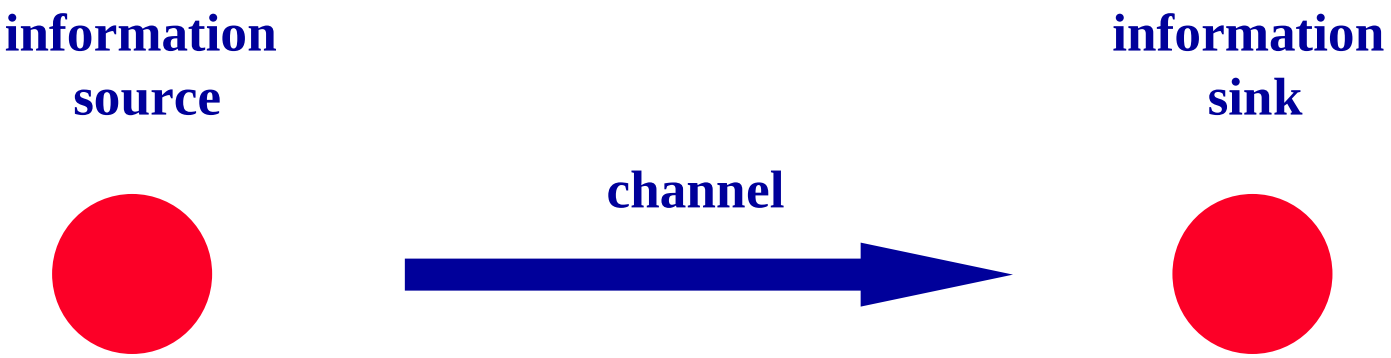
Mobile Radio Communications

Session 1: Introduction

COMMUNICATIONS



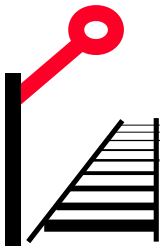
HISTORY: stone age

Initial communications were wireless:

human voice (air pressure)

visual messaging

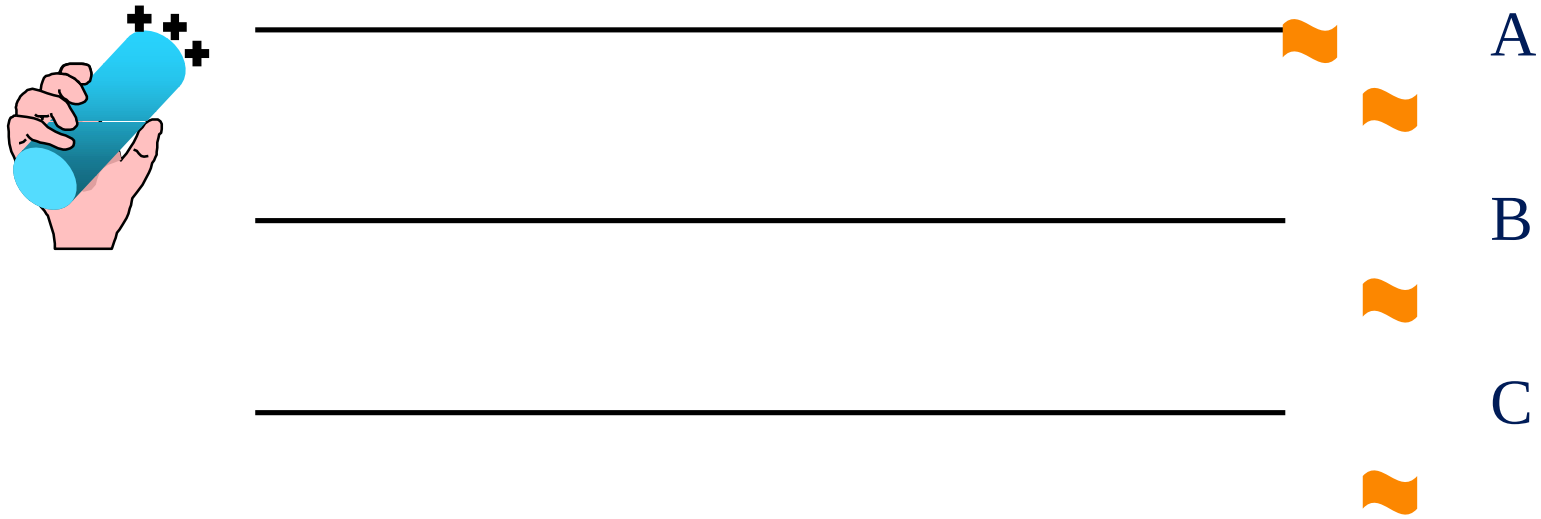
- **fires along chinese wall (3000 B.C.)**
- **Indian smoke signalling**
- **Semaphores**



HISTORY: electrical era

Communications through a wire:

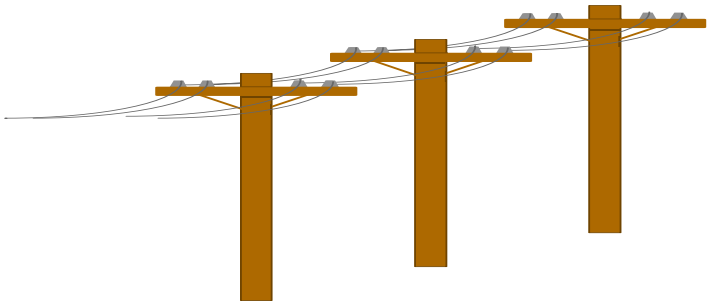
- 1729 Stephen Gray: electrostatic telegrahp



HISTORY: electrical era

Communications through a wire:

- 1850 Telegraph lines across US (Morse code)



- 1851 Submarine cables in the English Channel

- 1876 Alexander Graham Bell: telephony

DIGITAL → ANALOG

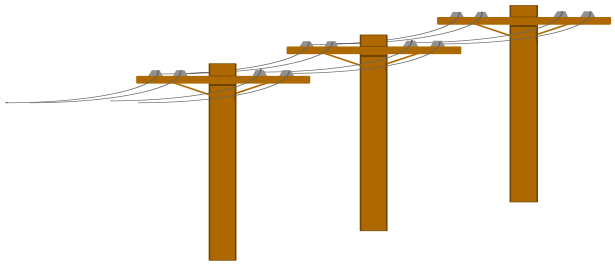
HISTORY: radio era

Communications through free space:

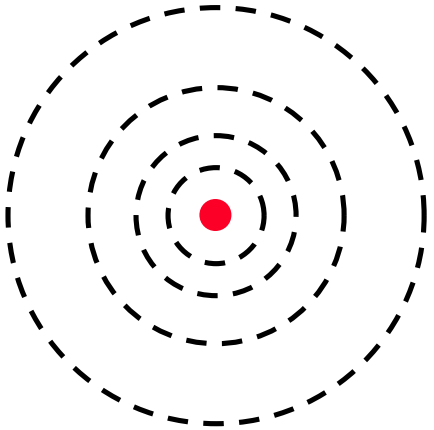
- 1890 Heinrich Rudolf Hertz: EM waves
- 1895 Guglielmo Marconi: RADIO
- 1921 Detroit Police Radio
- 1935 Armstrong: Frequency Modulation
- 1968 Cellular concept (Bell labs) / trunked radio

Electrical transmission

- **Guided wave transmission:**
  - **guided by material**
  - **copper/fiber**



- **Unguided wave transmission:**
  - **free-space propagation**
  - **radio, EM waves**



Modern mobile communications

- **1981** **Analog cellular radio: 1st generation**
  - reachability
  - voice, voice, voice

- **1990** **Digital cellular radio: 2nd generation**
  - improved capacity
  - improved performance
  - lower cost
  - security
  - voice, voice, data

- **2002** **Wideband cellular radio: 3rd generation**
  - increased data rate
  - packet services
  - multimedia services

Why 1st generation analog ?

- **History**

Messaging:

- **light → on/off keying**
- **semaphore → multilevel**
- **telegraph, marine radio → Morse code**

} digital

Telephony

- **voice**

analog

ANALOG TELEPHONE LINE → ANALOG MOBILE RADIO

Why 2st generation digital ?

Performance

- improved spectral efficiency
- increased capacity
- improved voice quality
- time division
- cheaper radio implementation
- encryption

Why 3rd generation at all ?

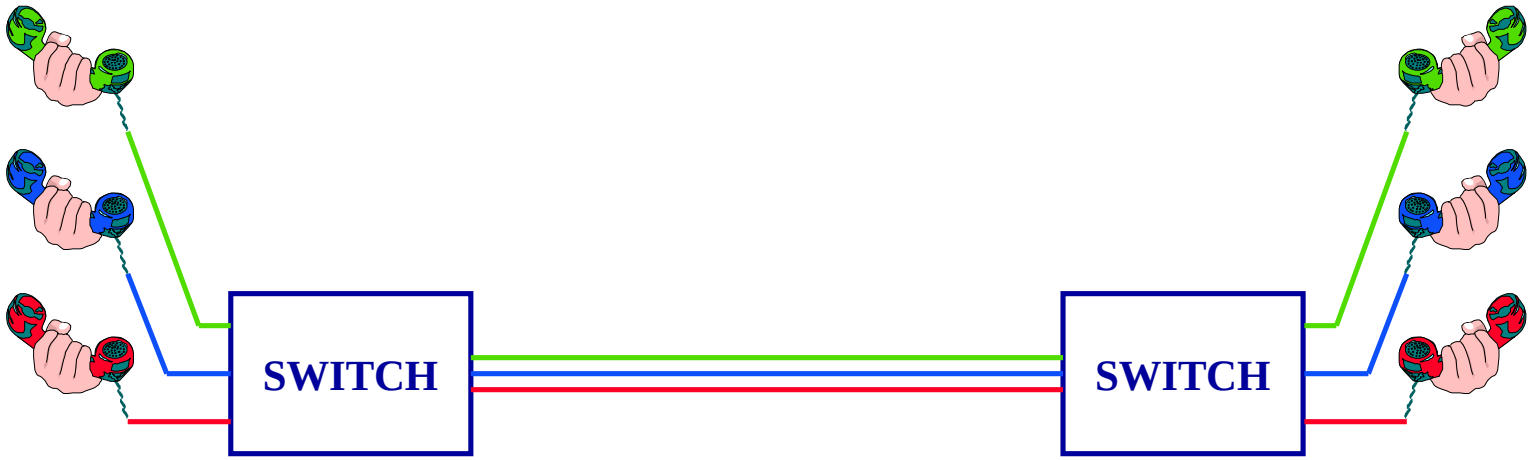
Services

- new IMT-2000 spectrum available
- increased data rates
- multimedia services
- service flexibility / differentiation

CIRCUIT ORIENTED → PACKET ORIENTED

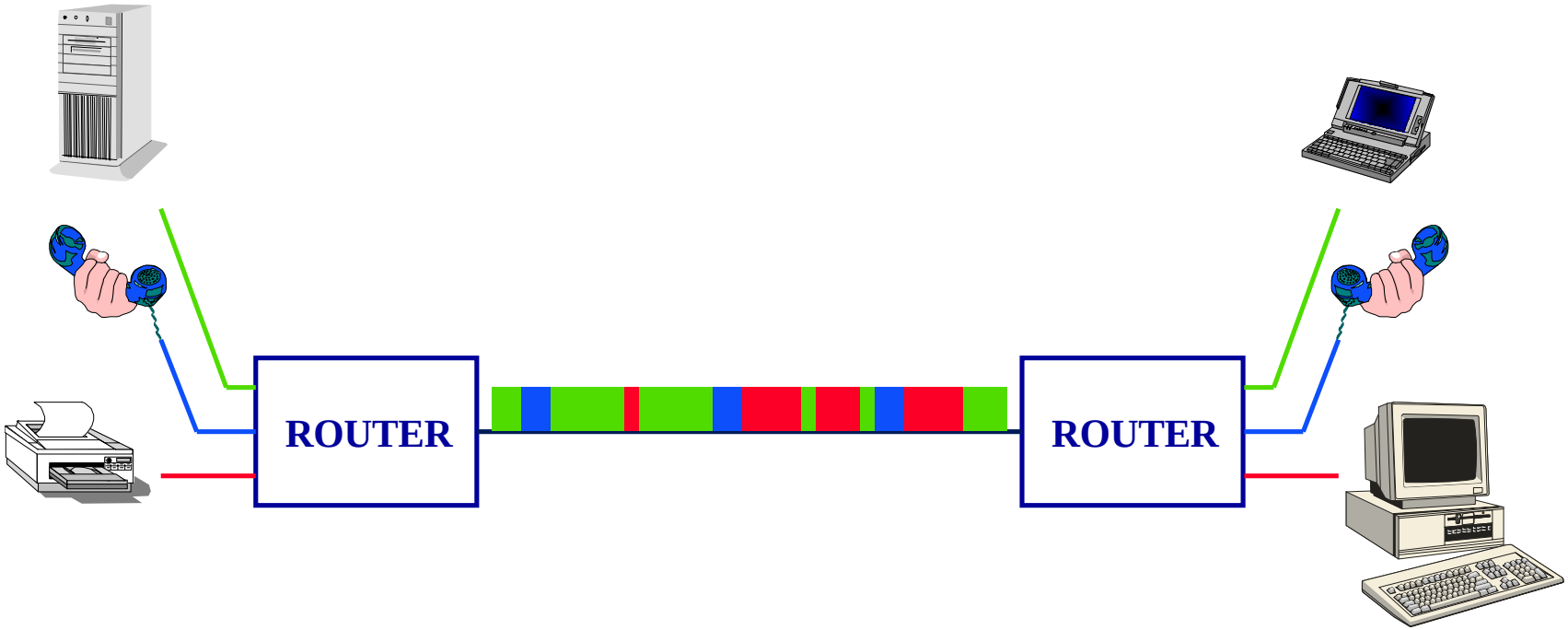
Circuit switching

- Reserved circuits
- Constant bandwidth
- Telephony paradigm



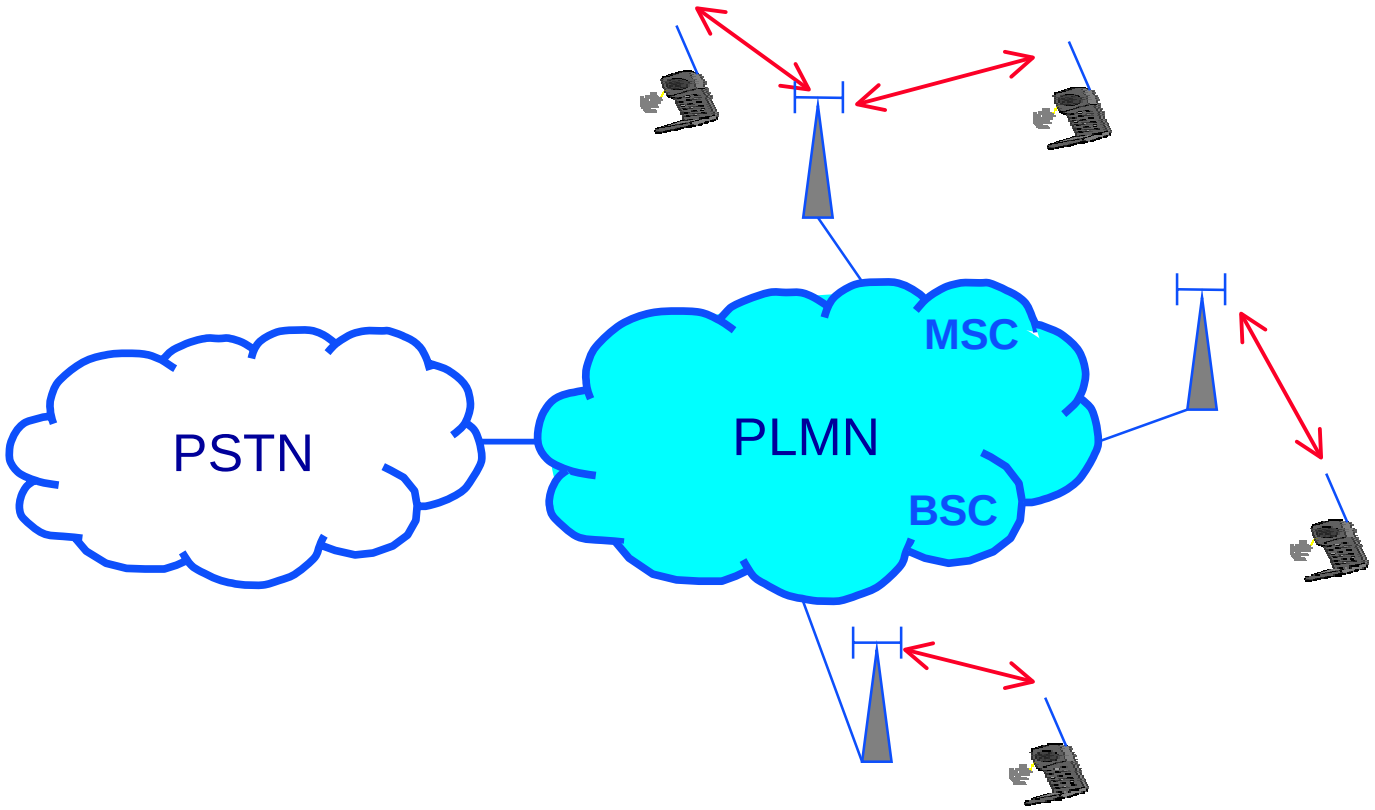
Packet switching

- Packet transmission
- Variable bandwidth
- Data paradigm



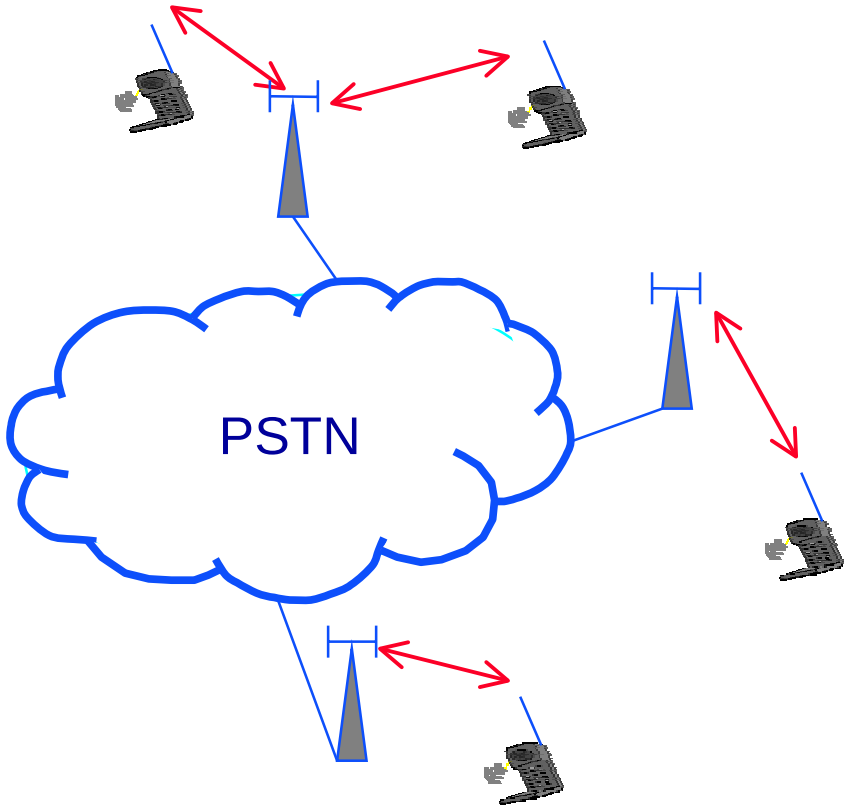
System classification (1)

- **Mobile systems**



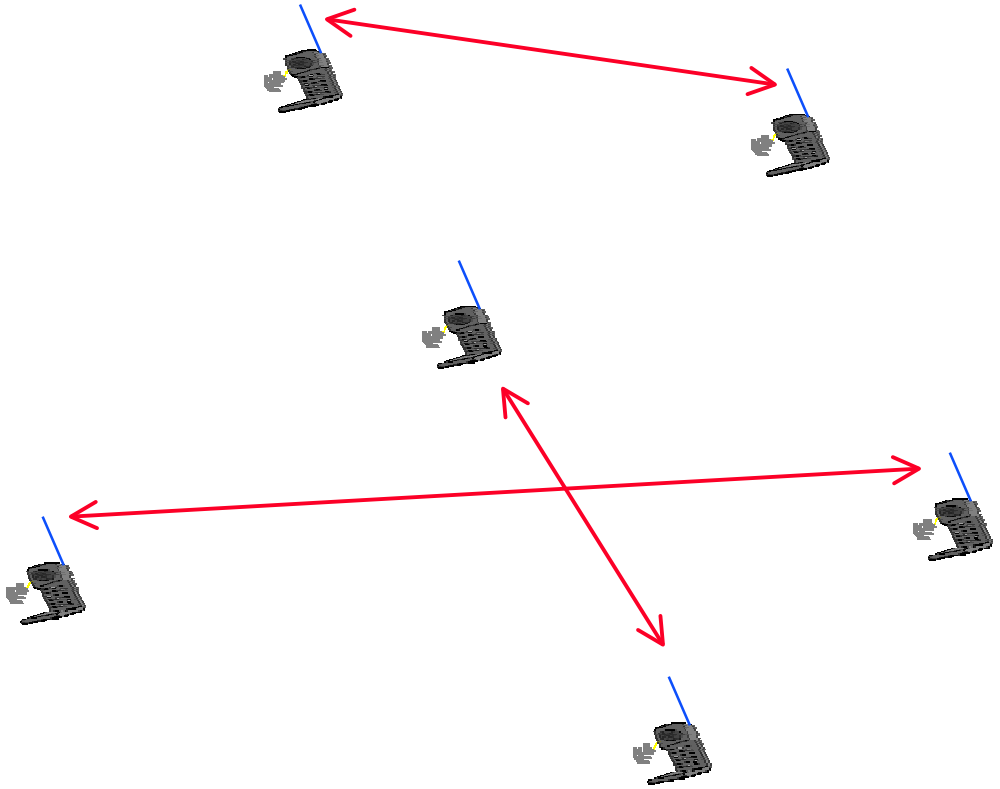
System classification (2)

- **Wireless extensions**



System classification (3)

- **Ad-hoc connectivity**



Radio systems in use

- **Mobile systems (public cellular, cell phone systems)**
  - **AMPS: Advanced Mobile Phone System**
  - **NMT: Nordic Mobile Telephone system**
  - **(E)TACS: (Extended) Total Access Cellular System**
  - **GSM: Groupe Spéciale Mobile/Global System for Mobile communication, PCS1900, DCS1800**
  - **IS-136: Interim Standard 136 (formally IS-54), D-AMPS, USDC**
  - **PDC: Pacific Digital Cellular**
  - **IS-95: Intermin Standard 95**

Radio systems in use

- **Future Mobile systems**
  - **UMTS: Universal Mobile Telephone System**
  - **CDMA2000**
  - **IMT-2000: International Mobile Telecommunications**

    (formerly FPLMTS: Future Public Land Mobile Telephone Systems)
  - **3G, 3GPP: Third Generation Partnership Project**

Radio systems in use

- **Wireless extensions**
  - **DECT: Digitally Enhanced Cordless Telephony system**
  - **PHS: Personal Handy Phone System**
  - **WLAN 802.11: Wireless Local Area Network**
  - **HIPERLAN: High Performance Local Area Network**

Radio systems in use

- **Ad-hoc connectivity**
  - **Walky-talky**
  - **Bluetooth™**

Public versus private

- **Private**
  - **emergency/rescue (land-mobile radio)**
  - **company/campus (WLAN)**
- **Public**
  - **telephony**
  - **internet**

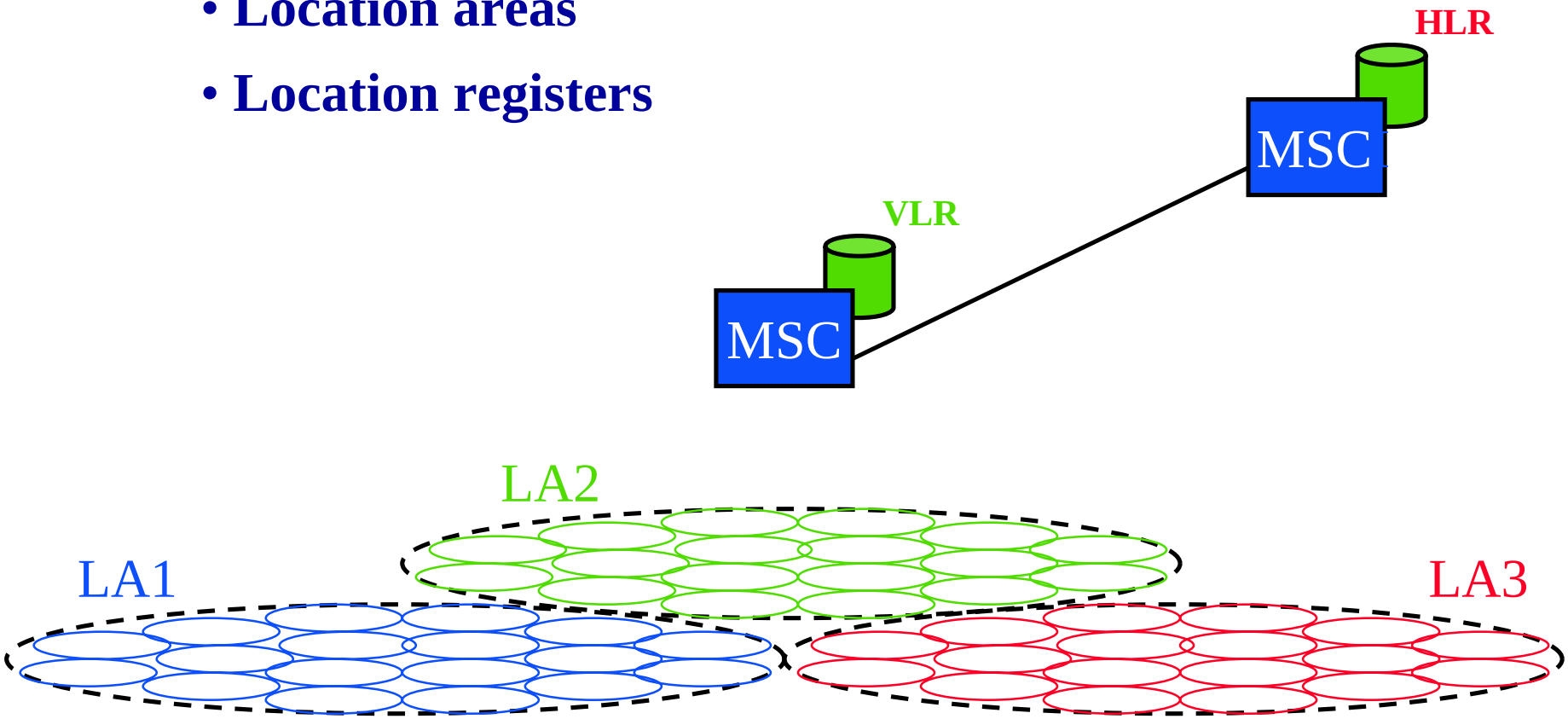
IMPORTANCE OF STANDARDS

Paging systems

- One-way messaging
- Replaced by two-way cellular solutions
- US use due to billing
- Satellite use due to in-building penetration
- Paging functionality in cellular systems
- ERMES, (RE-)FLEX

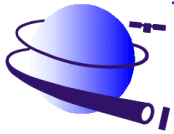
Paging in cellular systems

- Location areas
- Location registers



Mobile satellite systems

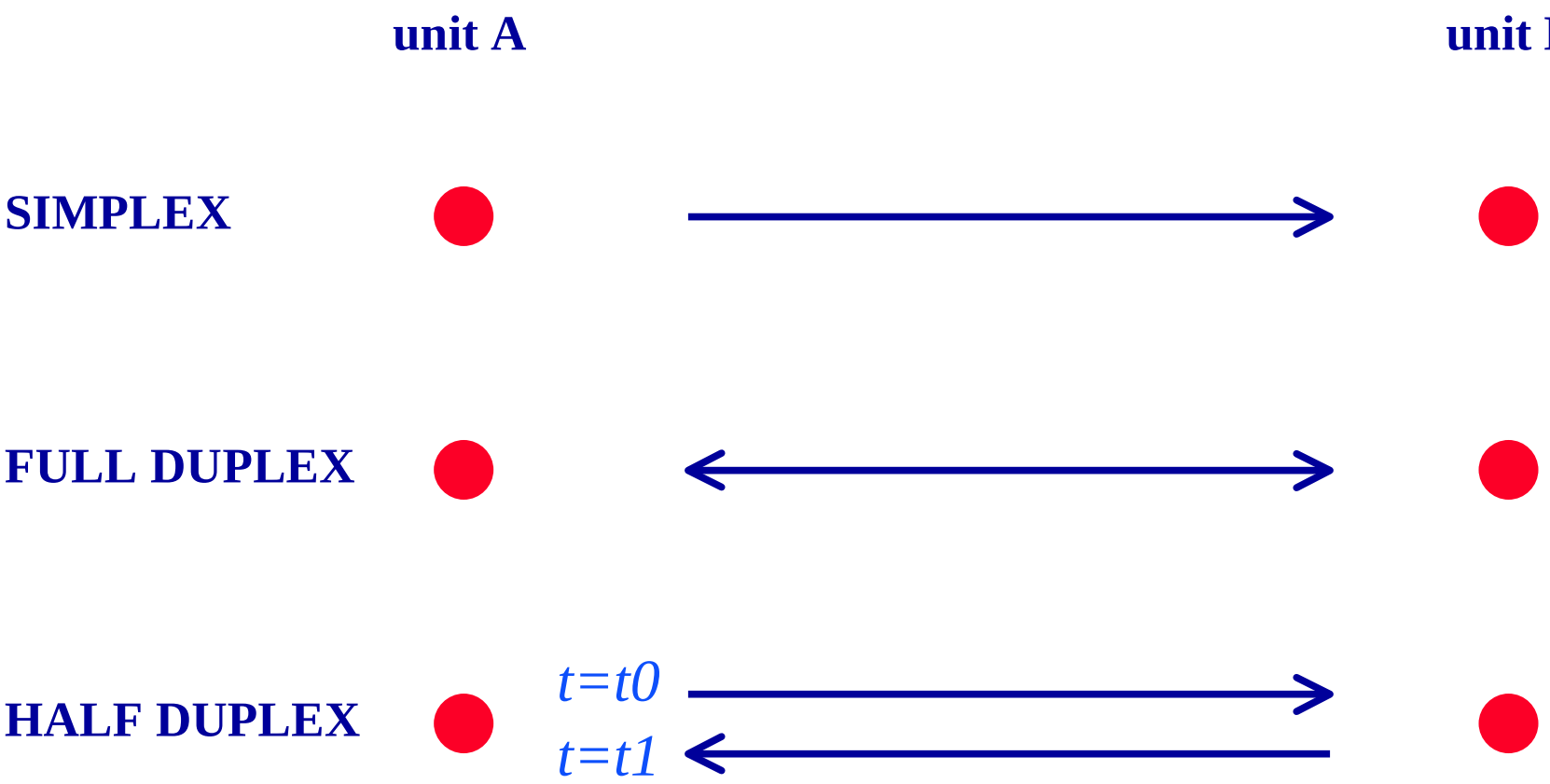
- **GEO: geostationary earth orbit**
  - **INMARSAT**
  - **ACeS (Asia Cellular Satellite**
- **MEO: medium earth orbit**
  - **ICO**
- **LEO: low earth orbit**
  - **GLOBALSTAR**
  - **IRIDIUM**
- **Satellite mode in IMT-2000**



System definitions

- operator ↔ subscriber, user
- base station ↔ mobile station
- mobile, terminal, portable, handy, cell phone
- forward ↔ reverse channel (downlink/uplink)
- control & traffic channels
- paging
- roaming

Forward and reverse transmissions



How to design a radio system ?

- System architecture
- Frequency band
- Multiple access method
- Medium access control
- Call setup
- Standby mode
- Radio protocol
- Security

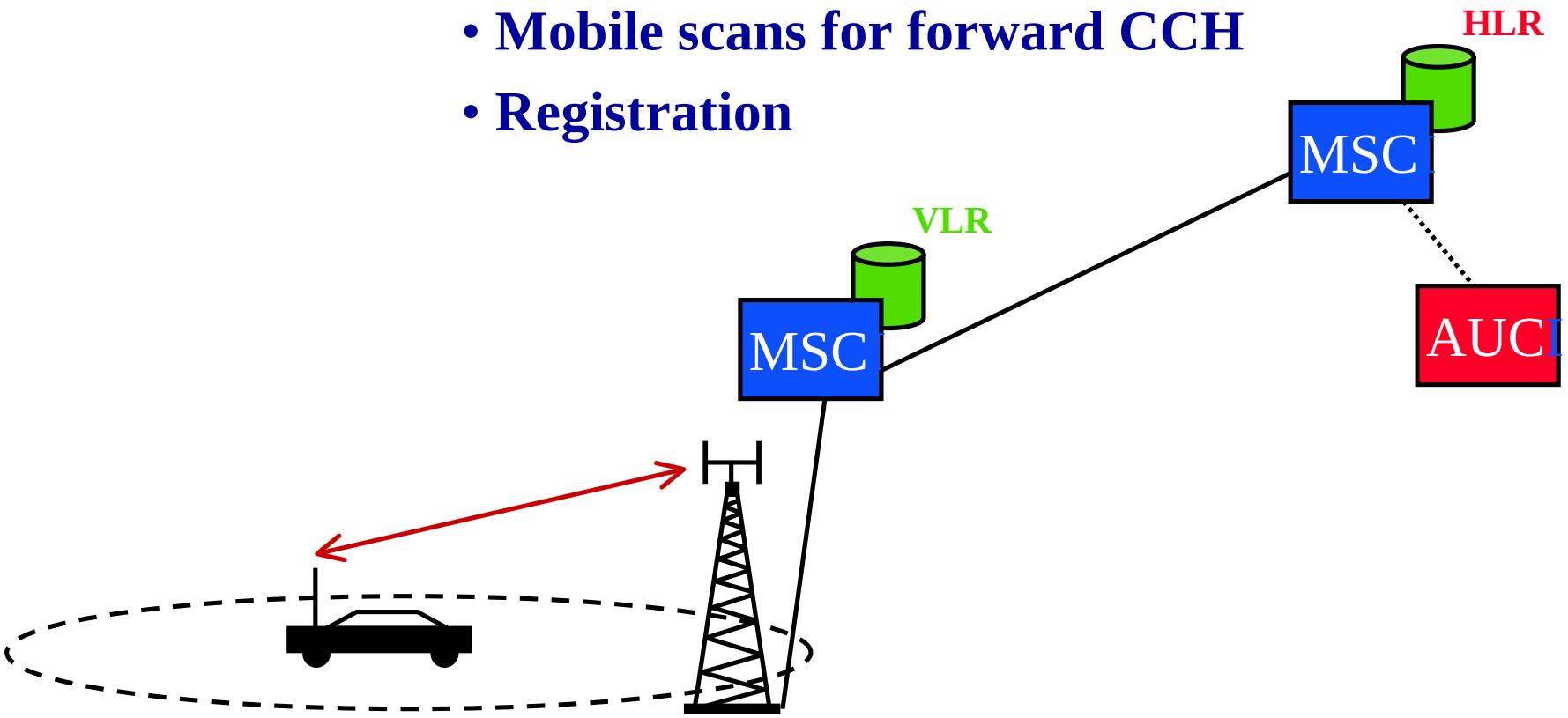
How a mobile call is made

- **Locking**
- **Registration**
- **Idle/standby mode**

- **Mobile-originated call: connection request**
- **Mobile-terminated call: page**

Registration

- Mobile scans for forward CCH
- Registration



Registration

- **Subscriber identity**
  - **MIN: Mobile Identification Number**
  - **IMSI: Internation Mobile Subscriber Identity**
  - **SIM: Subscriber Identity Mobile**
- **Equipment identity**
  - **ESN: Electronic Serial Number**
  - **IMEI: Internation Mobile Equipment Identity**
- **Authentication**
- **Roaming**

Connection

- Paging / channel request
- Authentication (billing)
- Traffic channel assignment
- Hand-off

- Attach/detach

Radio spectrum usage

0.1-0.5 MHz	LF	long-distance communications
0.5-3 MHz	MW	AM radio broadcasting
3-30 MHz	HF	CB radio
30-300 MHz	VHF	TV and FM radio broadcasting
300-1000 MHz	UHF	mobile radio
1-10 GHz	microwave	mobile radio, satellite
10-100 GHz	millimeter wave	satellite

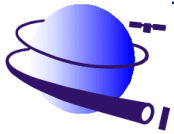
Why radio in 300MHz - 30GHz ?

antenna dimensions: $\lambda/4 = c/4f$

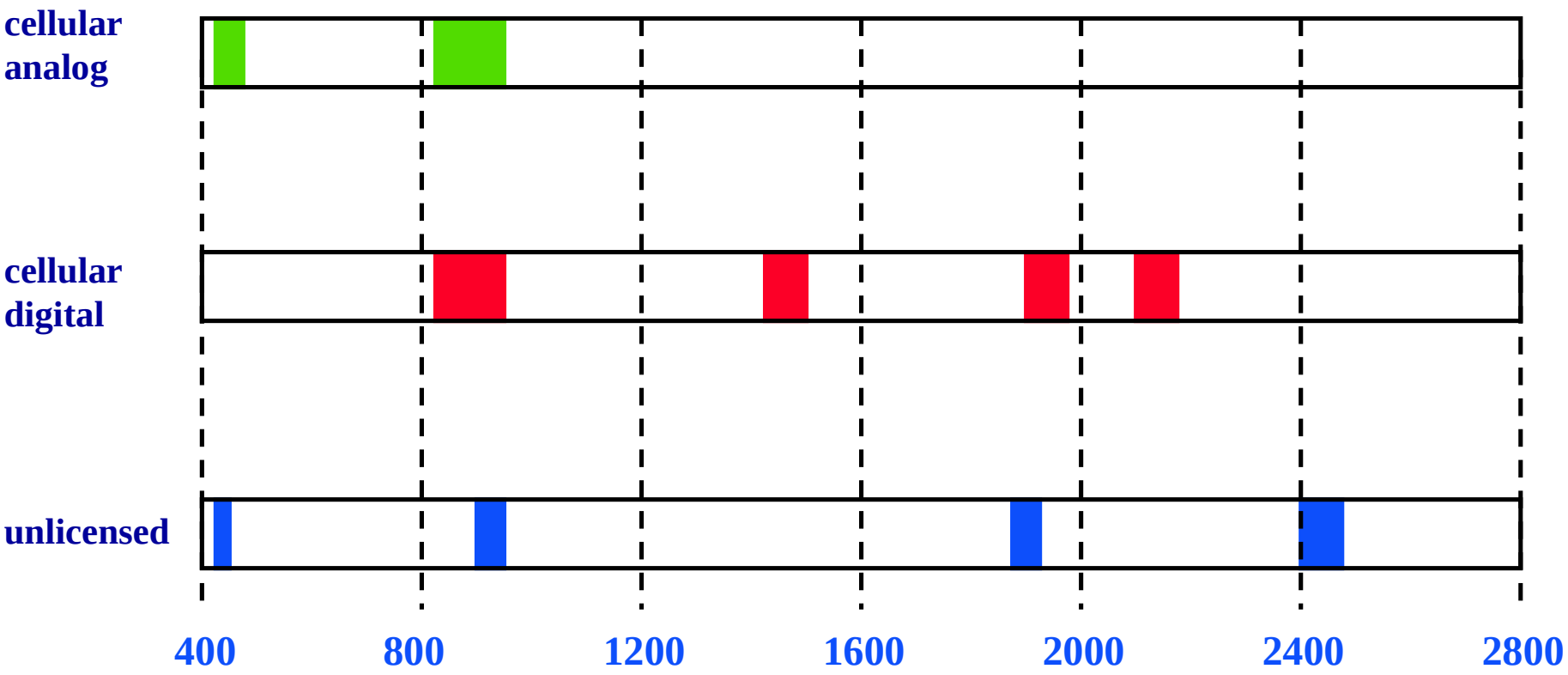
path loss: $PL = -10\log(\lambda^2/(4\pi d)^2)$

shadowing, directional

$$0.3\ \text{GHz} < f < 30\ \text{GHz}$$
$$1\ \text{m} < \lambda < 1\ \text{cm}$$



Spectrum allocation



Licensed and unlicensed

	licensed	unlicensed
dedicated	public cellular telephony	cordless telephonly
undedicated	high-power applications	local area

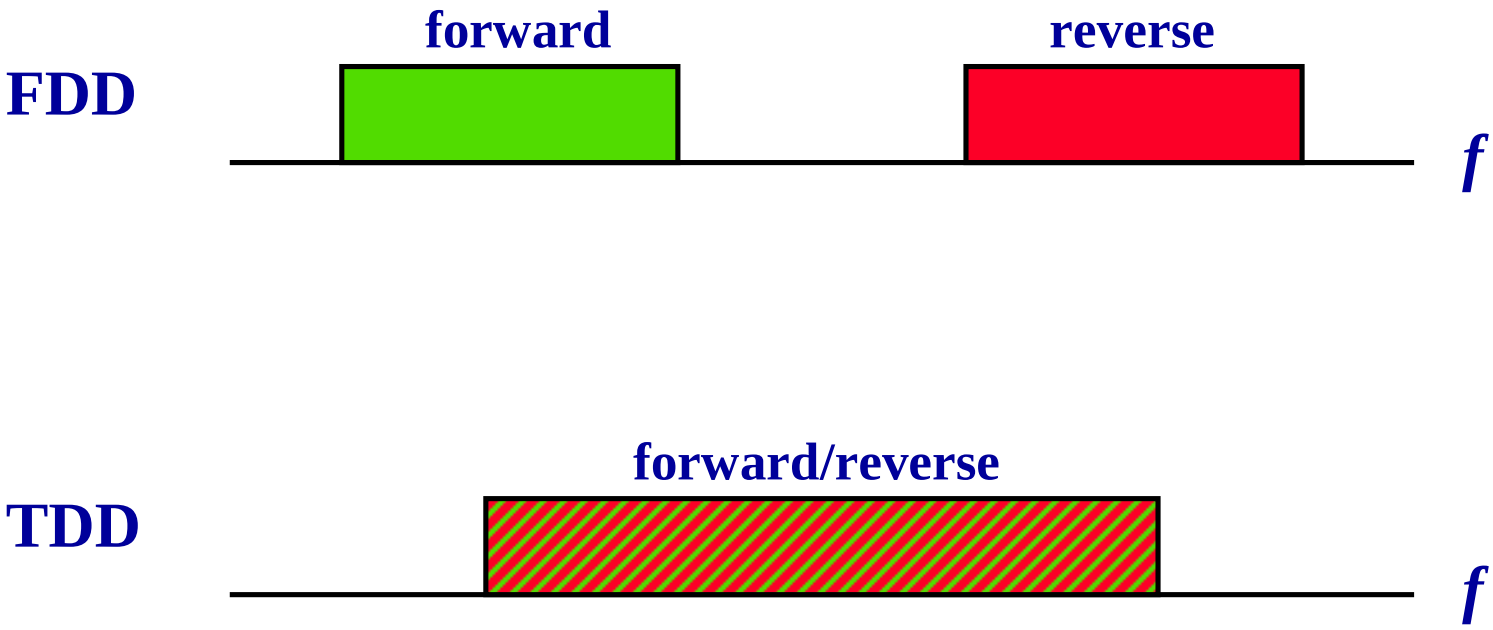
Regulatory bodies

- **CEPT: Conférence Européne des Administration des postes et des télécommunications**
- **ETSI: European Technical Standards Institute**
- **FCC: Federal Communications Commission**
- **MPT: Ministry of Posts and Telecommunications of Japan**
- **ITU-R: International Telecommunications Union - Radiocommunication section**
- **WARC: World Administration Radio Conference**

Standardization bodies

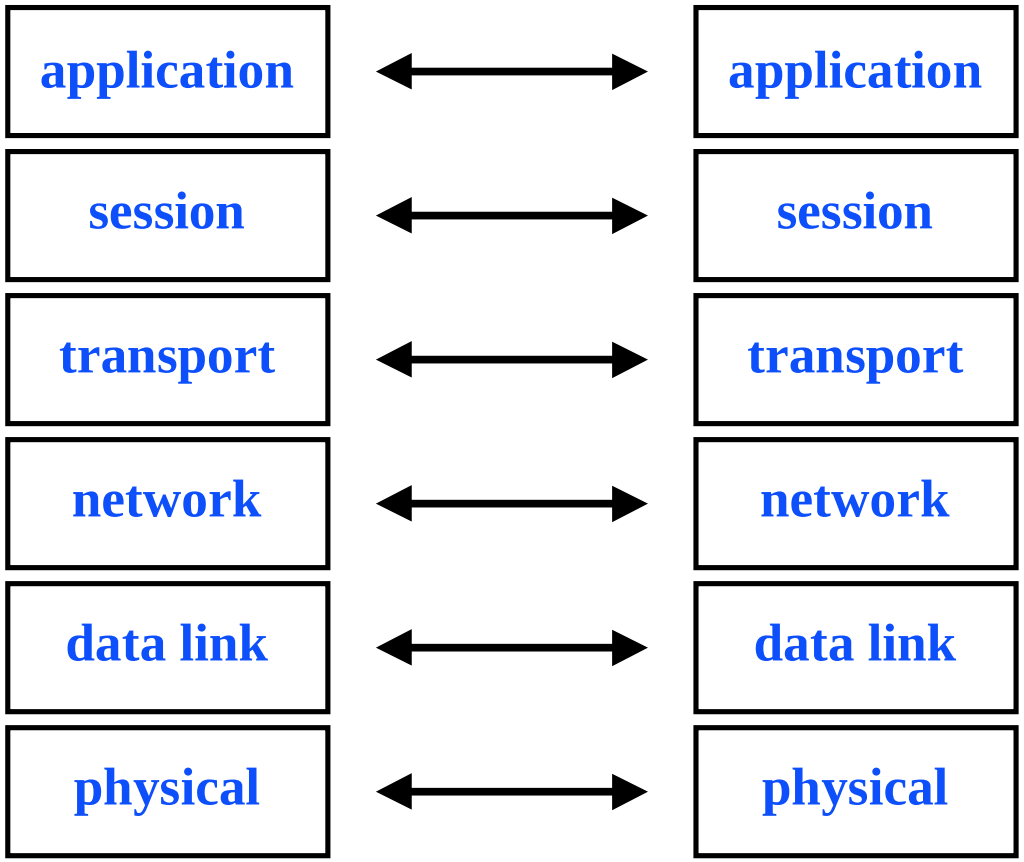
- **ETSI: European Technical Standards Institute**
- **TIA: Telecommunications Industry Association**
- **ARIB: Association of Radio Industries and Businesses**
- **ITU: International Telecommunications Union**
- **IEEE: Institute of Electrical and Electronics Engineers**

FDD AND TDD

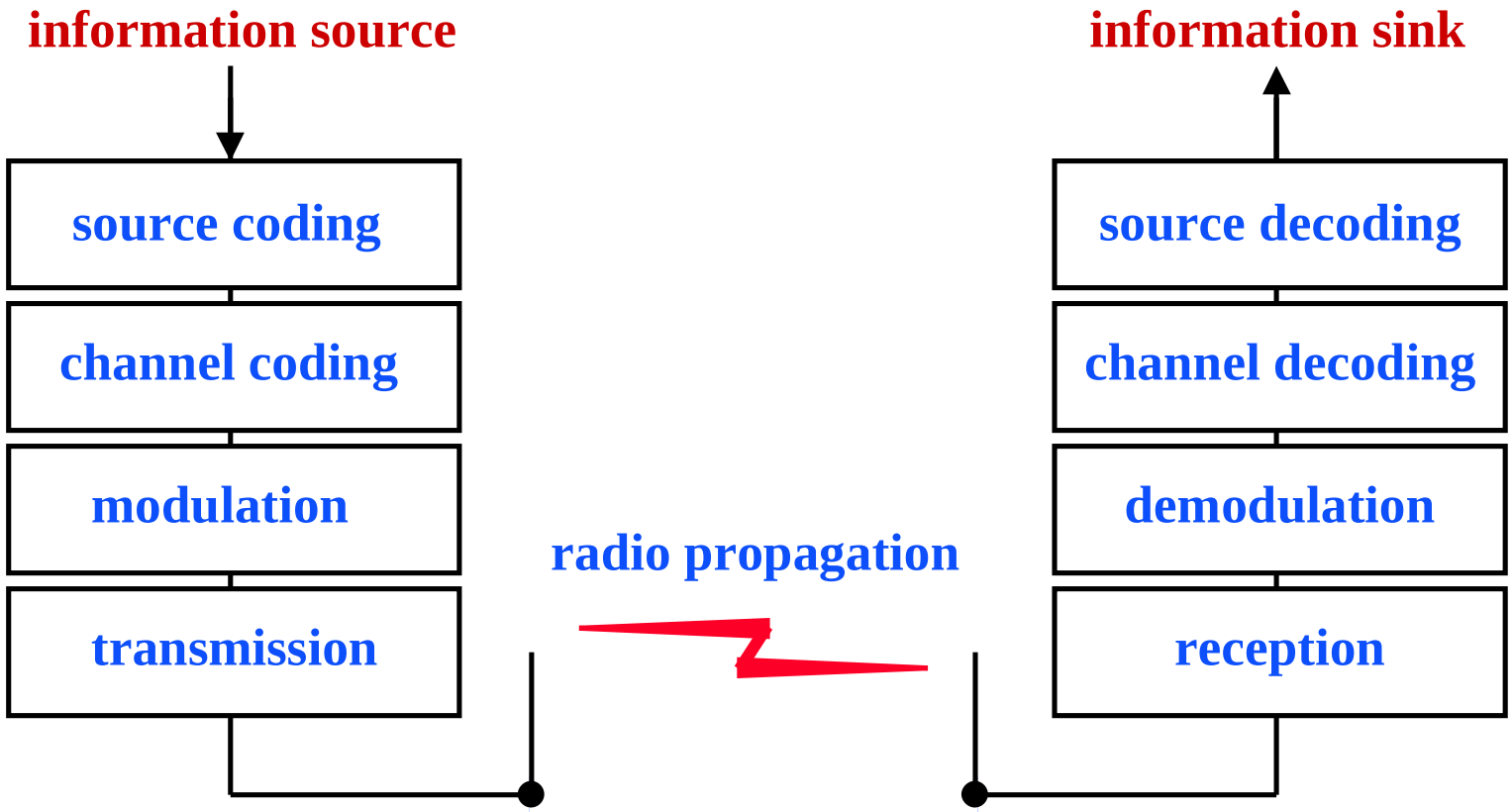


A layered structure

OSI protocol stack



From source to sink



Source coding/decoding

- **Remove redundancy**
- **Minimize amount of information to be transmitted**

Voice:	**vocoders (model + excitation), LPC**
Data:	**spaces, Huffman coding**
Video:	**transform techniques (DCT)**

Not covered in this course. Chapter 7 in book for those interested.

Channel coding/decoding

- Add controlled redundancy
- Correlation between correct and incorrect bits

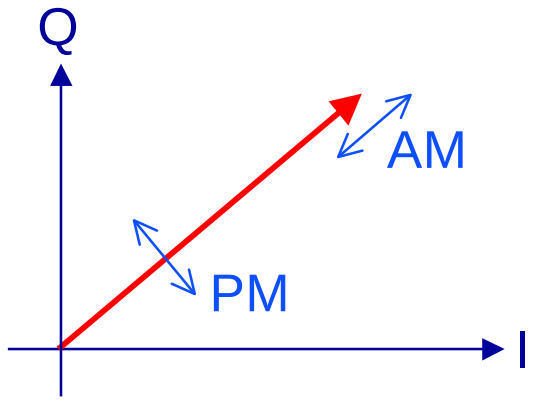
HELPS ONLY IF CHANNEL CONDITIONS VARY:
"good" bits help "bad" bits

Session 5: Equalization, channel coding, and interleaving

Modulation/demodulation

- **Mapping of bits to symbols**
- **Mapping of symbols to physical parameters**

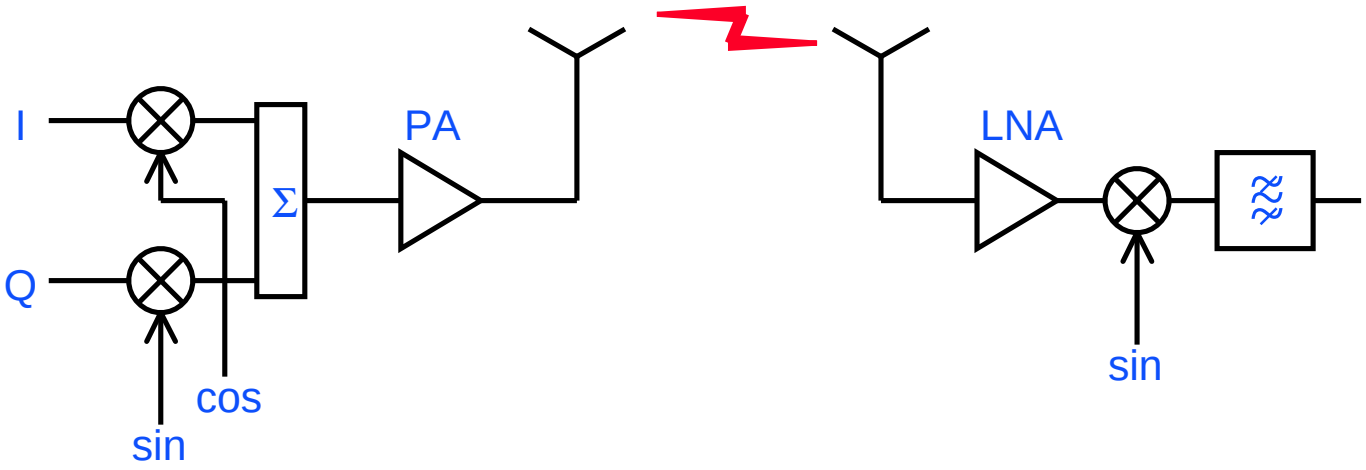
AMPLITUDE / PHASE



Session 4: Modulation & transmission

Transmission/reception

- Up and downconversion from baseband to RF
- Amplification, filtering



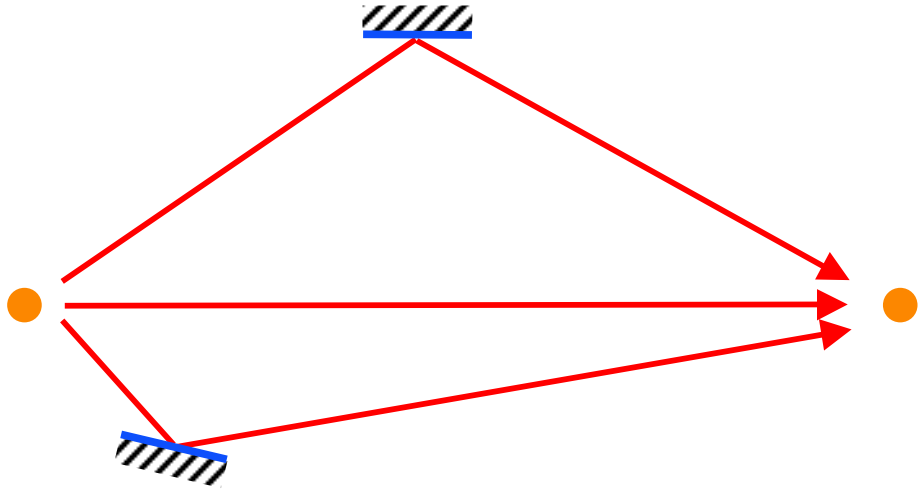
Session 4: Modulation & transmission

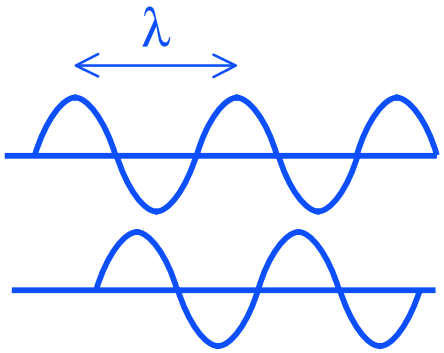
Propagation channel

- Radio wave propagation
- Noise, range
- Blocking, shadowing, diffraction
- Multi-path effects, reflections

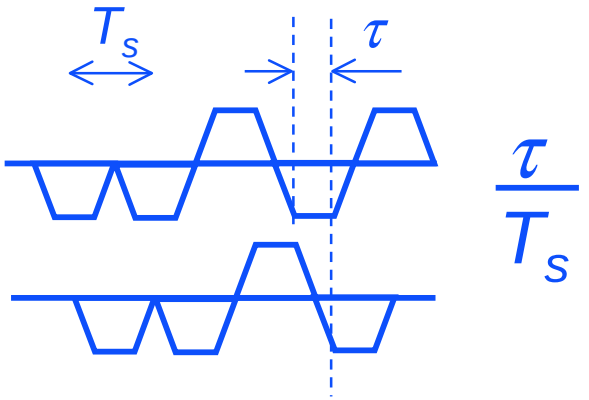
Session 3: Radio propagation

Multi-path effects



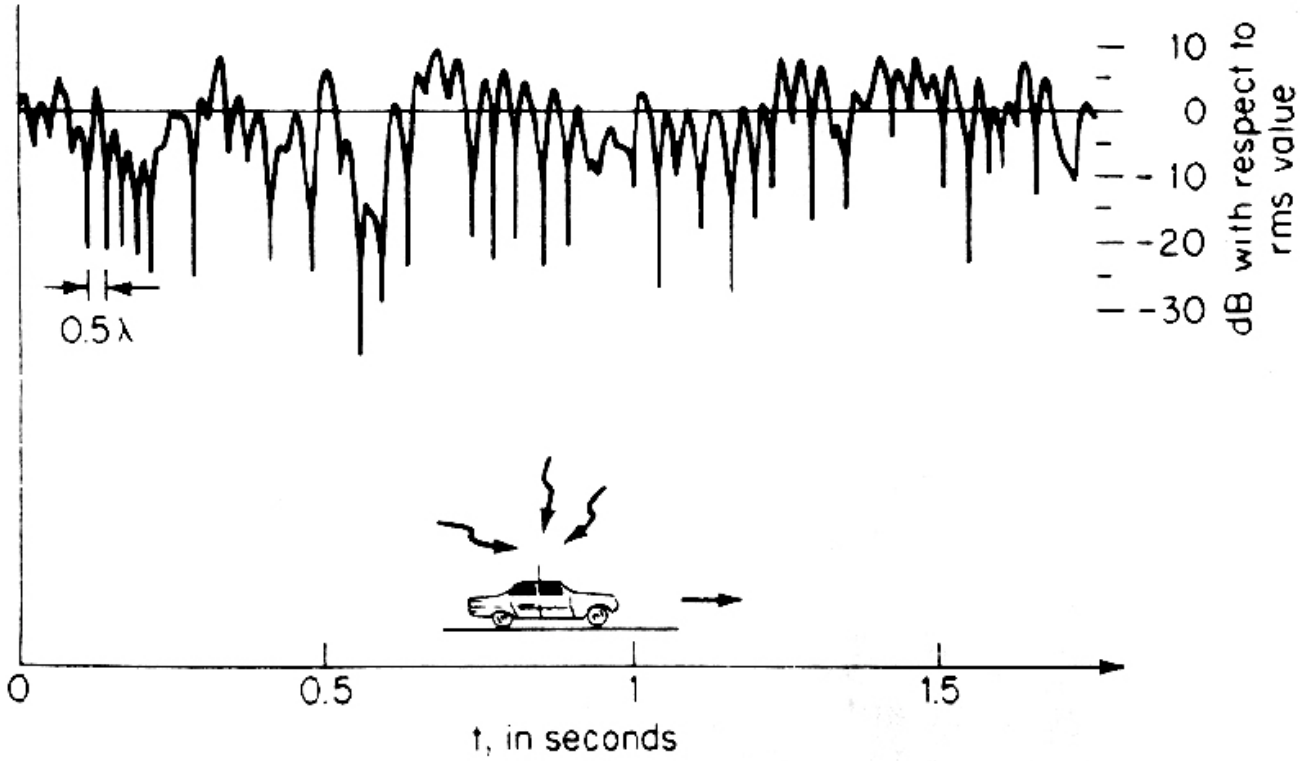


fading



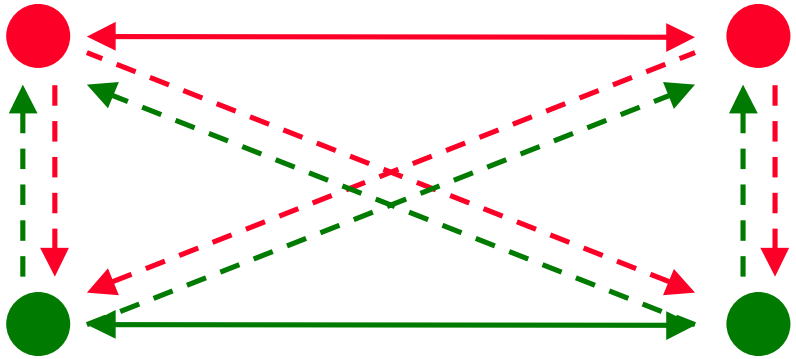
inter-symbol interference

Fading



Interference

- Co-channels and adjacent channels
- Capacity
- Medium access



Session 2: The cellular concept
Session 6: Multiple access

Radio systems

Session 7: Wireless LAN systems
Session 8: Mobile systems
Session 9: Ad-hoc systems

FOR NEXT WEEK

- **Read:**
  - **Chapter 1: §1.1 - 1.5**
  - **Chapter 2: §2.1 - 2.8 (not 2.7.3)**
  - **Chapter 8: §8.7**

- **Solve problems:**
  - **Chapter 1: 1.5, 1.6, 1.8, 1.10**

Case study

UMTS frequency auctioning:

UK: GBP 22.5 billion

Germany: DM 99 billion

Holland: DFL 5.9 billion

How many years before break-even point ?

Penetration

Population:

UK:	**59 million**
Germany:	**82 million**
Holland:	**16 million**

Subscriber growth:

year 1:	**0.5% of population**
year 2:	**2%**
year 3:	**10%**
year	**4 and beyond: 30%**

User traffic & expenses

Usage pattern:

voice:	10 minutes/day
data:	10Mbytes/day

Billing:

subscription:	DFL 25 / month
voice:	DFL 0.25/minute
data:	DFL 0.10/Mbyte

Total:

DFL 300 + 912.5 + 365 = DFL 1577.5 /user·year

Operator expenses

Network roll-out:

DFL 150 per (expected) user

Operation&maintenance:

DFL 200 per user

License