Wireless Networks for Mobile Applications

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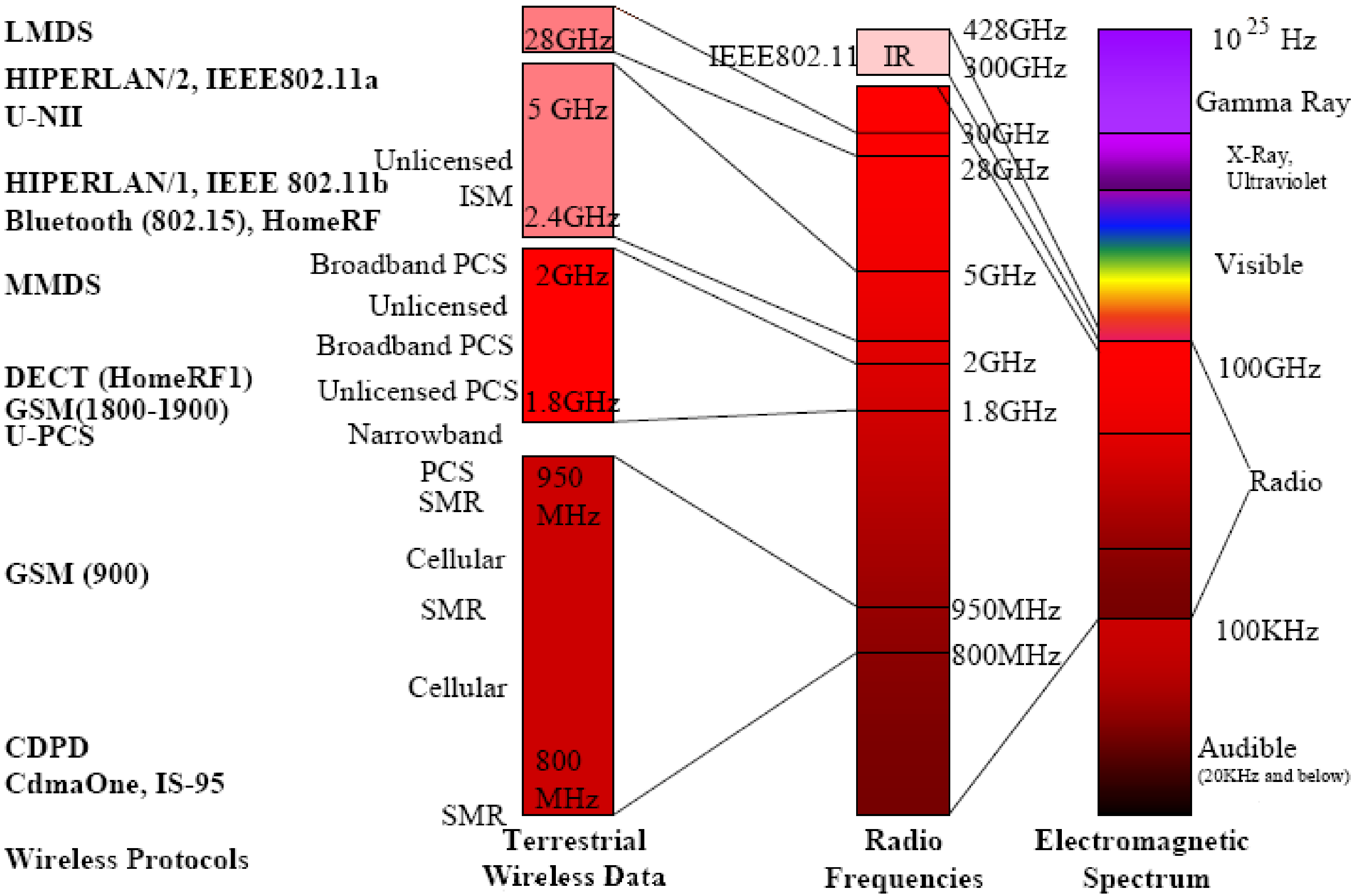
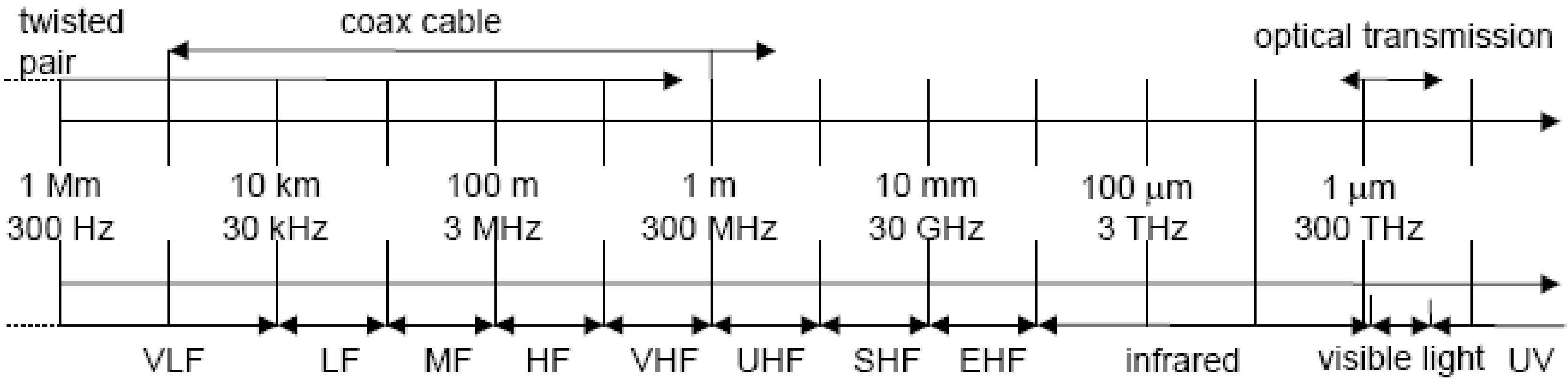
Wireless Spectrum



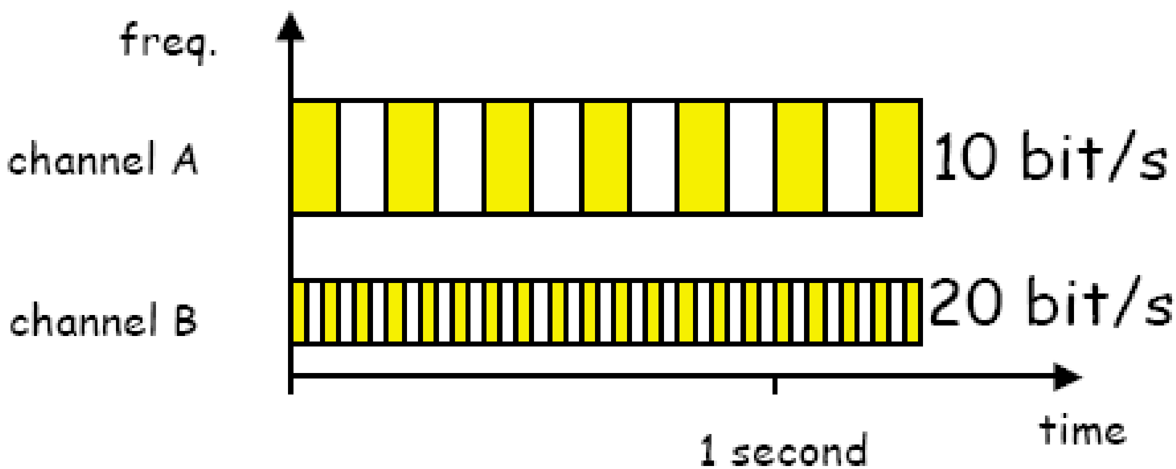
Wireless Frequencies



- VLF = Very Low Frequency
- LF = Low Frequency
- MF = Medium Frequency
- HF = High Frequency
- VHF = Very High Frequency
- UHF = Ultra High Frequency
- SHF = Super High Frequency
- EHF = Extra High Frequency
- UV = Ultraviolet Light
- Frequency and wave length:
- $\lambda = c/f$
- wave length λ, speed of light $c \cong 3\text{x}10^8$m/s, frequency f

Wireless Network Bandwidth

- **how can wireless channels have different bandwidth?**
  - bits run less or more faster? (NO)
    - Light speed: ˜ <300.000 Km/s for every bit
  - the channel pipe (spectrum) is bigger (YES/NO)
  - the channel requires less time to accomodate (i.e. to code) one bit on the channel (YES)

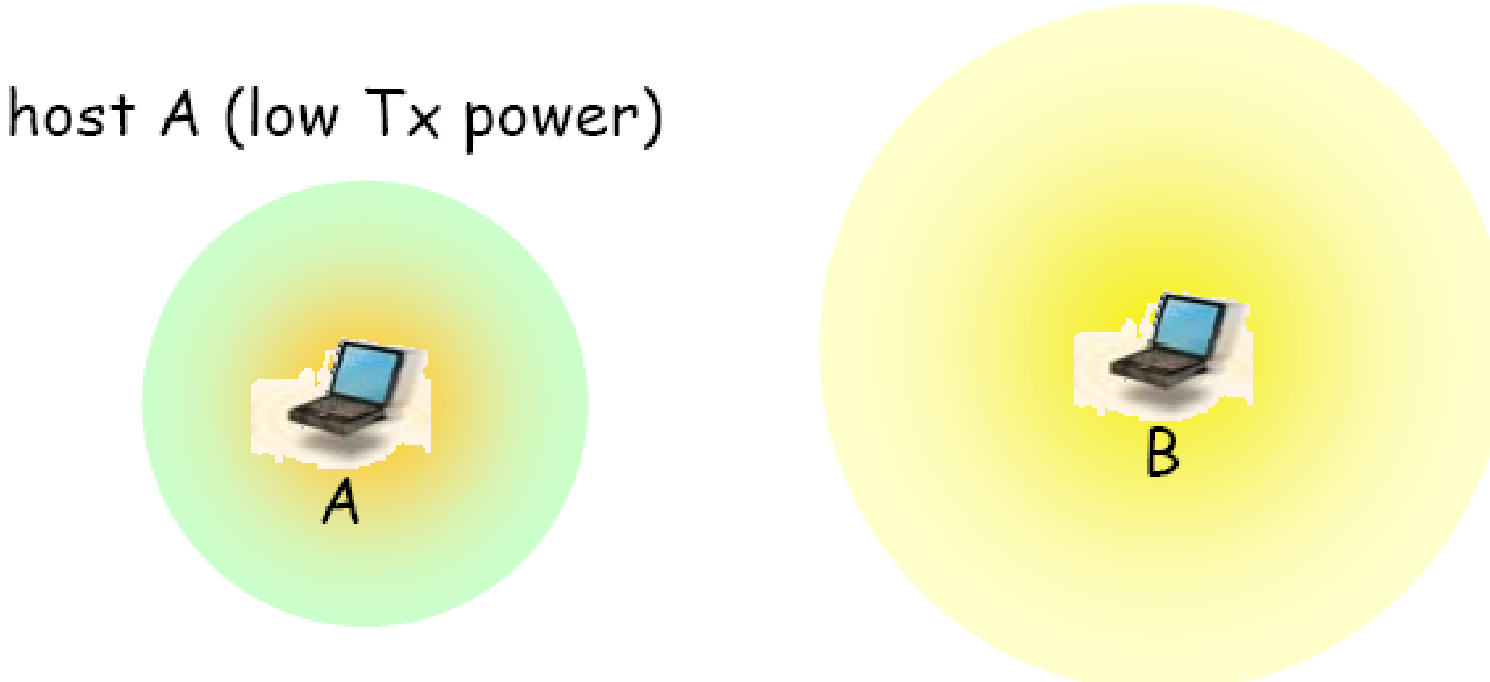


Wireless Network Technology

- **Narrowband radio system**
    - transmit/receive using a single radio frequency
- **Spread Spectrum technology**
    - bandwidth efficiency vs. reliability and security
  - Frequency Hopping Spread Spectrum
    - narrowband carrier hopping in a pattern sequence
  - Direct Sequence Spread Spectrum
    - bit coding and transmission spreading over the spectrum
- **Infrared technology**
    - line of sight or diffused, short range (in room)

Wireless Network Technology

- **Radio transmission coverage**

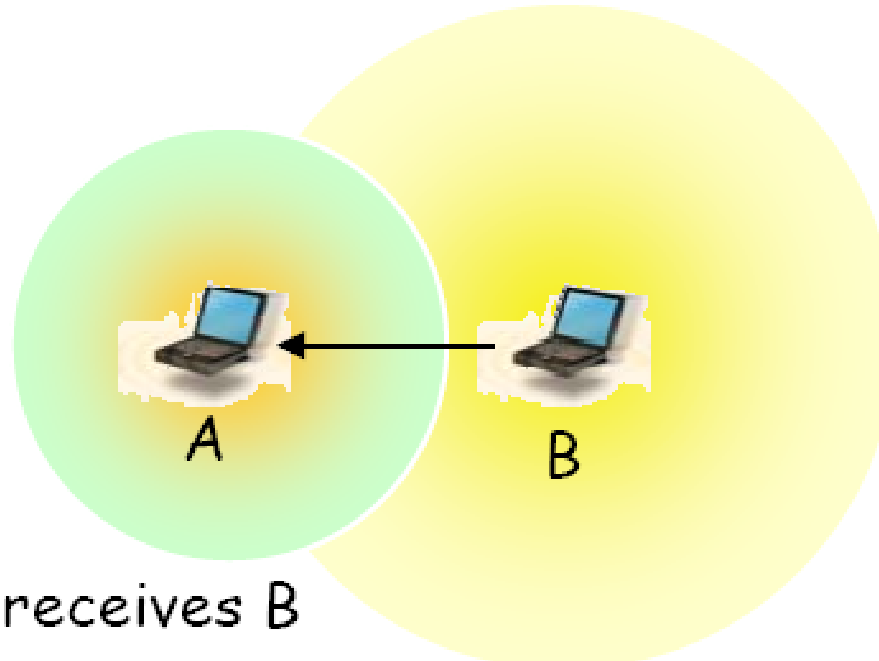


"…is there anybody outhere?"

both isolated

Wireless Network Technology

- **Radio transmission coverage**



A receives B

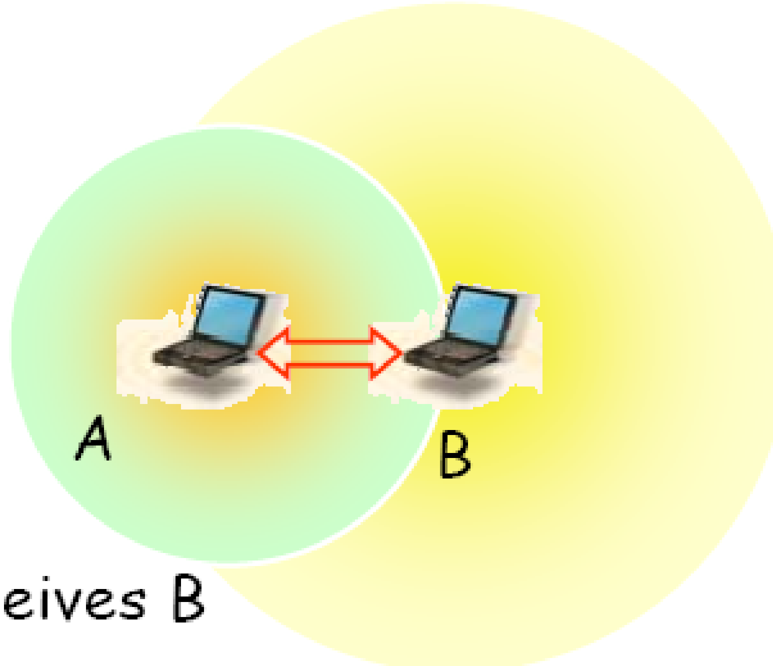
B cannot receive A

unidirectional(*) link

(*) sometimes improperly referred to as "asymmetric link"

Wireless Network Technology

- **Radio transmission coverage**



A receives B

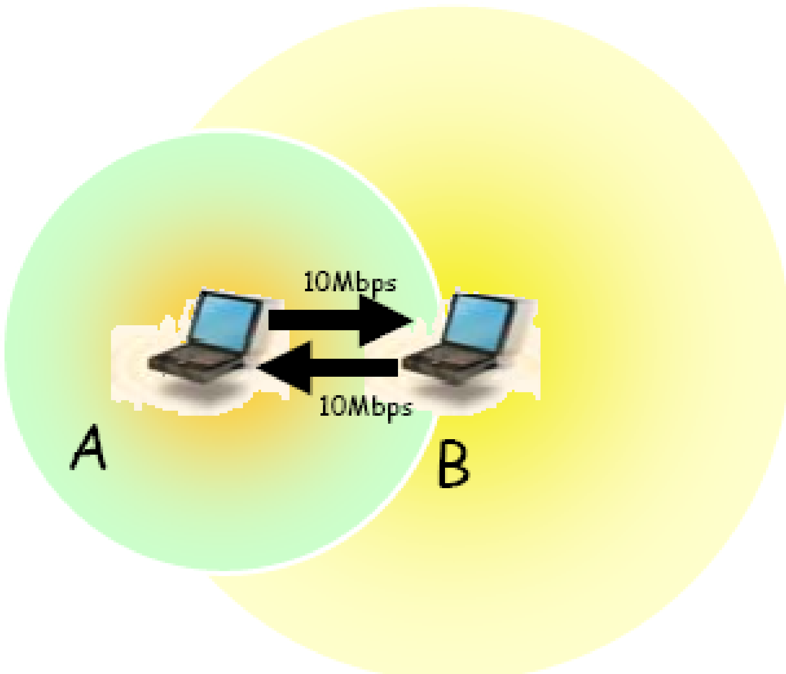
B receives A

bidirectional(*) link

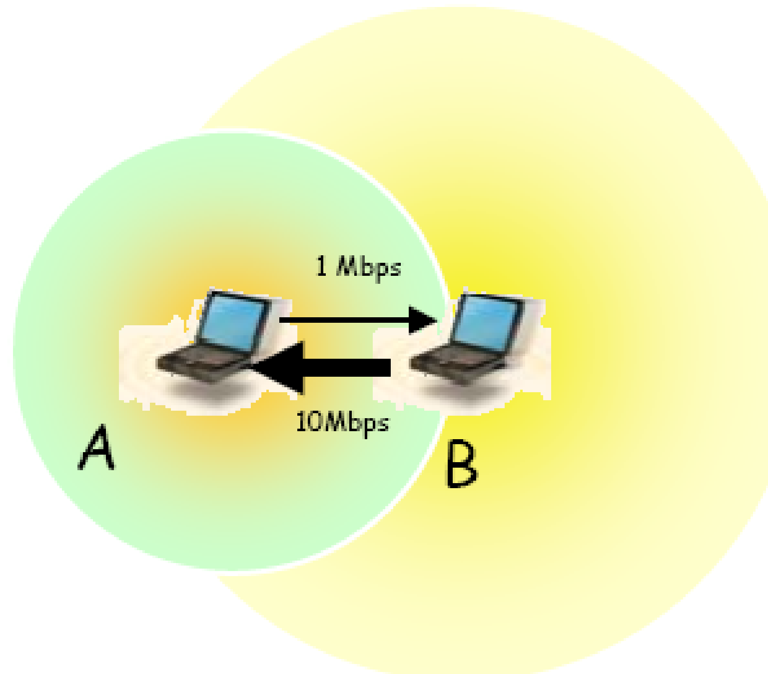
(*) sometimes improperly referred
to as "symmetric link"

Wireless Network Technology

- **Radio transmission coverage**



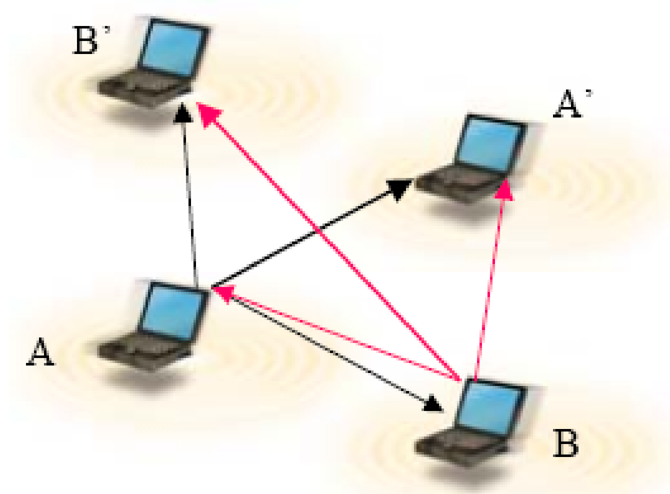
bidirectional symmetric link



bidirectional asymmetric link

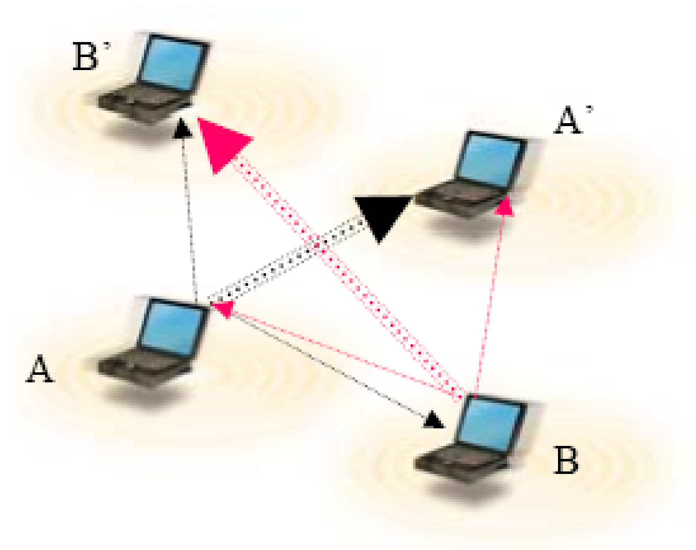
Wireless Network Technology

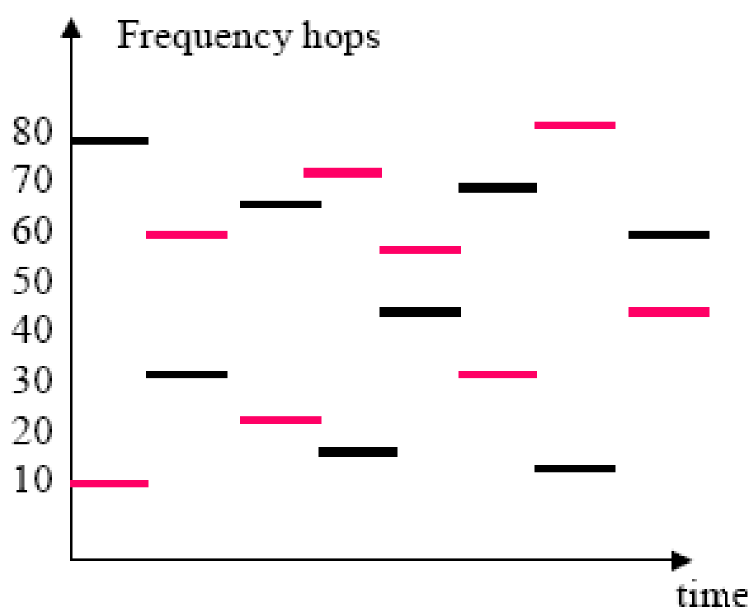
- **Narrowband radio system**
  - transmit/receive using a single, licensed, as narrow as possible radio frequency
  - undesired cross-talk between channels requires coordination and license for each site
  - low data-rates
  - e.g. → frequency X
  - e.g. → frequency Y



Wireless Network Technology

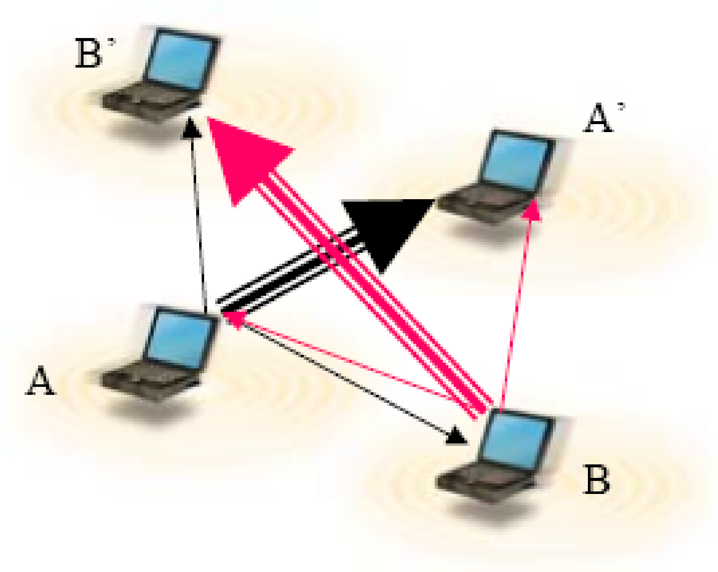
- **Frequency Hopping Spread Spectrum**
  - narrow band carrier changes frequency in a pattern known by both transmitter and receiver (single logical channel)
  - to unintended receiver FHSS appears as impulse noise

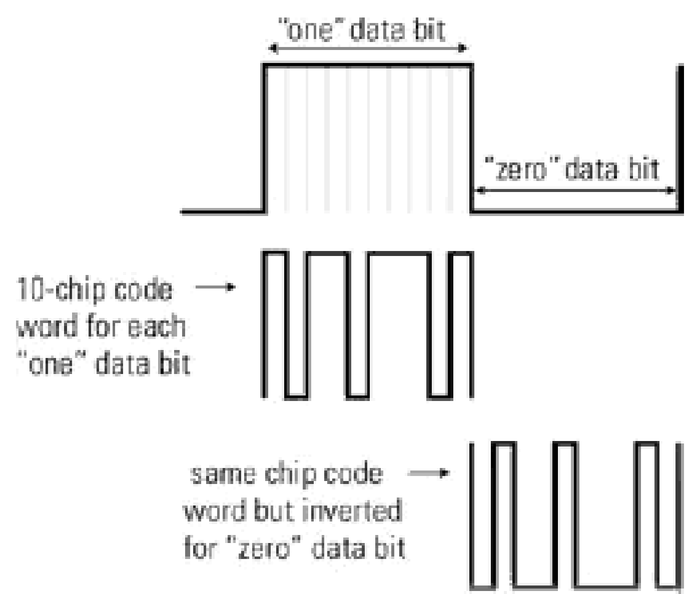




Wireless Network Technology

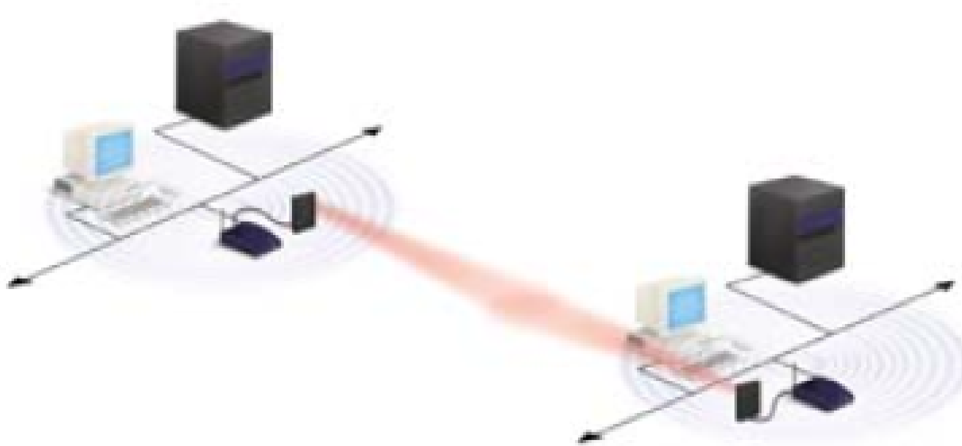
- **Direct Sequence Spread Spectrum**
  - redundant bit pattern (chipping code) spreaded over a large spectrum. Long chips increase probability of recovering the original bit (with no retransmission)
  - to unintended receiver DSSS appears as low power wideband noise





Wireless Network Technology

- **Infrared Technology (IR)**
  - frequencies just below the visible light
  - cannot penetrate opaque objects, and low diffusion
  - line-of-sight limitates mobility
  - short range technology (indoor, PAN, LAN nets)
  - High data-rate potential



Wireless Network Technology

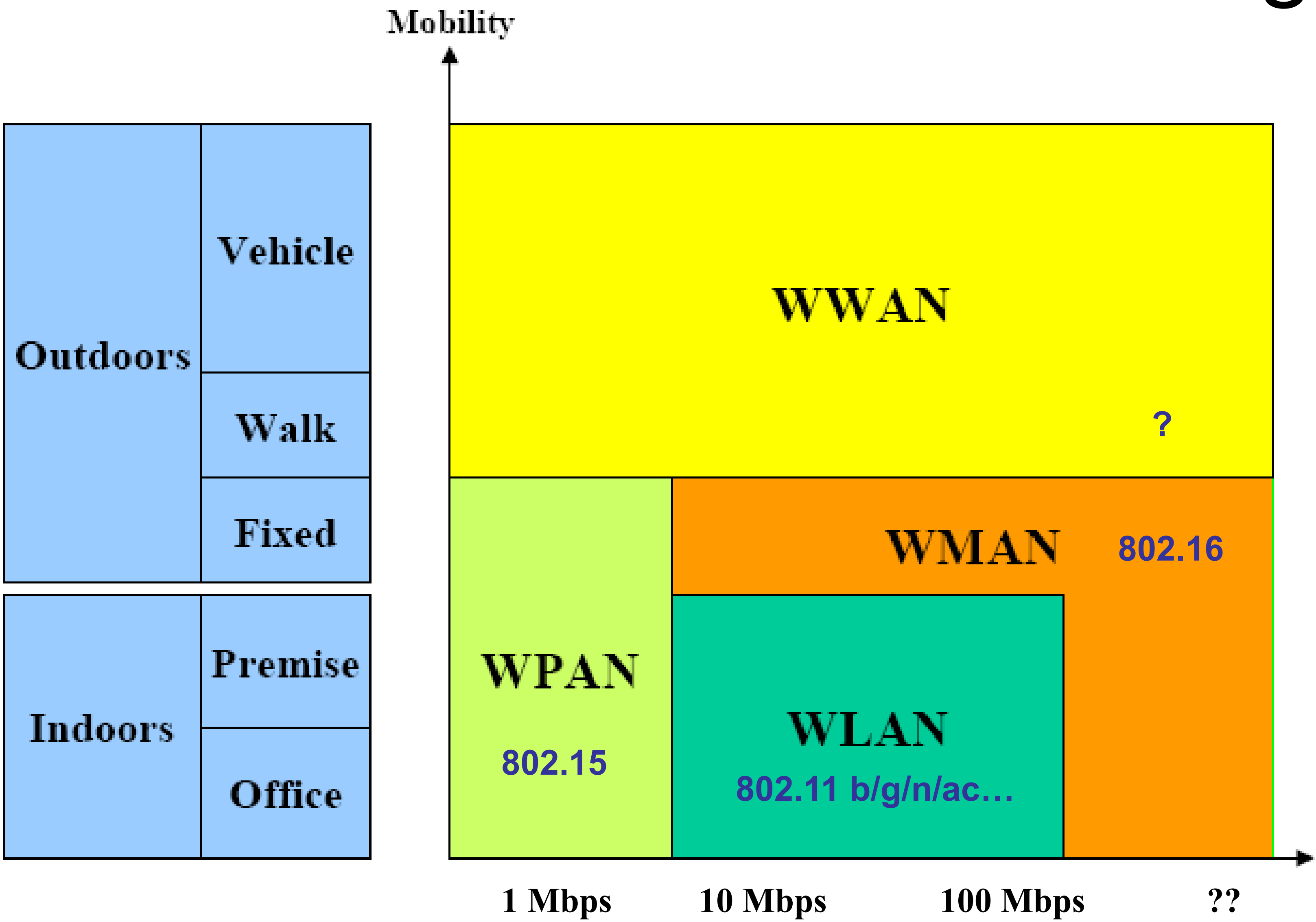
Comparison:

	PROS	CONS
Frequency Hopping Spread Spectrum (FHSS)	• Use less power than DSSS • Lower cost • Increased security due to frequency switching	• Lower throughput than DSSS
Direct Sequence Spread Spectrum (DSSS)	• High performance • Low interference • Increased security due to chip coding	• Expensive
Narrowband Microwave	• Long distance	• Line-of-sight with satellite dish • Requires FCC license • Not designed for WLAN use
Infrared	• High bandwidth	• Easily obstructed • Inexpensive

Wireless Network Coverage

- **Wireless Wide Area Network (WWAN)**
  - geographic coverage (e.g. satellite, cellular)
- **Wireless Metropolitan Area Net. (WMAN)**
  - Metropolitan coverage (e.g. town, large campus)
- **Wireless Local Area Network (WLAN)**
  - local area coverage (e.g. campus, building, home)
- **Wireless Personal Area Network (WPAN)**
  - reduced local area coverage (e.g. house, office)
- **Wireless Indoor Area Network (indoor)**
  - short range coverage (e.g. room, office)

Wireless Network Positioning

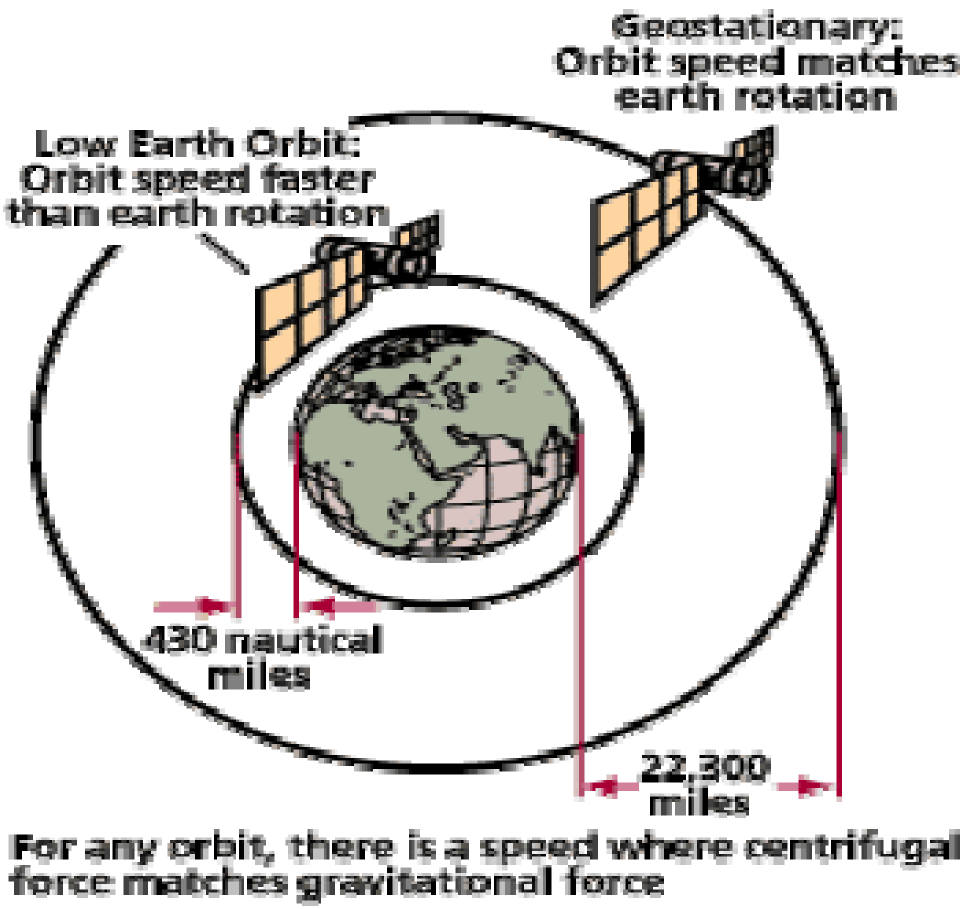


Wireless Network Structures

- **WWAN and WMAN**
  - Satellite (low orbit, geo-stationary)

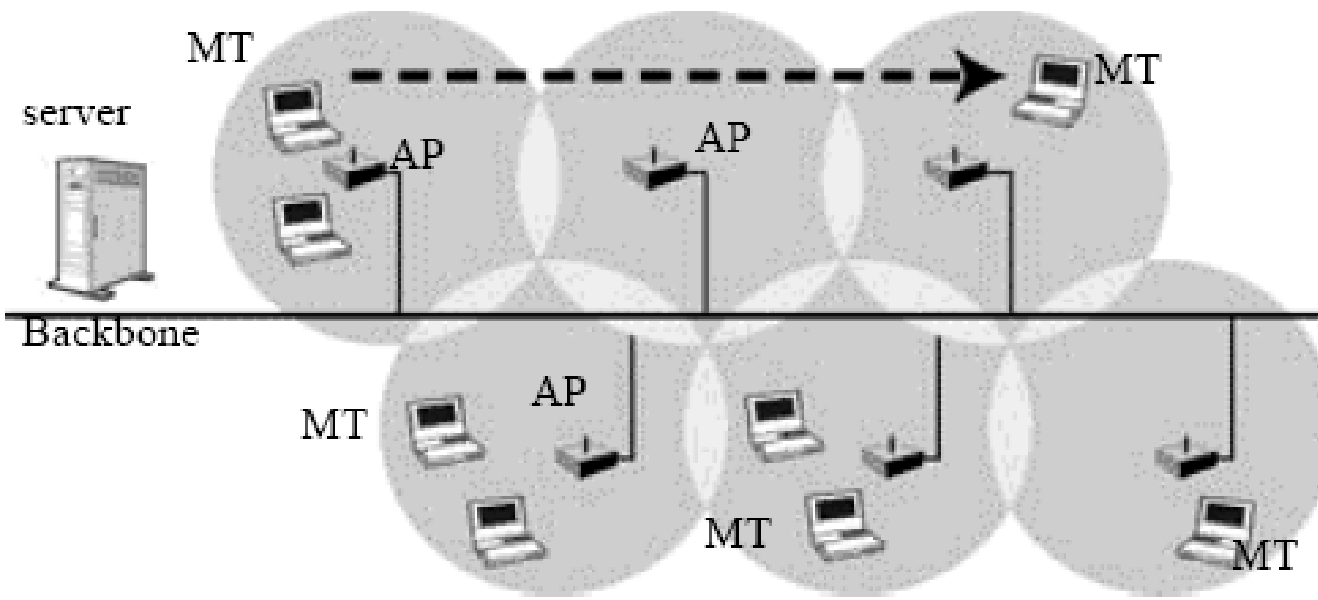
3 GEO satellites can cover the whole globe; yet they have around 500 ms of Round Trip Time (RTT)

LEO satellites sufers from *handovers/handoffs* (nodes have to switch from one connection to another one) due to satellite mobility.



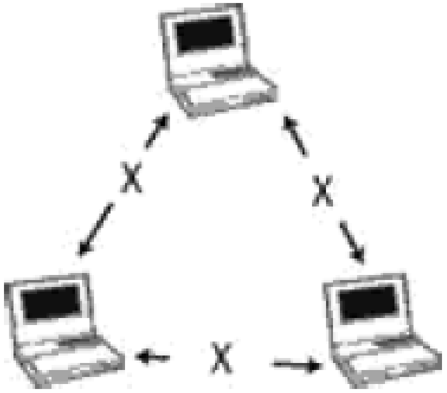
Wireless Network Structures

- **WWAN and WMAN**
  - Cellular or multi-Infrastructure WLAN
    - grid of Access Points (AP), managing local Mobiles terminals (MT), and connected to Backbones

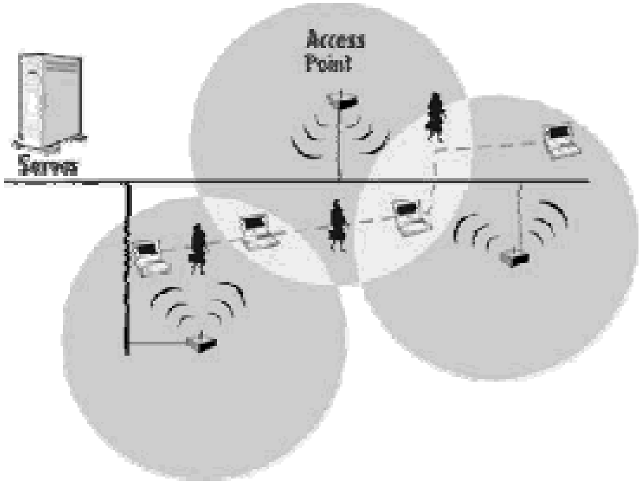


Wireless Network Structures

- **WLAN:**
  - Ad-Hoc:
    - peer-to-peer (P2P) “on the fly” communication
    - the network “is” the set of computers
    - no administration, no setup, no cost?

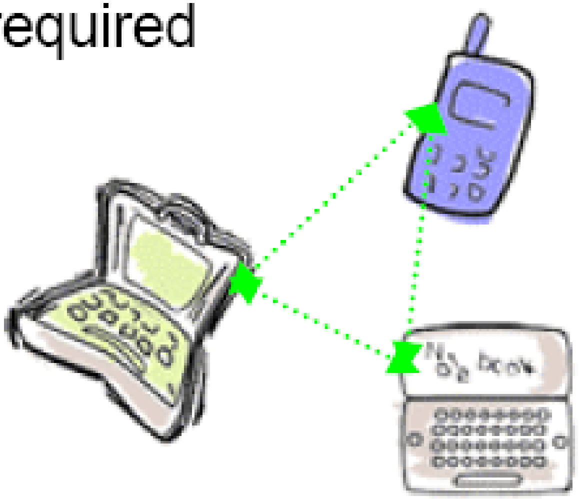


  - Infrastructure:
    - Centralized control unit (Access Point, local server)
    - Roaming between cells
    - resource sharing and backbone connection



Wireless Network Structures

- **WPAN:**
  - cable connection alternative for in-home/office/workspace device connection
  - common technology and protocols required (e.g. HomeRF, Bluetooth)



- **Indoor:**
  - in room/workspace device connection

Wireless vs Wired

Attribute	Wireless PAN/LAN	Wired LAN/PAN
Throughput	10-100 Mbps	10-100 Mbps (and more)
Integrity & Reliability	Subject to interference	Highly reliable
Simplicity/ Ease of Use	• No need to pull cable • Set up time is significantly lower • Moves, additions & changes much simpler	• Cable required • Set up time is significantly higher
Security	• Susceptible to interception • encryption	• Not as susceptible to interception

Wireless vs Wired

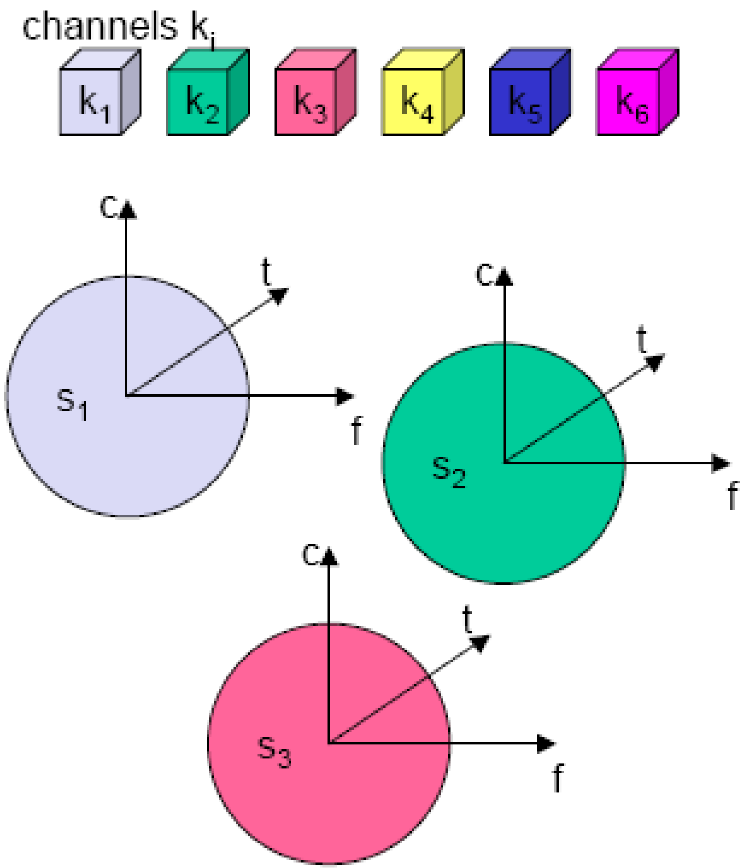
Attribute	Wireless LAN/PAN	Wired LAN/PAN
Cost	• Initial investment in hardware costs more • Installation expenses and maintenance costs can be significantly lower	• Investment cost in hardware lower • Installation and maintenance costs can be significantly higher
Scalability	simple to complex networks	simple to complex networks
Safety	Very little exposure to radio frequency energy	No exposure to radio frequency energy
Mobility	Provides access to real-time information anywhere	Does not support mobility

In a Wireless Environment

- **New assumptions for the physical system...**
- **...willing to maintain needs for services and applications**
  - e.g. audio/video applications, interactive services
- **... dealing with limited resources (e.g. bandwidth, energy)**
- **... dealing with device limits (I/O, user interfaces)**
  - limited display, no keyboard, no mouse
- **... mobility of users and devices**
  - variable number of users in the system
- **... QoS problems, reliability, negotiation**

Multiplexing

- **Multiplexing in 4 dimensions**
  - space (s_i)
  - time (t)
  - frequency (f)
  - code (c)

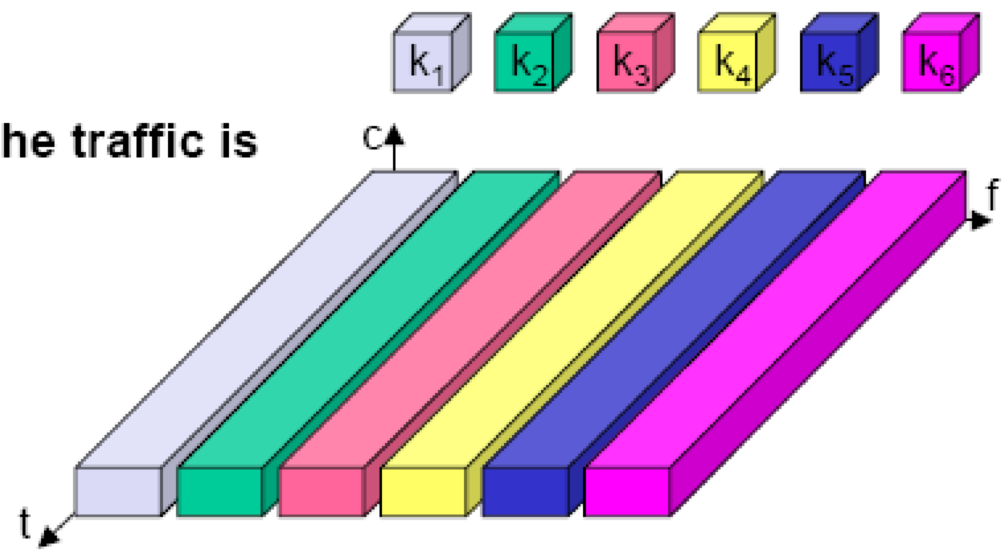


- **Goal: multiple use of a shared medium**

- **Important: guard spaces needed!**

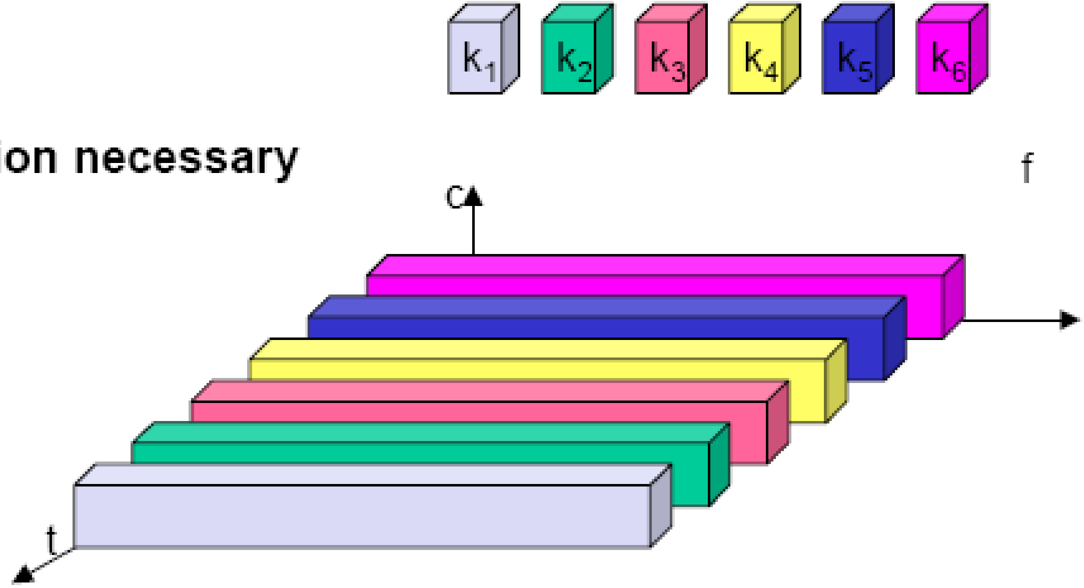
Frequency Multiplex

- Separation of the whole spectrum into smaller frequency bands
- A channel gets a certain band of the spectrum for the whole time
- Advantages:
  - no dynamic coordination necessary
  - works also for analog signals
- Disadvantages:
  - waste of bandwidth if the traffic is distributed unevenly
  - inflexible
  - guard spaces



Time Multiplex

- A channel gets the whole spectrum for a certain amount of time
- Advantages:
  - only one carrier in the medium at any time
  - throughput high even for many users
- Disadvantages:
  - precise synchronization necessary



Code Multiplex

- Each channel has a unique code
- All channels use the same spectrum at the same time
- Advantages:
  - bandwidth efficient
  - no coordination and synchronization necessary
  - good protection against interference and tapping
- Disadvantages:
  - lower user data rates
  - more complex signal regeneration (€)
- Implemented using spread spectrum technology