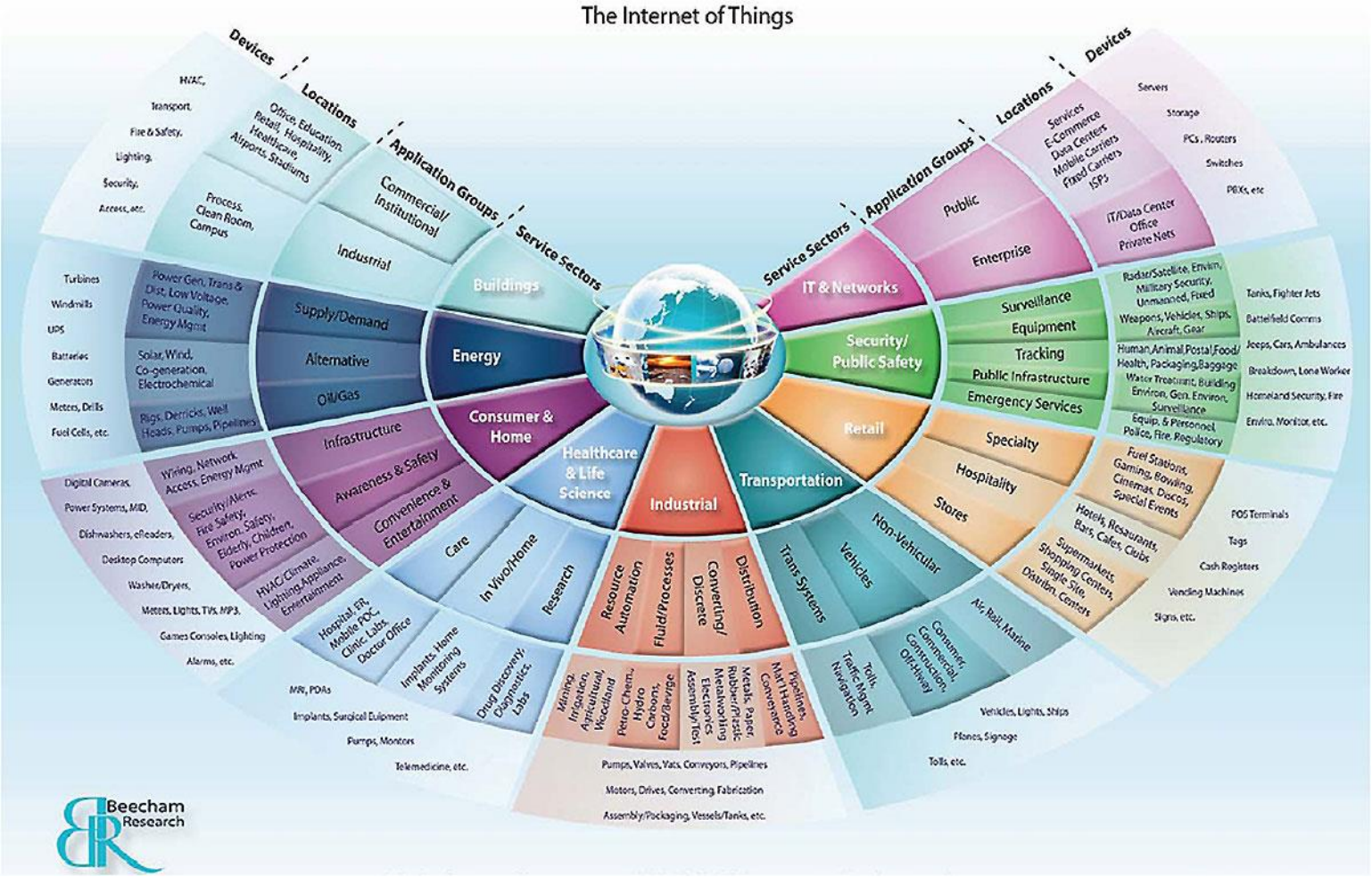


1 ExaByte = 10^{18} bytes

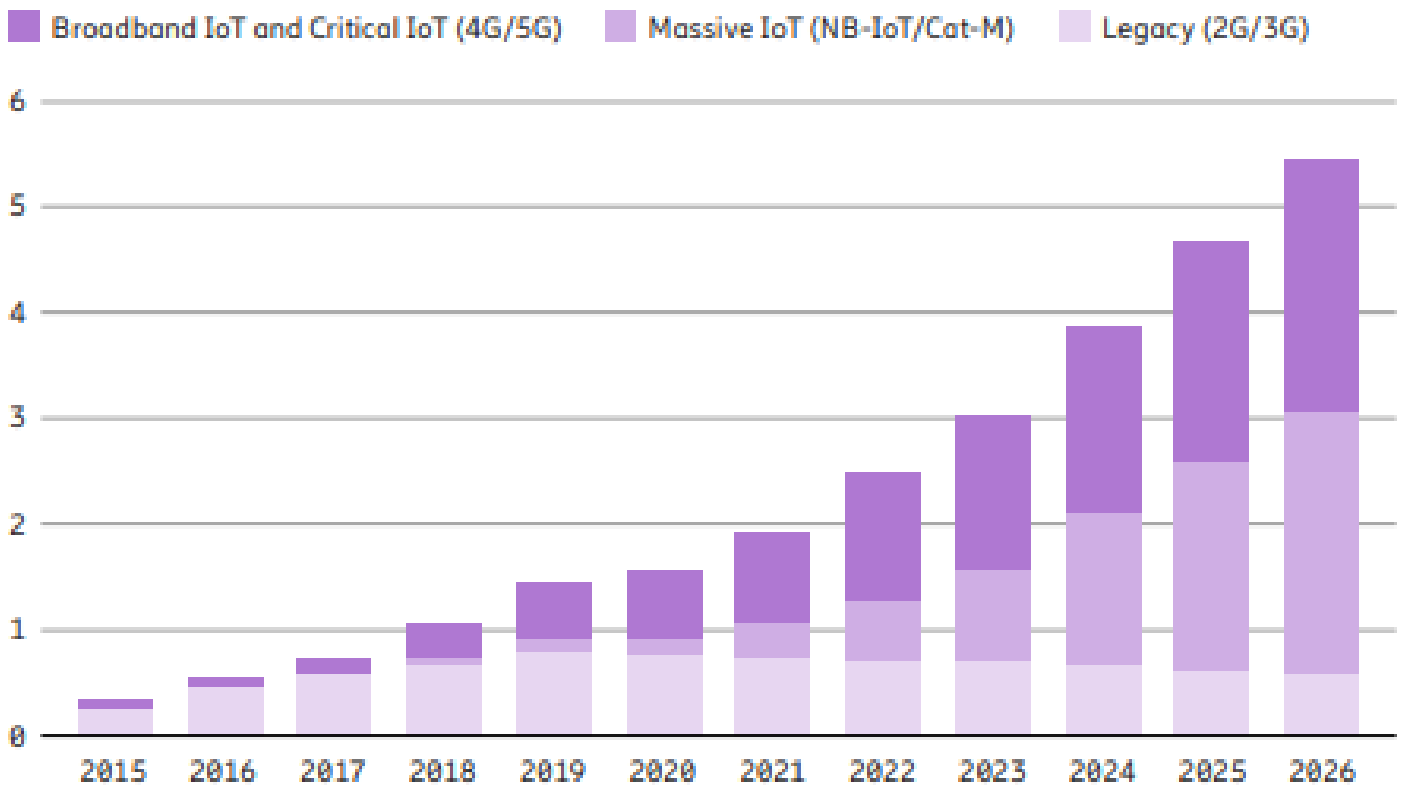
Internet of Things (IoT)



Internet of Things (IoT)



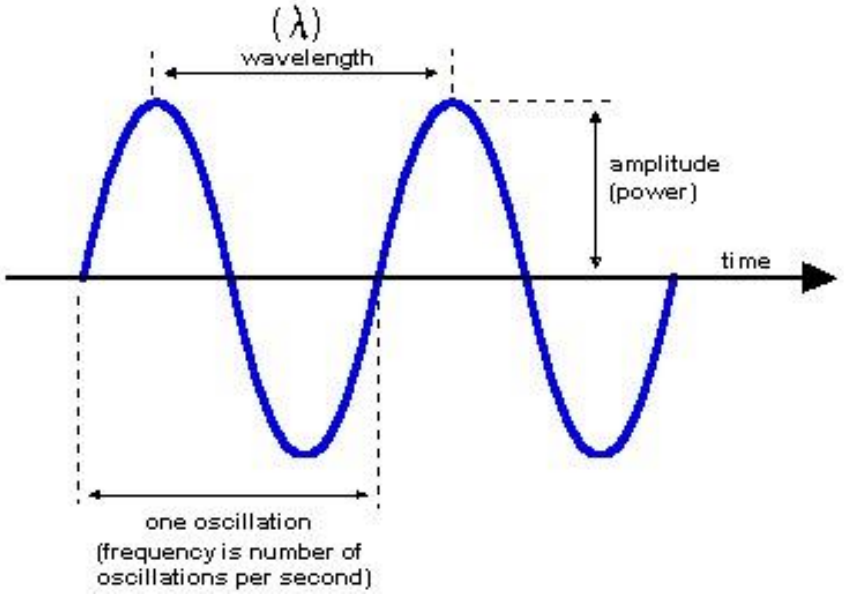
IoT growth

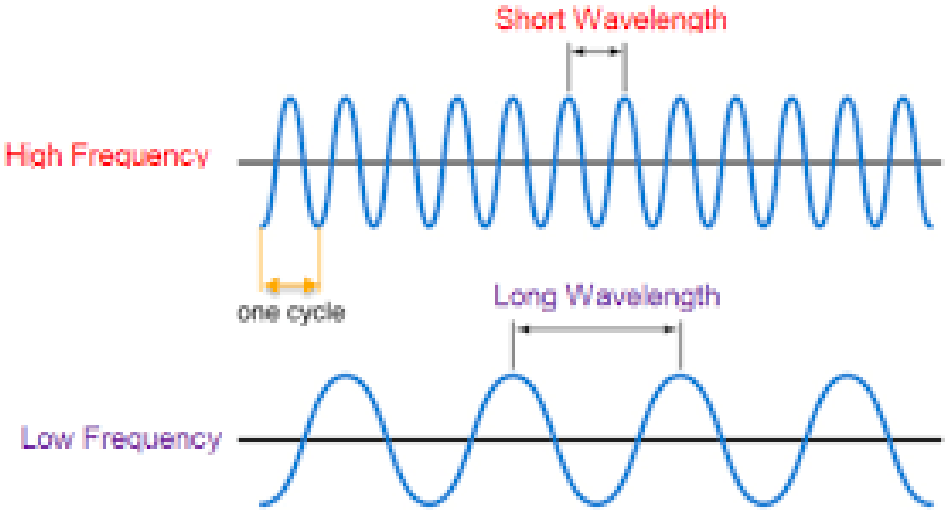


IoT	2020	2026	CAGR
Wide-area IoT	1.7	5.8	23%
Cellular IoT[2]	1.6	5.4	23%
Short-range IoT	10.7	20.6	12%
Total	**12.4**	**26.4**	**13%**

Frequency and Wave length

- Relationship:
- $\lambda = c/f$
- wave length λ,
- speed of light c $\cong 3x10^8 m/s$,
- frequency f





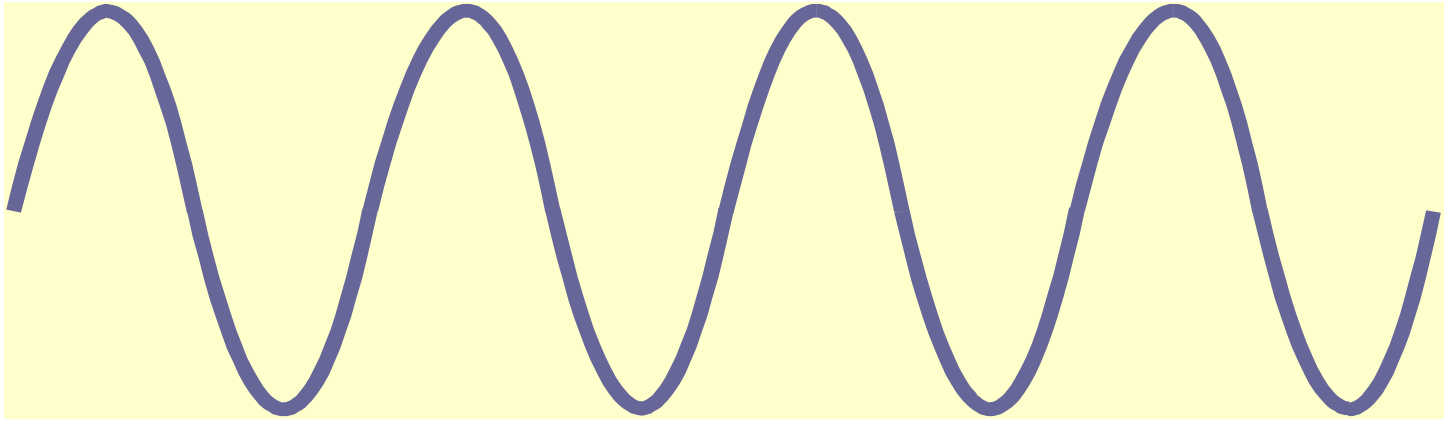
Frequency of transverse waves

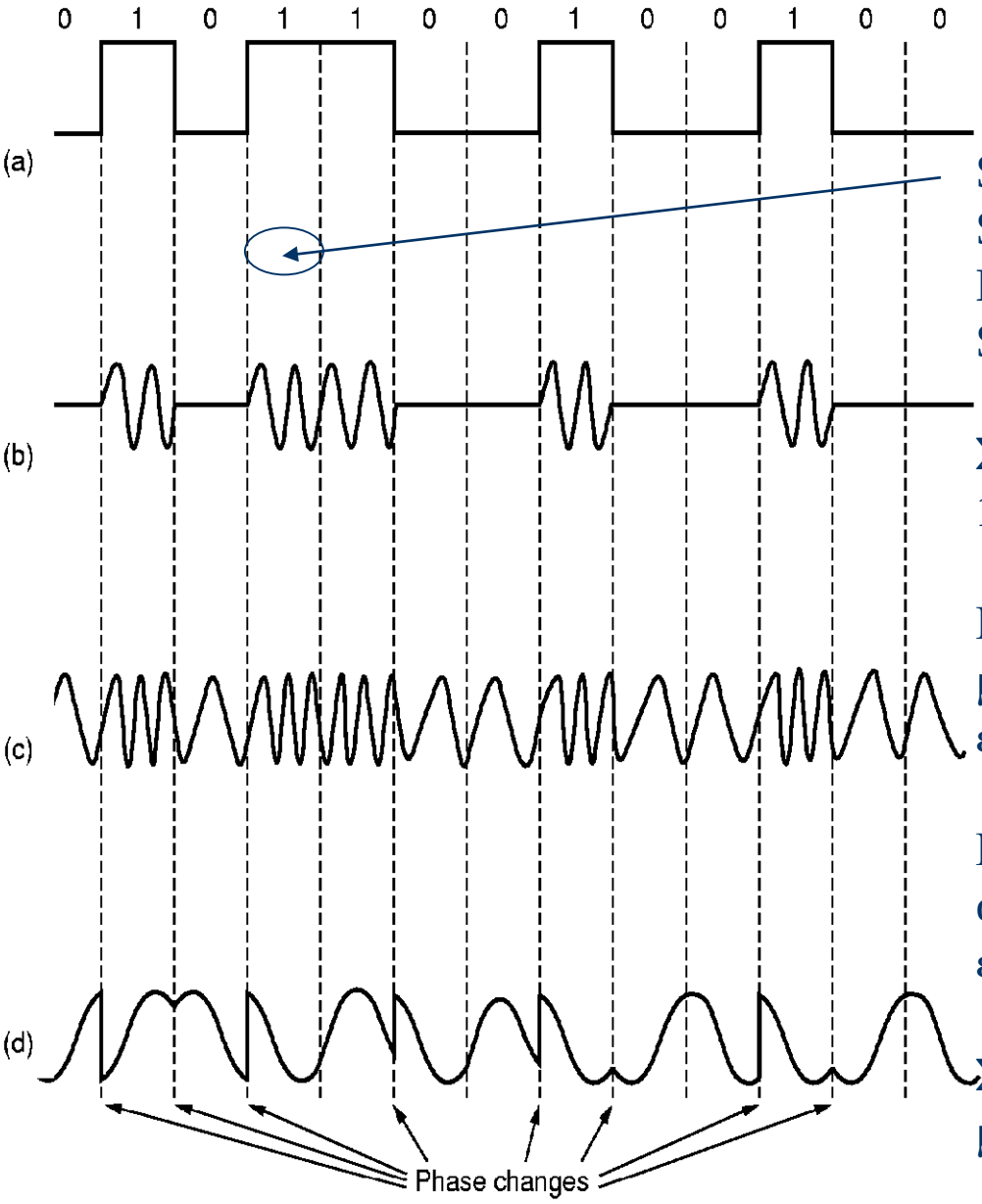
The **frequency** is the number of waves passing any point each second.

- frequency = number of waves past a point / time
- frequency is measured in hertz (Hz)
- 1 wave per second = 1 Hz

If this set of transverse waves pass a point in one second, what is the frequency?

4 Hz





Sample
Sample Rate=Samples/sec (Baud Rate)
During one Sample one **"symbol"** is sent
Symbol=piece of information=level of voltage

Στην απλούστερη περίπτωση:
1 symbol = 1 bit (0/1) = voltage/no voltage

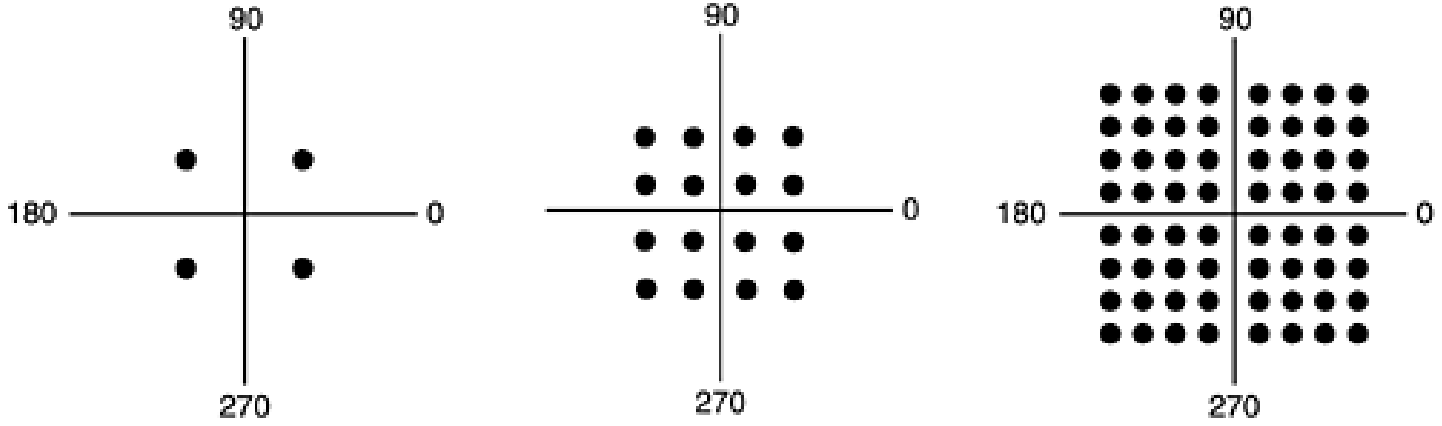
Για να αυξήσουμε την ταχύτητα μετάδοσης δε μπορούμε να μειώνουμε το sample επ' άπειρον.

Μπορούμε όμως να αυξάνουμε τον αριθμό των πιθανών symbols (επιπέδων έντασης μετάδοσης, δηλαδή εύρους σήματος)

Συνηθέστερος συνδυασμός της τεχνικής αυτής με PSK.

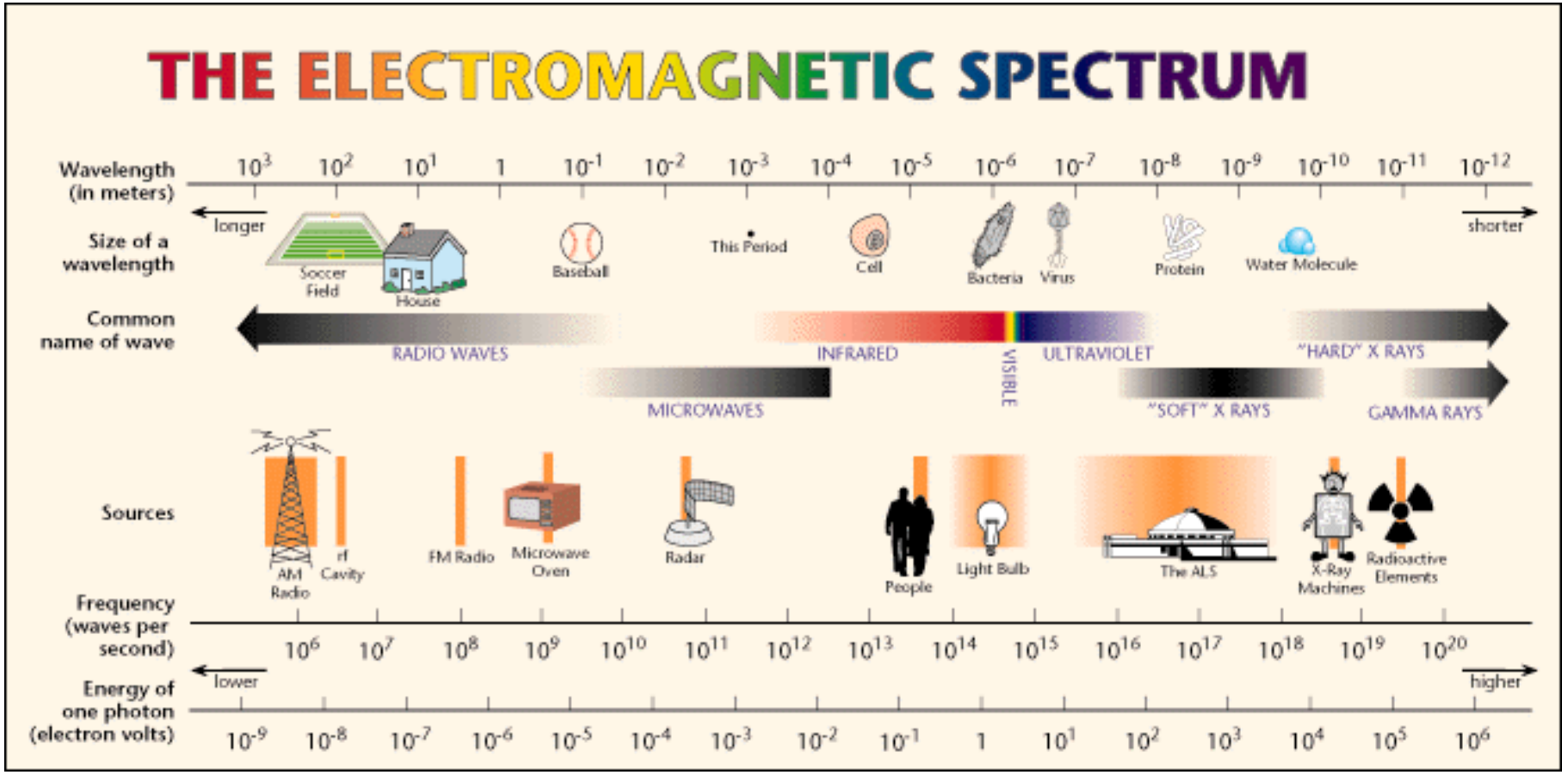
Multiple modulations

- QPSK (Quadrature Phase Shift Keying) = 4 phase shifts, 1 amplitude level, 2 bits/symbol
- QAM-16 = 4 phase shifts, 4 amplitude levels, 4 bits/symbol
- QAM-64 = 4 phase shifts, 16 amplitude levels, 6 bits/symbol



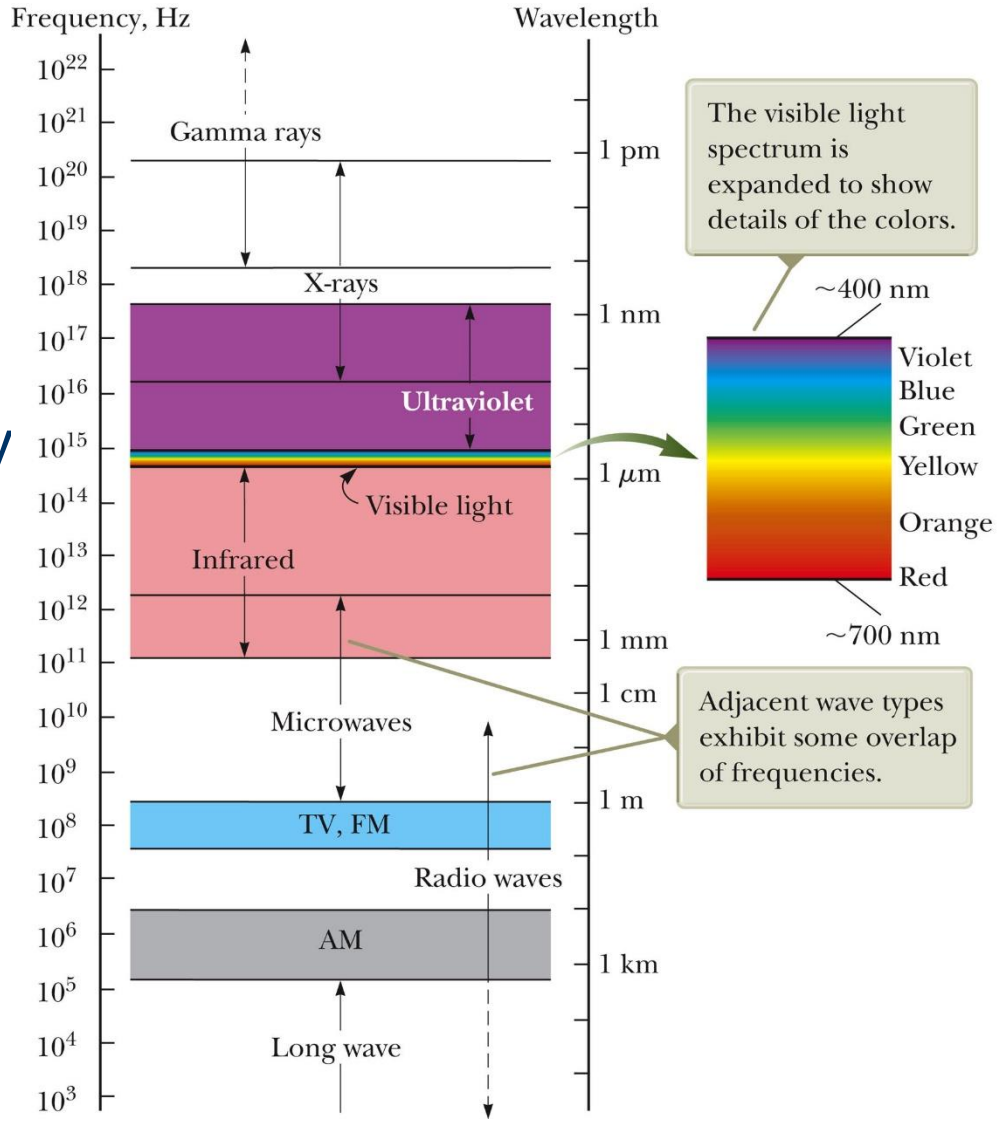
QPSK QAM-16 QAM-64

Electromagnetic spectrum

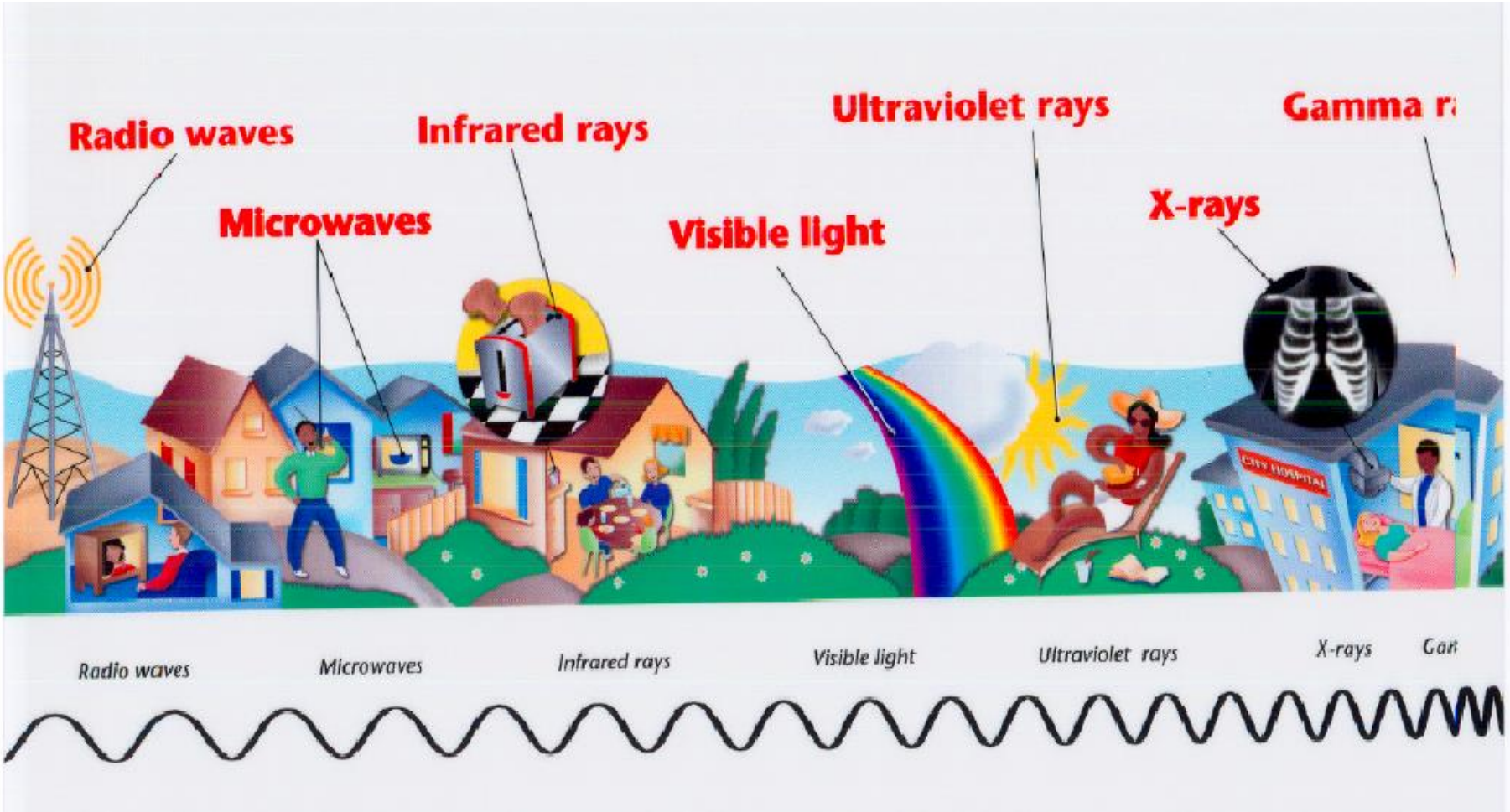


The EM Spectrum

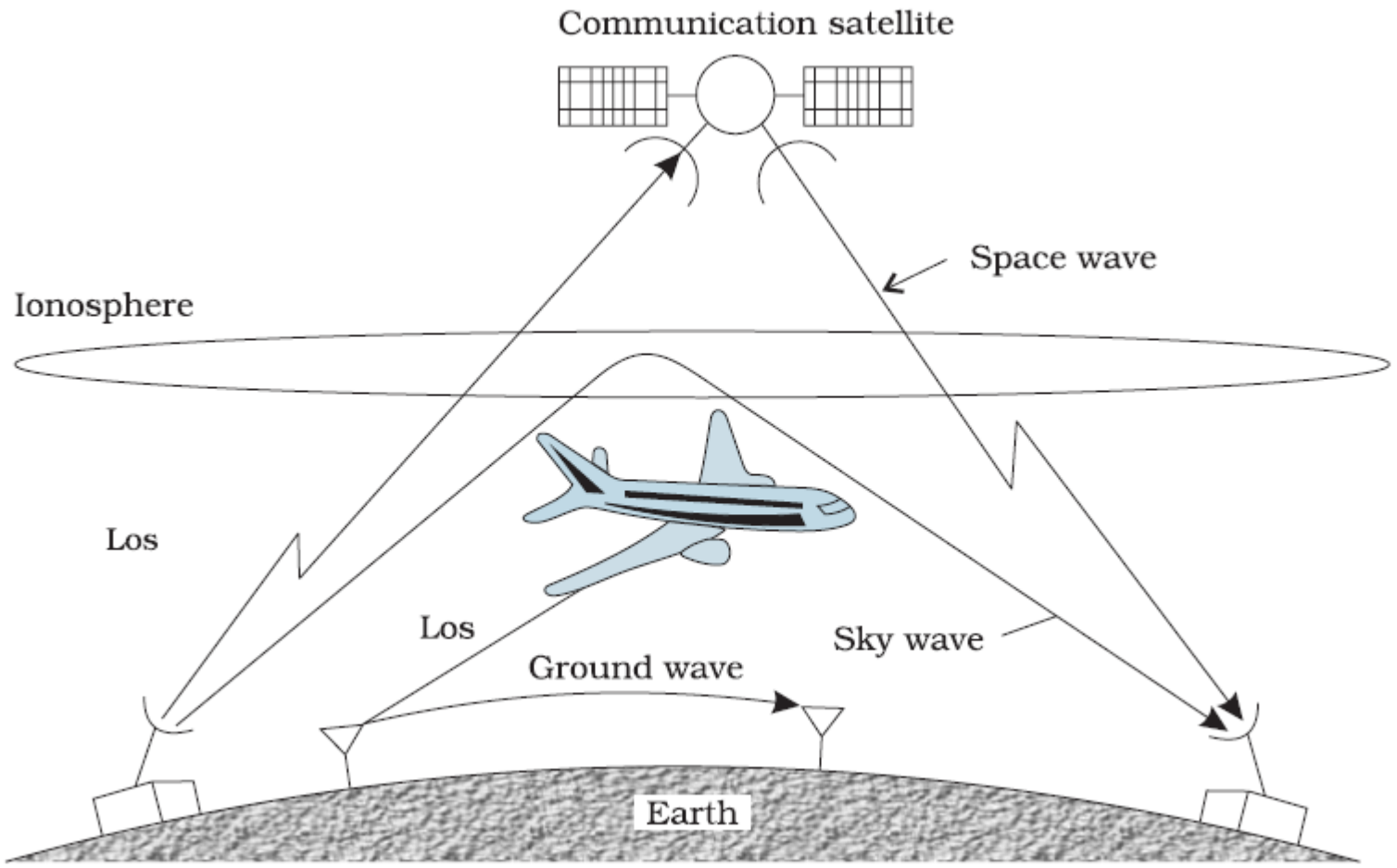
- Note the overlap between types of waves
- Visible light is a small portion of the spectrum.
- Types are distinguished by frequency or wavelength
- Signal behavior based on the frequency



Electromagnetic spectrum



Signal propagation

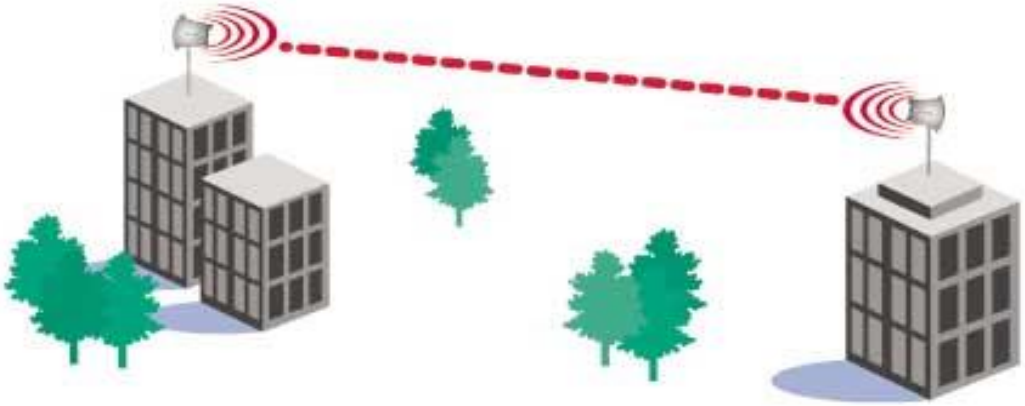


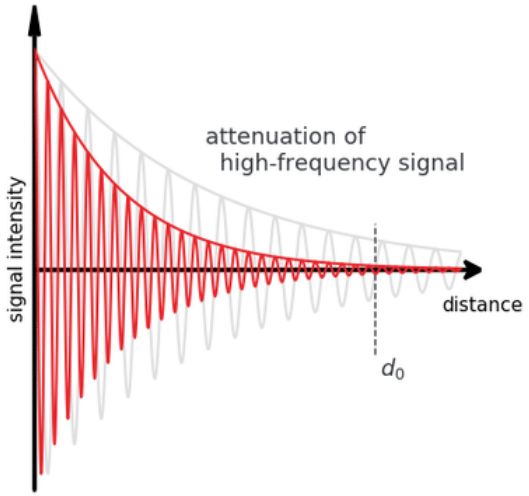
Signal propagation

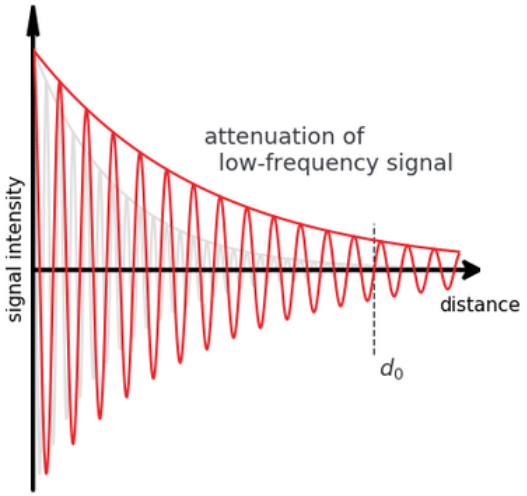
Classification Band	Initials	Frequency Range	Characteristics
Extremely low	ELF	< 300 Hz	Ground wave
Infra low	ILF	300 Hz - 3 kHz	
Very low	VLF	3 kHz - 30 kHz	
Low	LF	30 kHz - 300 kHz	
Medium	MF	300 kHz - 3 MHz	Ground/Sky wave
High	HF	3 MHz - 30 MHz	Sky wave
Very high	VHF	30 MHz - 300 MHz	Space wave
Ultra high	UHF	300 MHz - 3 GHz	
Super high	SHF	3 GHz - 30 GHz	
Extremely high	EHF	30 GHz - 300 GHz	
Tremendously high	THF	300 GHz - 3000 GHz	

Signal propagation

- Signal attenuation due to
  - Distance
  - Obstacles







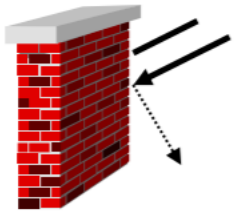
Signal propagation

Propagation in free space always like light (straight line)

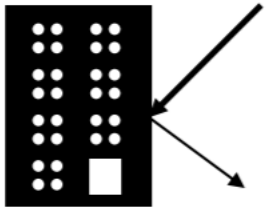
Receiving power proportional to $1/d^2$
(d = distance between sender and receiver)

Receiving power additionally influenced by

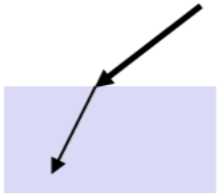
- fading (frequency dependent)
- shadowing
- reflection at large obstacles
- refraction depending on the density of a medium
- scattering at small obstacles
- diffraction at edges



shadowing



reflection

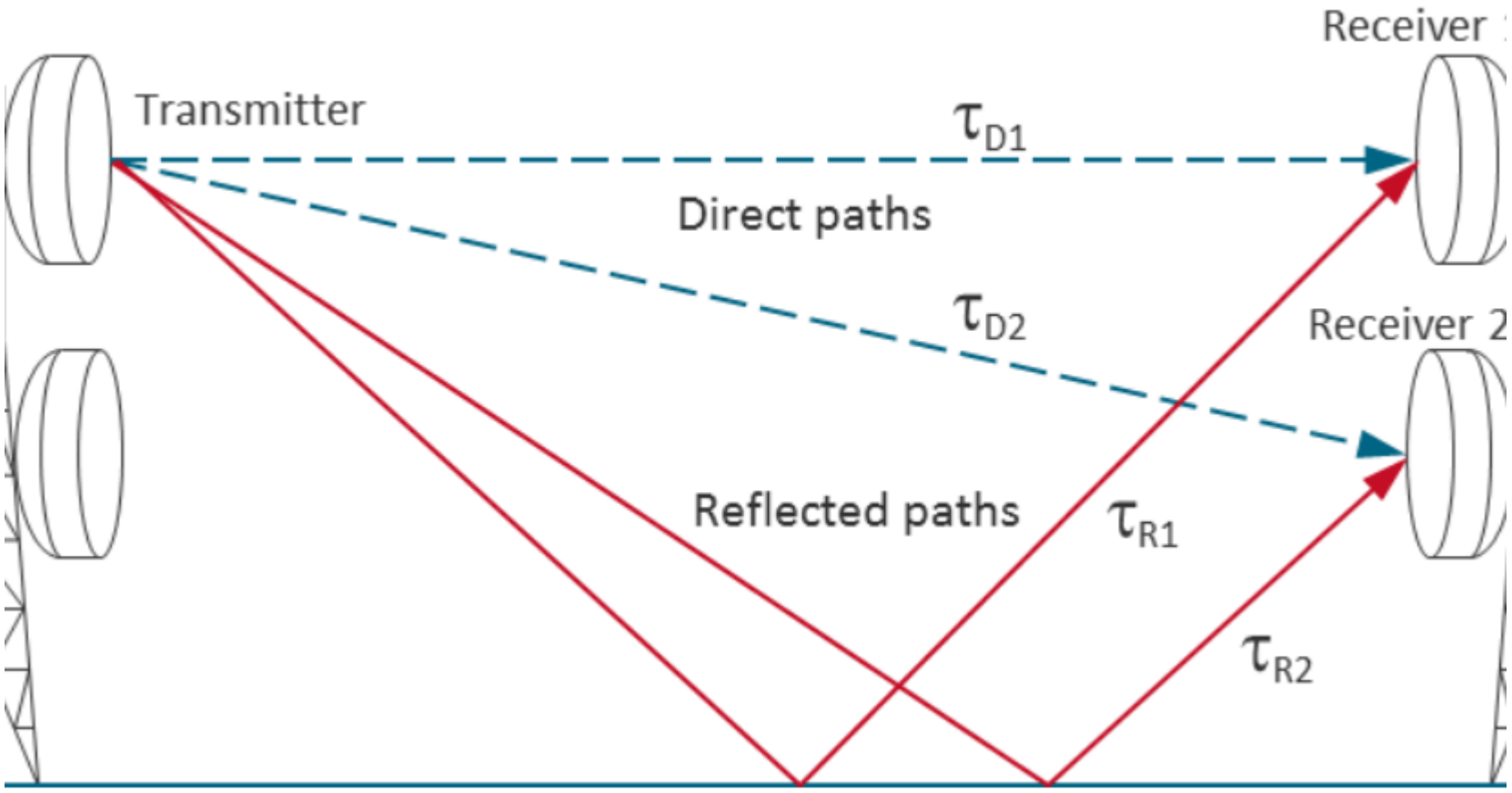


refraction

scattering

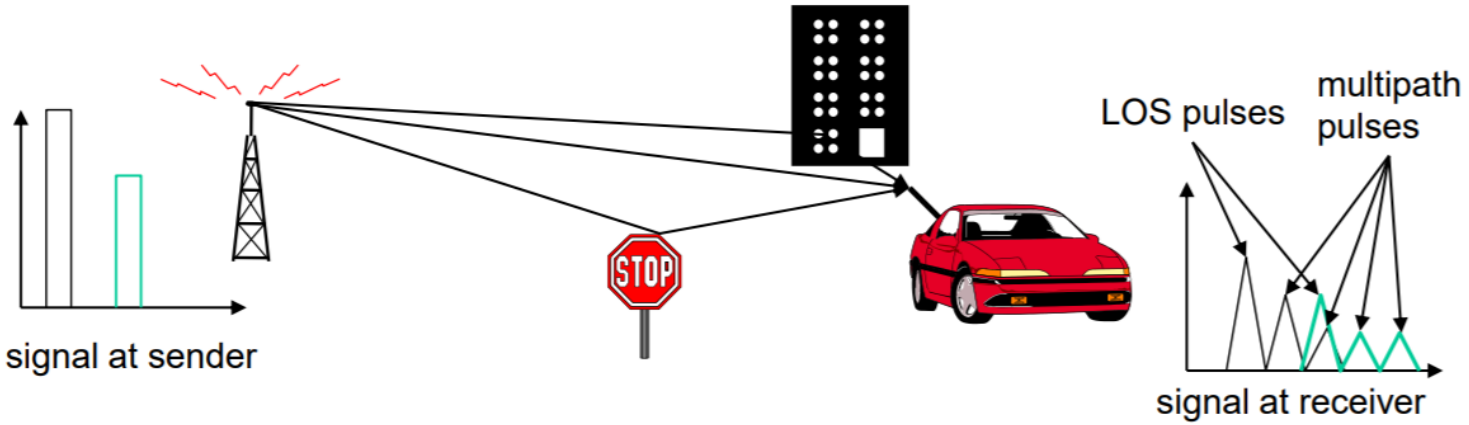
diffraction

Multipath propagation



Multipath propagation

Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction



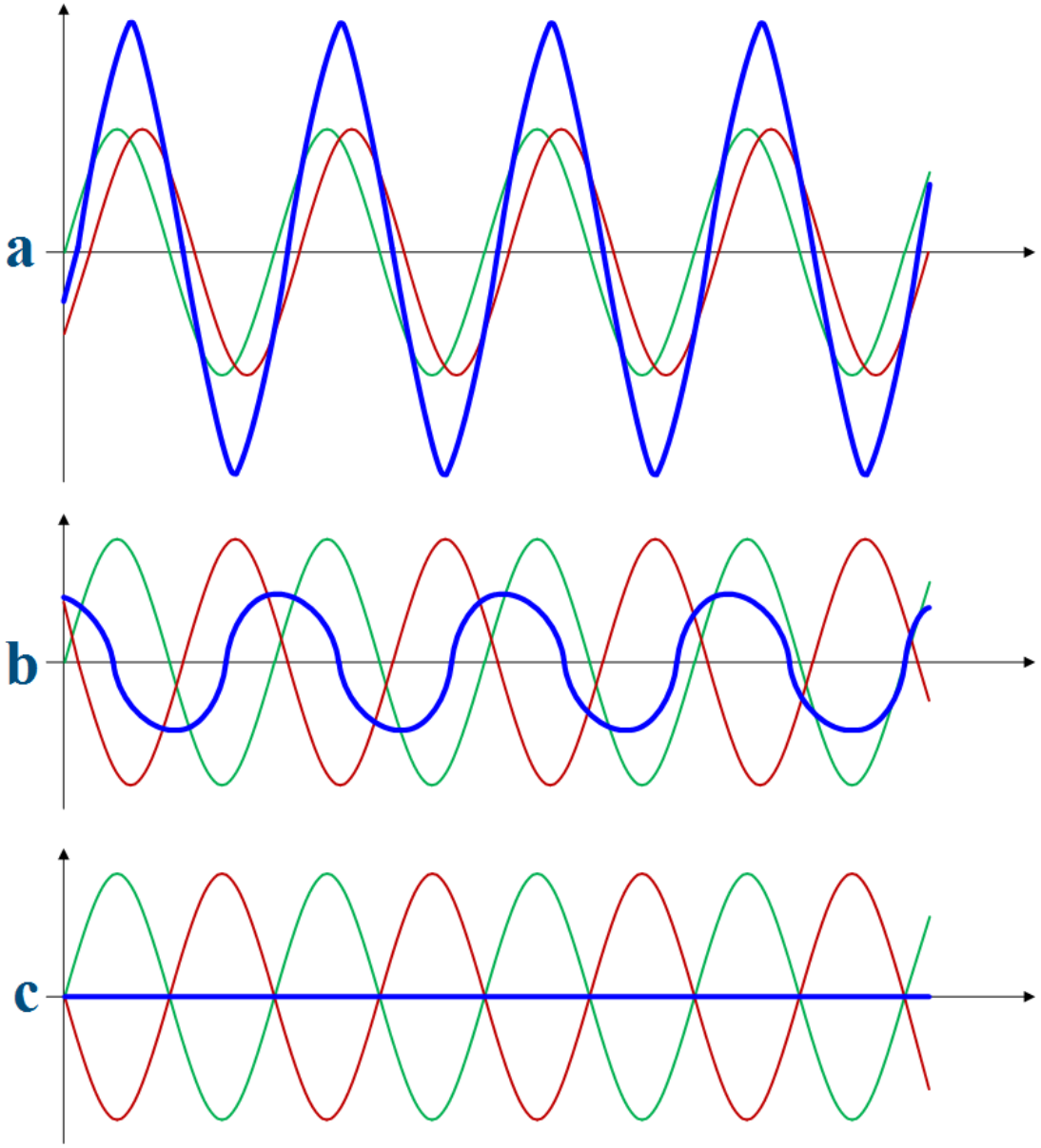
Time dispersion: signal is dispersed over time

➔ interference with “neighbor” symbols, Inter Symbol Interference (ISI)

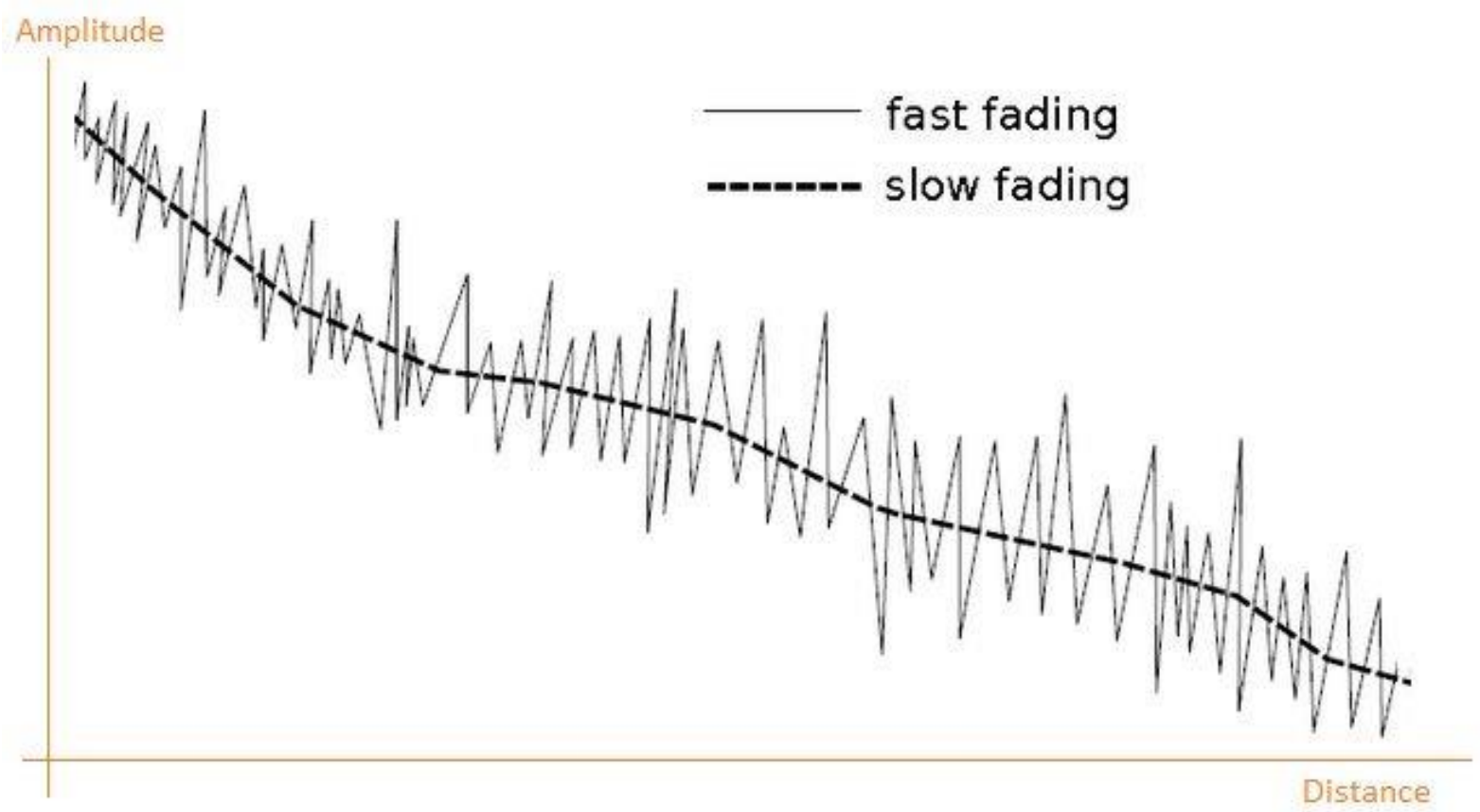
The signal reaches a receiver directly and phase shifted

➔ distorted signal depending on the phases of the different parts

Multipath propagation



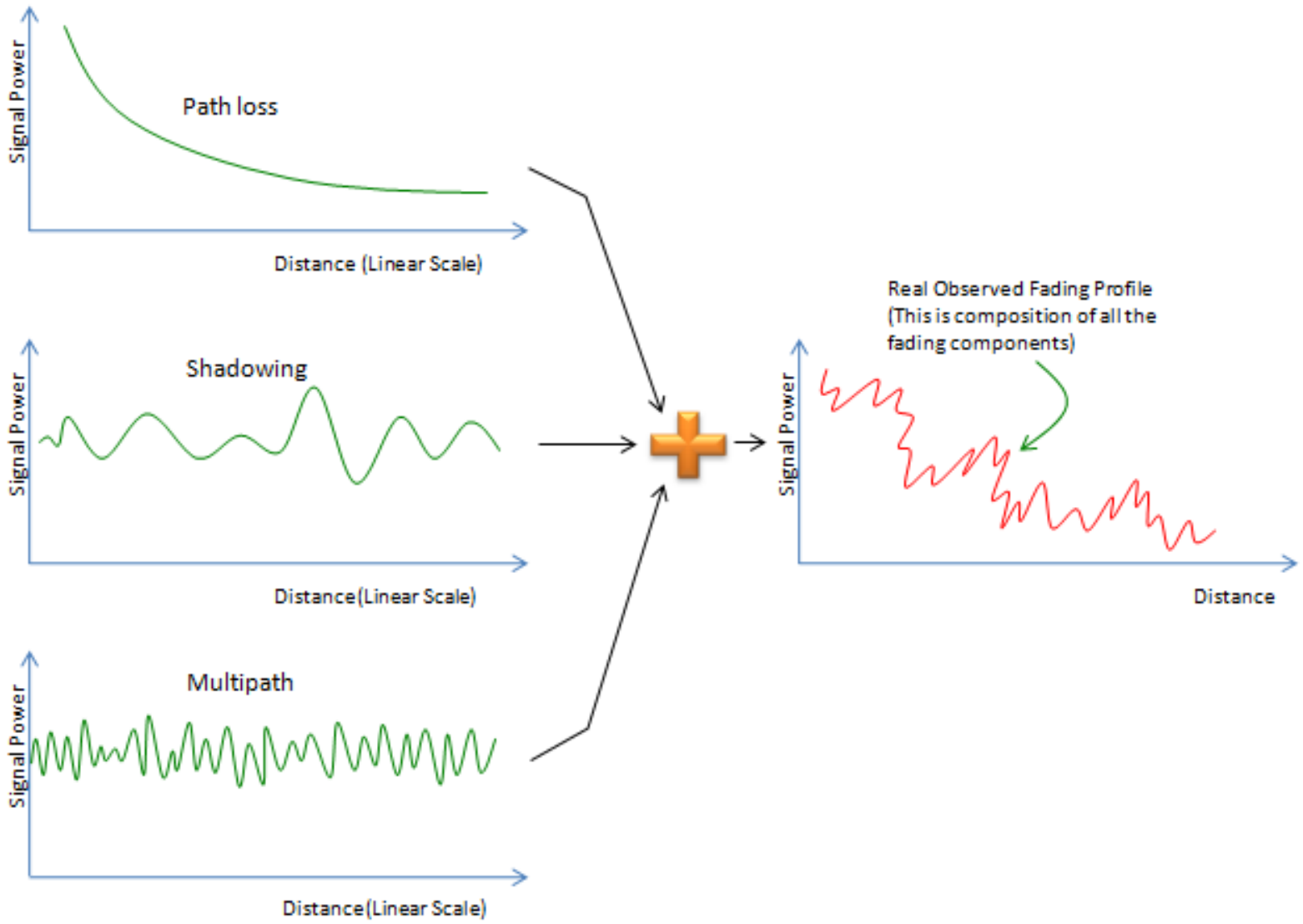
Fading



Fading

- Large-scale fading (slow - shadowing)
  - Long term variation in the mean signal level caused by the mobile unit moving into the shadow of surrounding objects
- Small-scale fading (fast - multipath)
  - Short term fluctuation in the signal amplitude caused by the local multipath

Fading


Signal Power
Path loss
Distance (Linear Scale)
Signal Power
Shadowing
Distance(Linear Scale)
Signal Power
Multipath
Distance(Linear Scale)
Real Observed Fading Profile
(This is composition of all the
fading components)
Signal Power
Distance

Noise and interference

- Transmissions from other sources
  - Many devices transmitting in the same frequency
  - E.g., 2.4 GHz wireless telephone, Bluetooth and Wi-Fi use the same frequency band
  - Electromagnetic noise (e.g., microwave oven)

Effects of mobility

Channel characteristics change over time and location

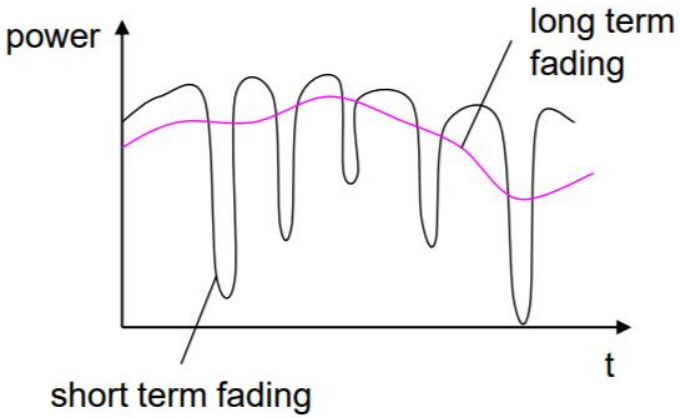
- signal paths change
- different delay variations of different signal parts
- different phases of signal parts

➔ quick changes in the power received (short term fading)

Additional changes in

- distance to sender
- obstacles further away

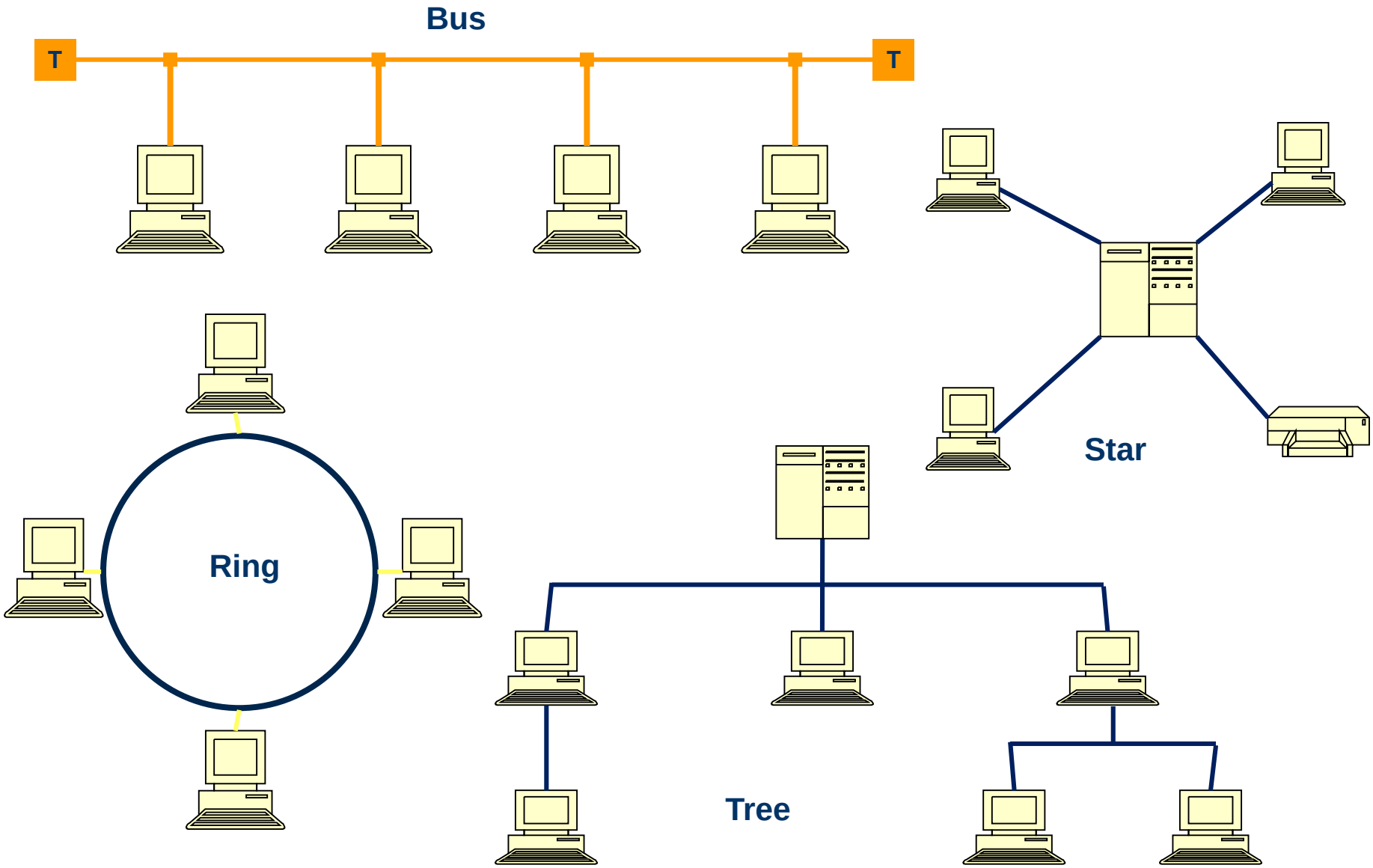
➔ slow changes in the average power received (long term fading)



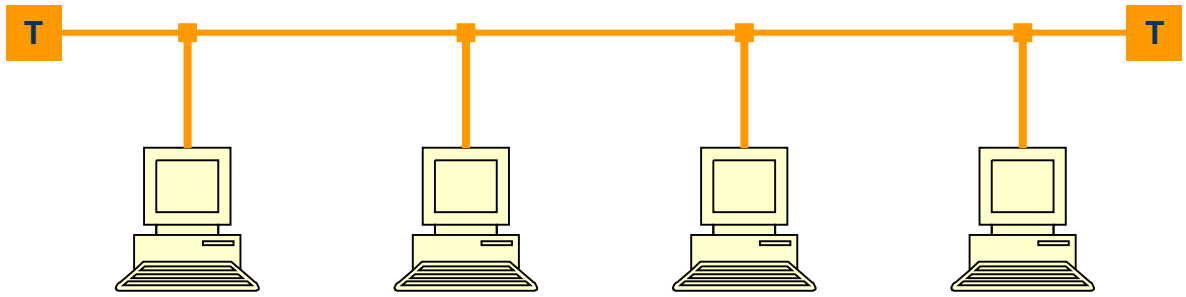
How we handle errors

- Fixed vs. Wireless
  - Fixed: Errors due to congestion
  - Wireless: many different reasons
- What to do
  - Increase of transmitting power
    - Increased power consumption (bad for the battery)
    - Increased interference to other receivers
  - Error detection and correction
    - More powerful codes (processing, channel overhead)
    - retransmissions (power consumption, channel overhead)

Network Topologies

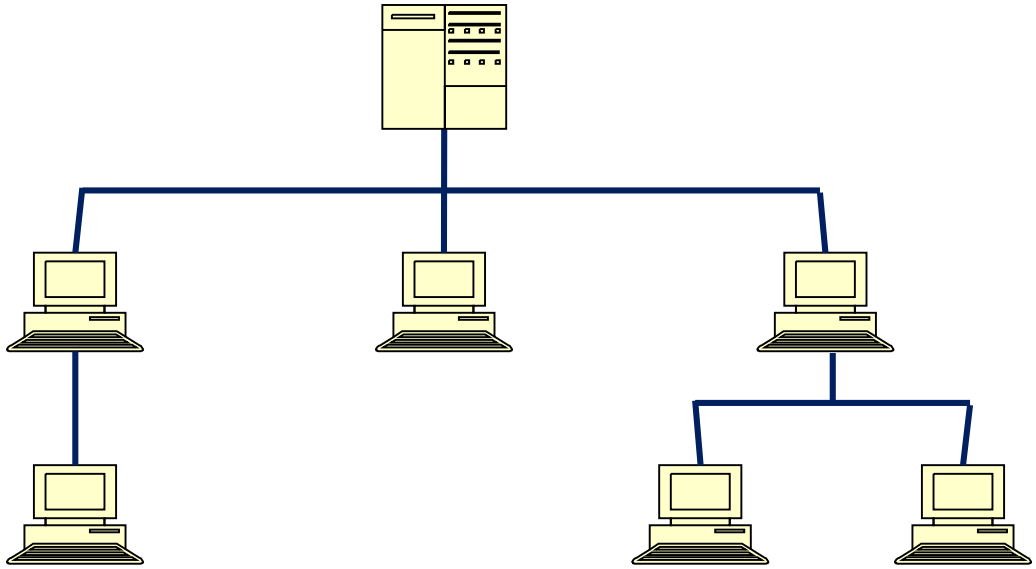


Bus



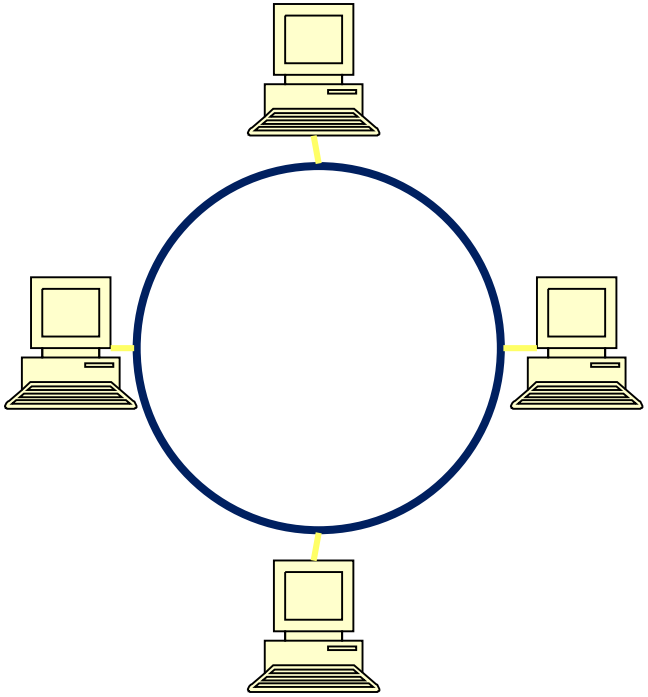
- All terminals on the bus
- Terminals can be connected/disconnected seamlessly
- End points
- Only one message at a time
- Low cable cost

Tree



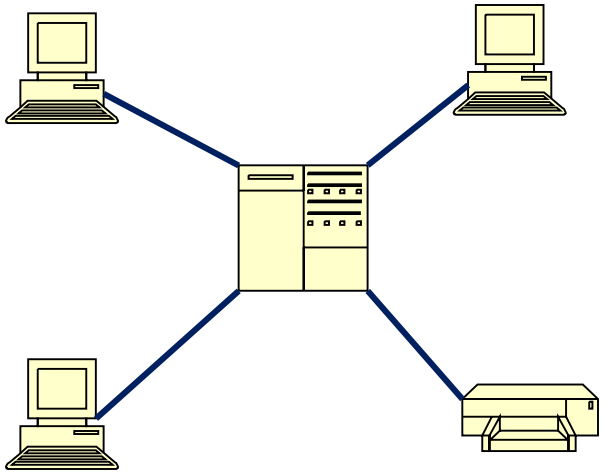
- Parent node can be a bottleneck
- Parent node out of order -> all tree out of order
- Add nodes at the lowest level

Ring



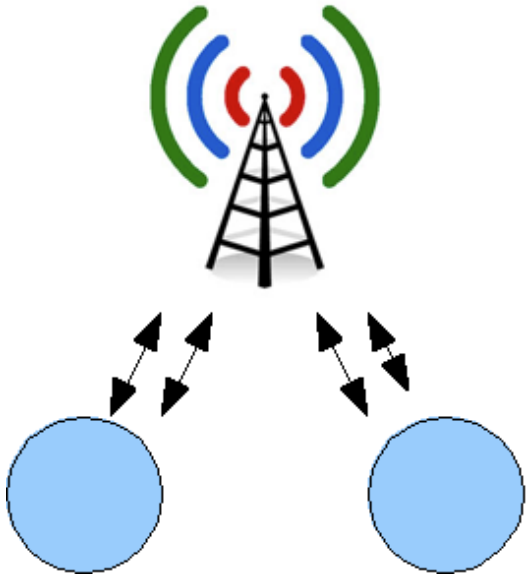
- Hop by hop transmissions
- Transmit/receive/check/forward
- Networks keep working on node errors

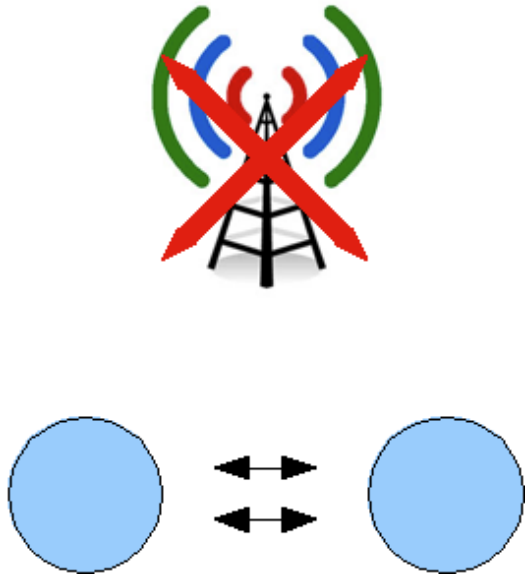
Star



- All nodes connected in a central node
- Single point of failure

Mobile network topologies





- Cellular or Ad-hoc
- Common medium (bus)
- All traffic through a node (star)
- Hop-by-hop transmissions (ring)
- Multiple access control
- Error control
- Mobility