Wireless Communication

Lecture workshop: Wireless Communication
Course: Minor Smart Things

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Learning Objectives

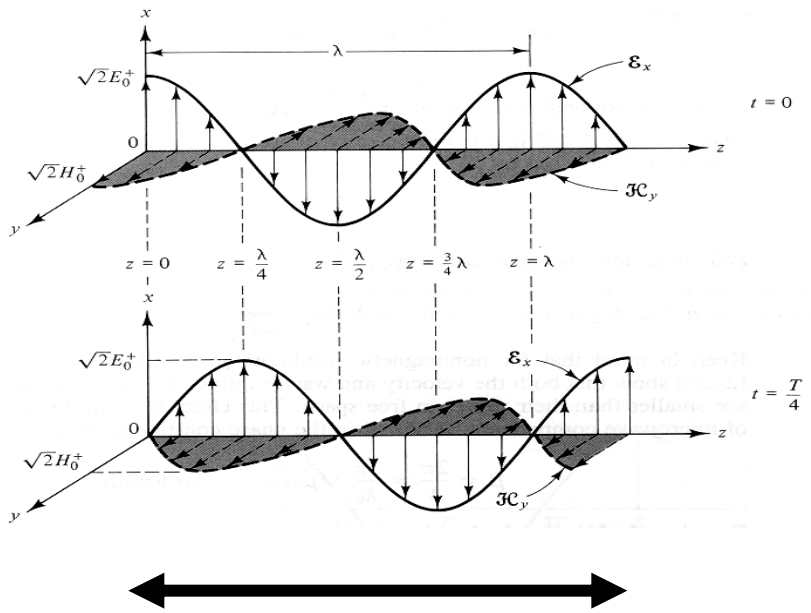
- Working principal of wireless communication.
- Access Technique.
- Different types of wireless communications:
  - Long range: GSM, UMTS
  - Short range: Wi-Fi, Bluetooth
- Workshop: Arduino with Xbee shield.

Wireless Communication

- **Why do we need these technologies?**
  - **Mobility,**
  - **Reachability independent of time and space,**
  - **Speed,**
  - **Communication over long and short distances,**
  - **Huge impact on Smart products, medical, safety, meetings, ramp situation, and many, many more.**

Wireless Communication

- To communicate using Electromagnetic radio waves through time and space.
- Electromagnetic fields travel with speed of light 3×10^8 m/s.



Two way communication

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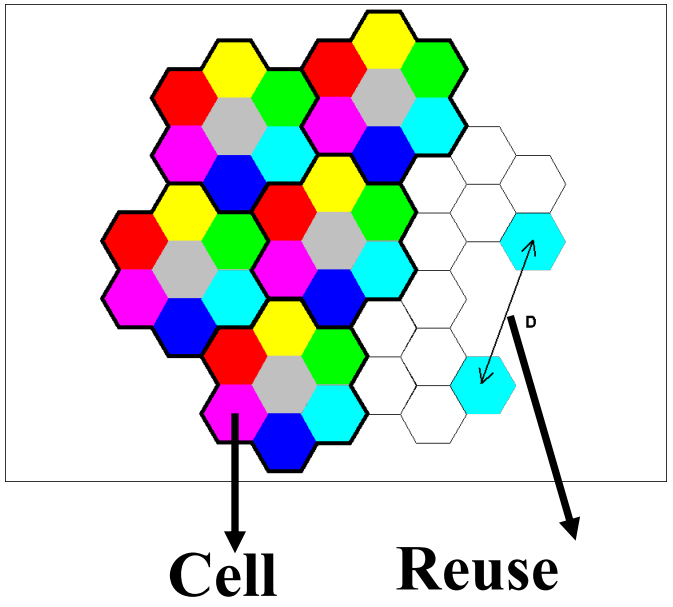
Operation principle: UMTS

- Cellular network or mobile network
- Geographical area divided in cells
- Cells has shape of hexagonal
- Each cell has his own set of resources



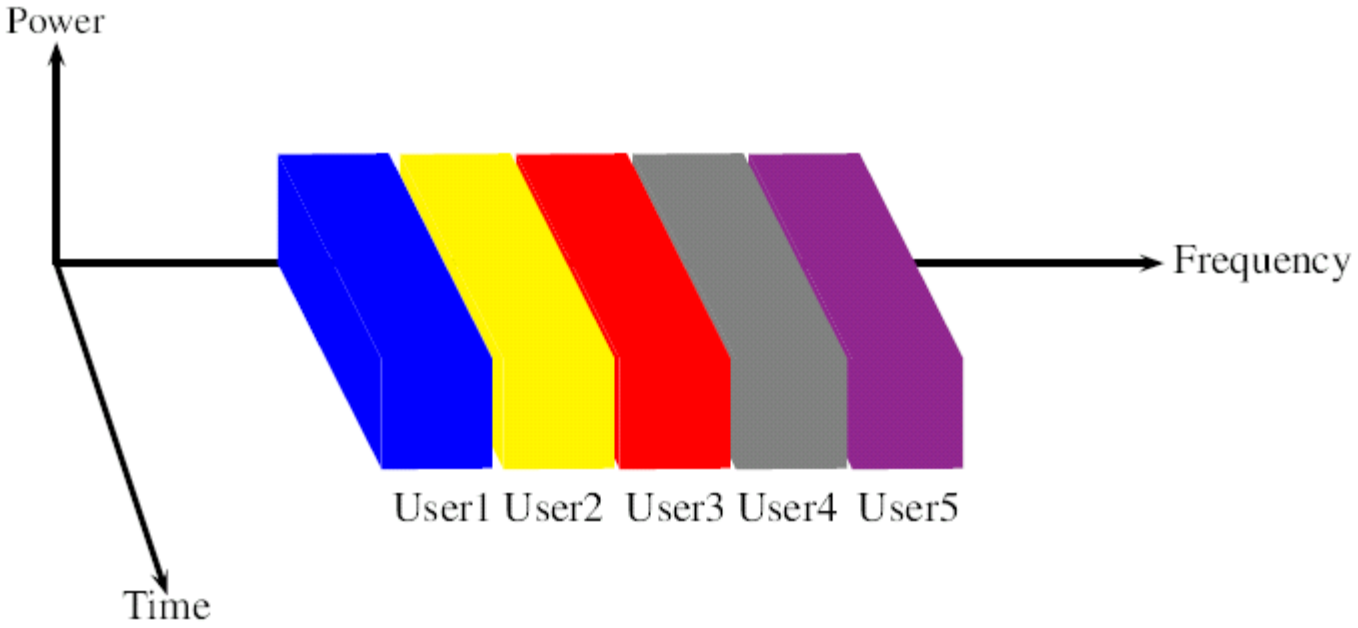
- Cells radius:
  - Signal strength
  - Signal-to-Noise ratio (SNR) expressed in dB
  - Signal-to-(Noise + Interference) ratio (SINR) expressed in dB
  - Capacity

Access techniques

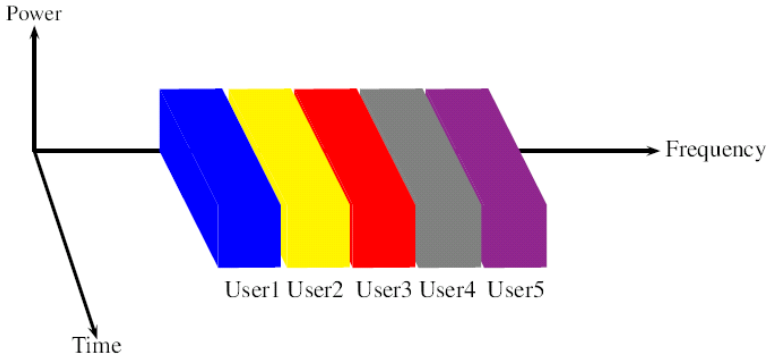
- Access the users
- Information of one user should not interfere with others:
  - Time
  - Frequency
  - Code
  - Space
- Orthogonality

Access techniques

- **Frequency: FDMA: Frequency Division Multiple Access**



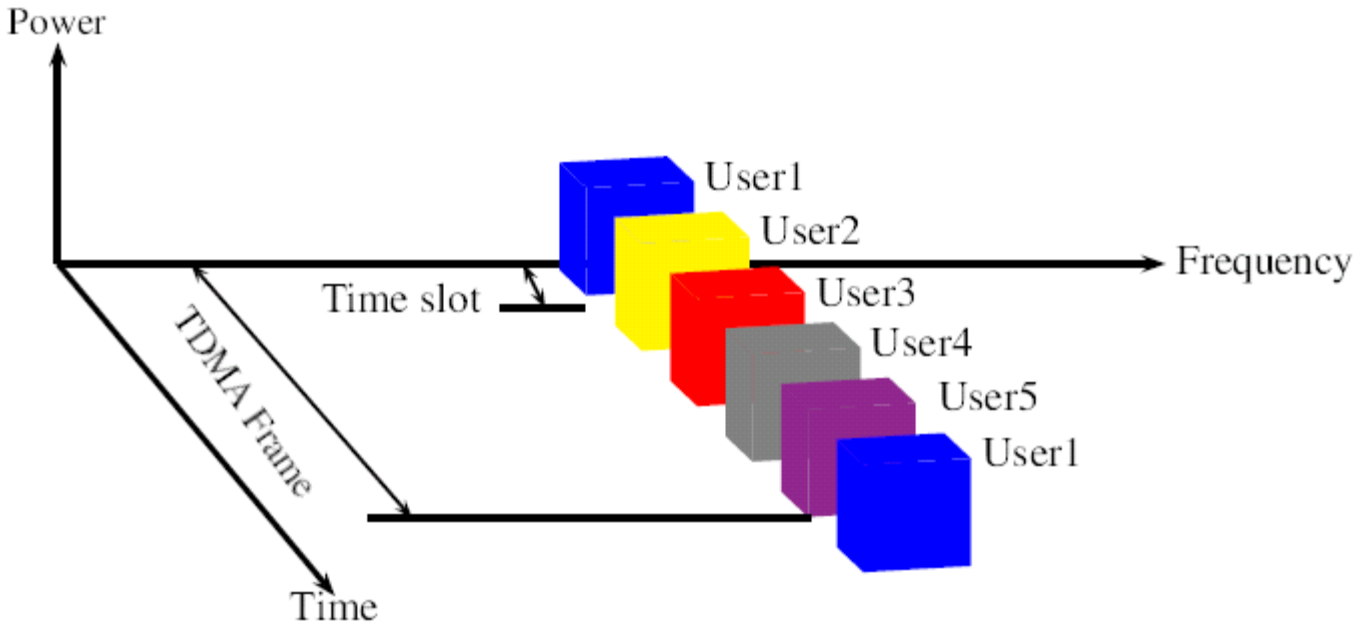
Access techniques



- **FDMA**
- **GSM: Global System for Mobile Communication: Outdoor**
- **Uplink: Mobile to Base Station: 890MHz ≤ f ≤ 915MHz**
- **25MHz bandwidth divided into 124 one way carrier: 200kHz spacing**
- **DECT: Digital European Cordless Telecommunication: Indoor**
- **10MHz bandwidth divided into 10 carrier: 1,78MHz spacing**

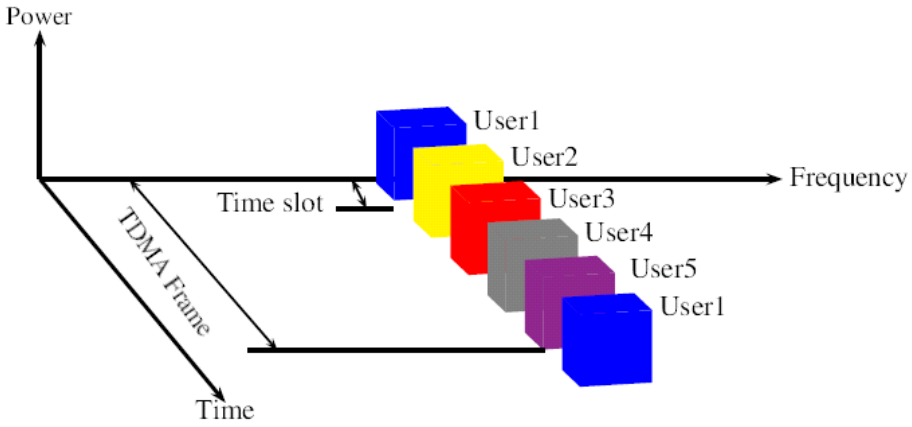
Access techniques

- **Time: TDMA: Time Division Multiple Access**



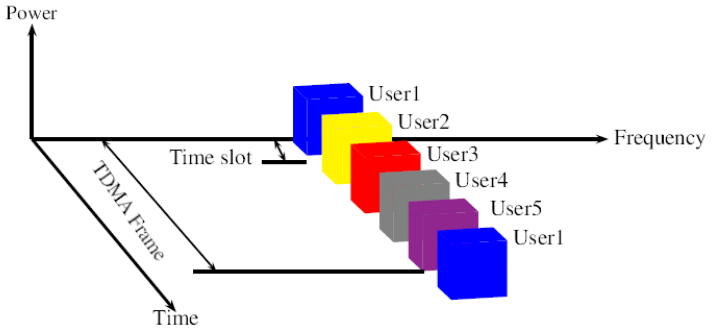
Access techniques

- **TDMA**

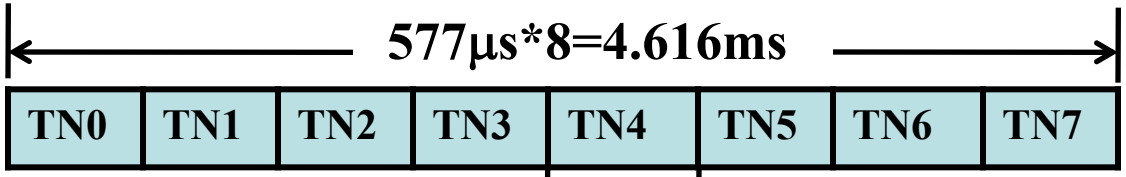


- **One frequency channel is divided in a number of orthogonal time slots**
- **GSM: 8 slots takes 4.16538ms**
- **DECT: 12 slots takes 5.0ms**
- **Each slot:**
  - **GSM 557µsec**
  - **DECT 368 µsec**

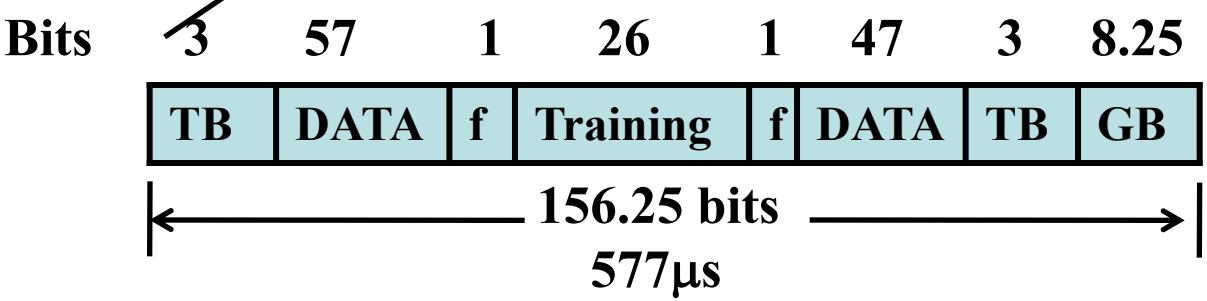
Access techniques



- **GSM TDMA frame:**



- **TDMA slot:**



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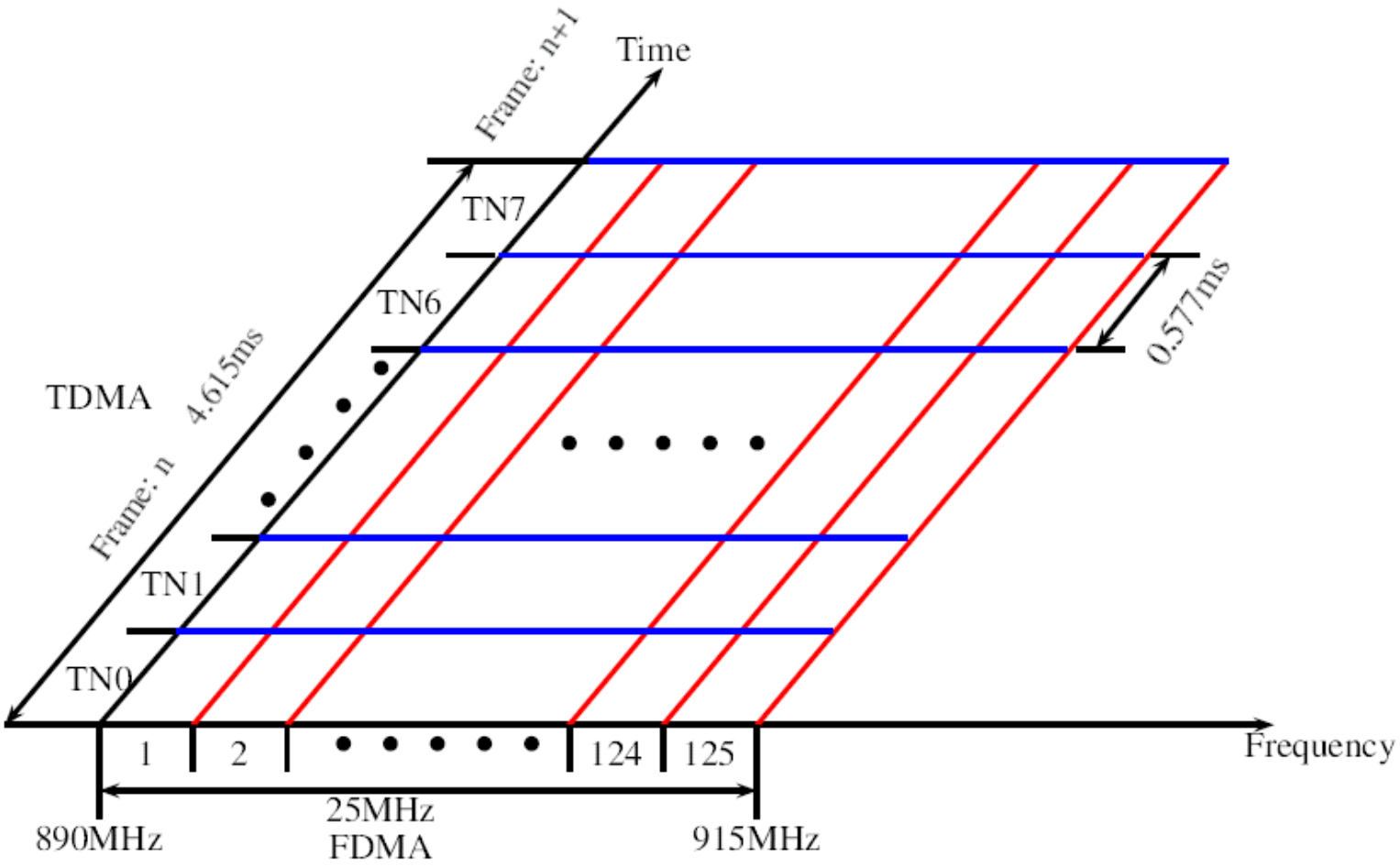
GSM: FDMA + TDMA



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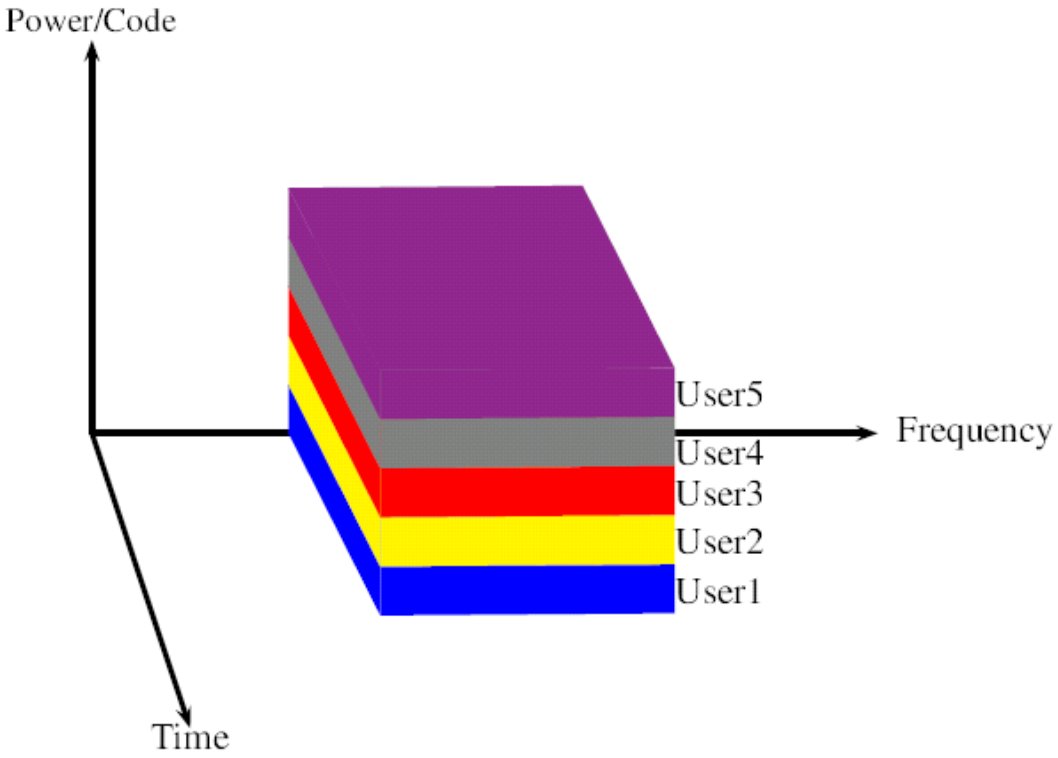
Access techniques

- **Code: CDMA: Code Division Multiple Access**



Access techniques

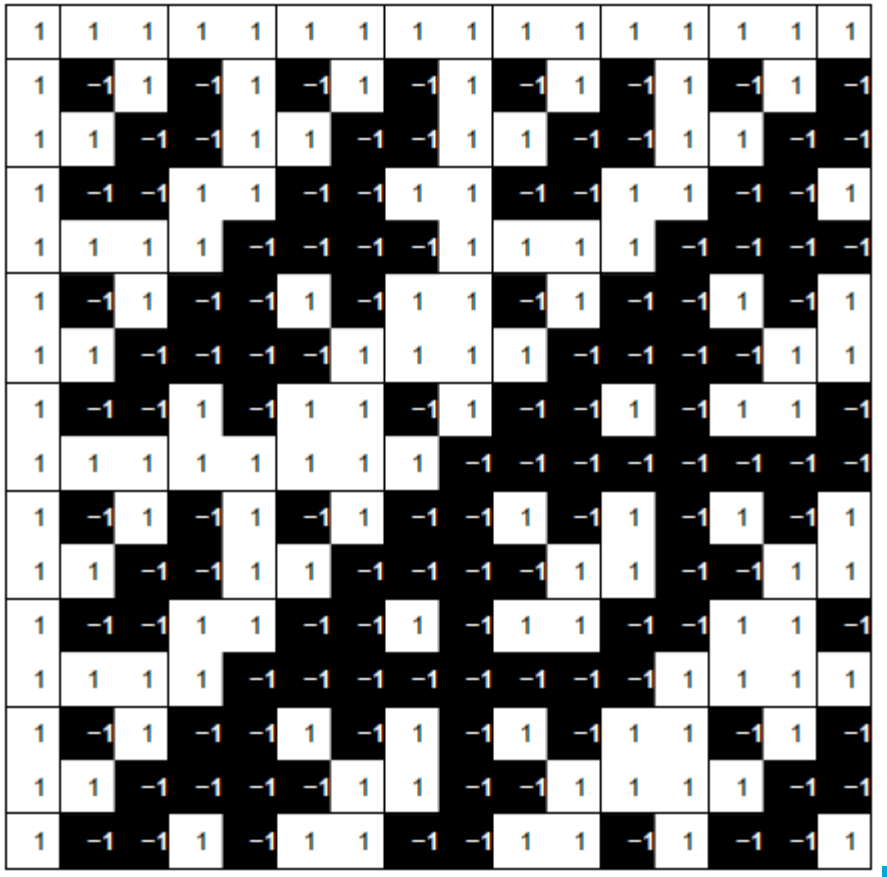
- CDMA

- UMTS: 3rd generation mobile communication

- UMTS: Universal Mobile Telecommunications System

- Hadamard code
  - Orthogonal code
  - Code length 64

Hadamard code with length 16 generated in MATLAB



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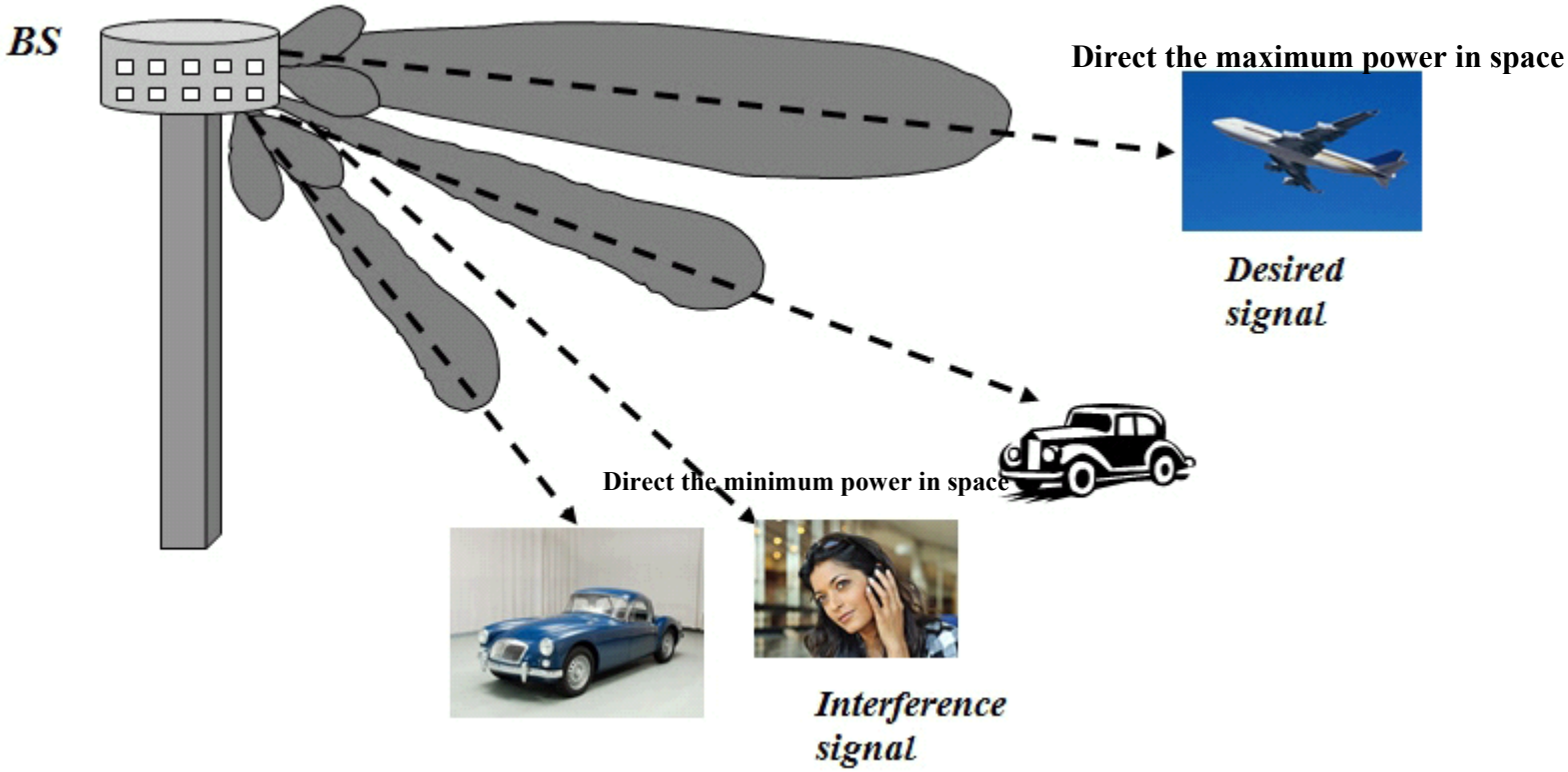
Access techniques

- **FDMA, TDMA, CDMA: temporal**
- **SDMA: Space Division Multiple Access**



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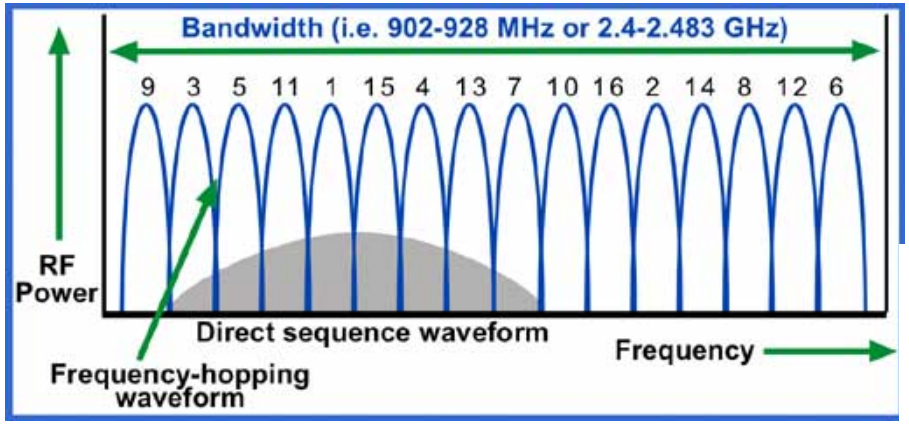
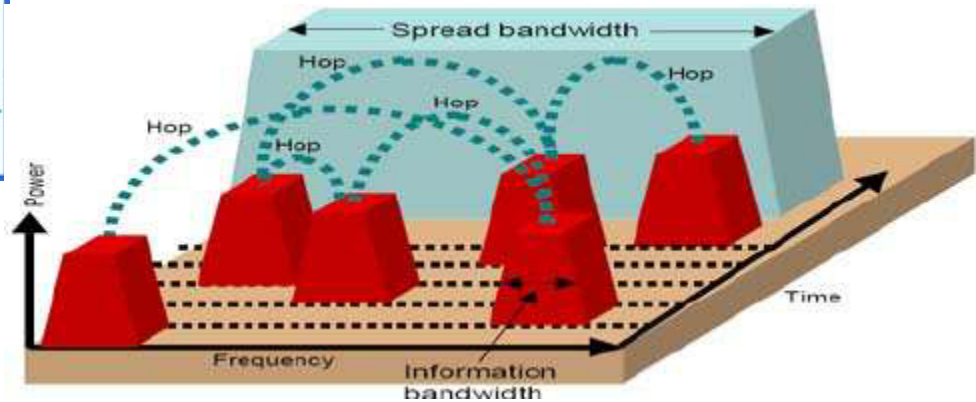
What is Wi-Fi?

- WiFi stands for Wireless Fidelity.
- Based on the IEEE 802.11 family of standards.
- Local area networking (LAN) technology to provide in-building broadband coverage.
- Coverage up to 300m.

802.11 Physical Layers

- **802.11b - 2.4 GHz ISM band**
  - **FHSS (Frequency hopping spread spectrum): combat interference.**
  - **DSSS (Direct sequence spread spectrum)**
  - **Up to 11 Mbps**





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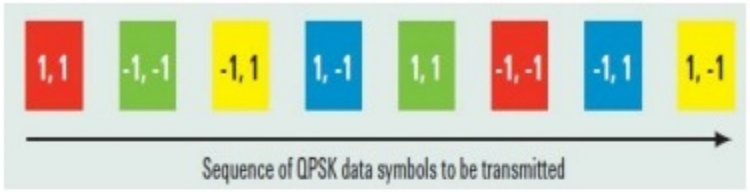
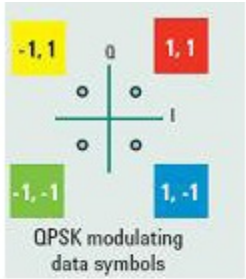
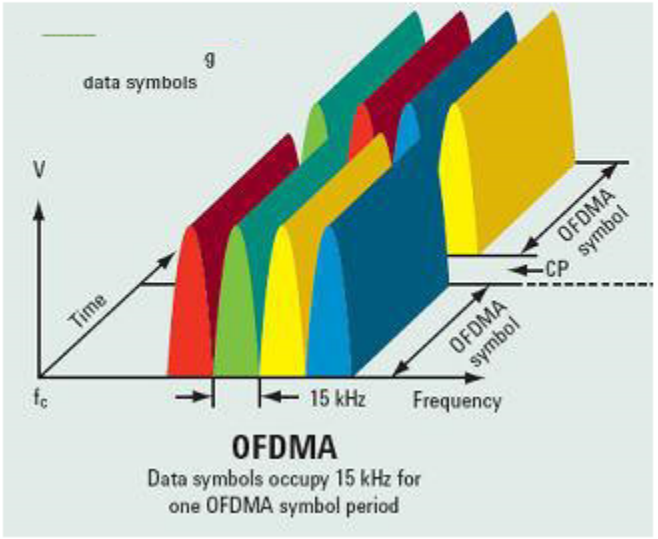
802.11 Physical Layers

- **802.11a/g - 2.4 GHz ISM band / 5.0 GHz UNII band**
  - **OFDM (Orthogonal frequency domain multiplexing)**
  - **Up to 54 Mbps**







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802.11 Physical Layers

- 802.11n – 2.4/5.0 GHz bands
  - Adds MIMO and other tricks to 802.11g
  - Up to 300-500 Mbps!
- Each backwards compatible with the previous ones

What is Bluetooth (BT)?

- **BT is wireless communication standard which allows electronic devices to connect and interact with each other.**
- **Applications:**
  - **computers from Apple and mice from Microsoft, is what Bluetooth technology is all about—all at a low cost**
  - **Printers, mouse,**
  - **Listening to music: your smartphone to wireless speakers or headphones.**
  - **Hands-free headsets.**
  - **File transfer**
  - **Healthcare + high dedicated applications:**
    - **https://web.mst.edu/~mobildat/Bluetooth%20Applications/index.html**

What is Bluetooth (BT)?

- **Applications:**
  - **Wearable devices:**
    - **Smart bracelet.**
    - **Smart watch.**
    - **Smart shoes.**
    - **Smart pen.**

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Bluetooth

- Short range communication
- ISM free band, 2.4GHz, IEEE 802.15 Standards
- Access technique: Frequency Hopping Spread Spectrum (FHSS)
- Maximum network speed: 1M bit/sec
- Network range: 1 or 100m, depending on radio class.
- Typical Network joint time: 3 Sec.

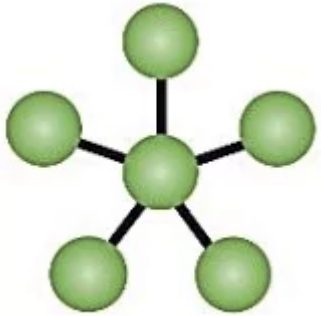
Different classes

Device class	Tx power	Intended Range
Class 3	1mW: 0dBm.	<10m
Class 2	2.5mW: ≈4dBm	10m
Class 1	100mW: 20dBm	100m

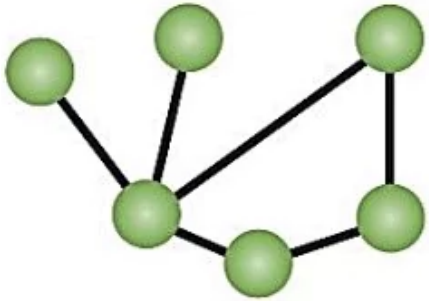
Network topology

- **Point-to-point:**

- **Broadcasting (Star):**
  - **All devices are connected to a central hub.**
  - **Range is limited.**



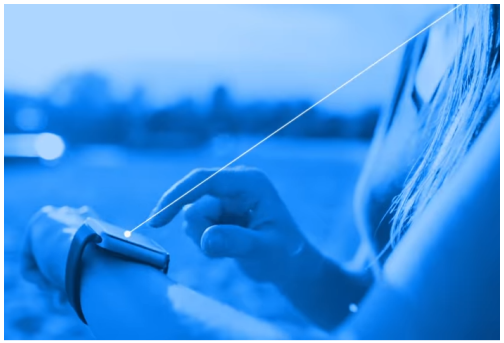
- **Mesh:**
  - **All devices communicate with each other.**
  - **Size and area covered by the network virtually unlimited.**



Network topology

- **Point-to-point:**

Audio



Device to device

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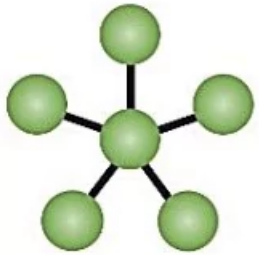
Network topology



- **Broadcasting (Star) applications: one to many**
  - **Beacon revolution**
  - **Advertisement.**
  - **In-door location.**

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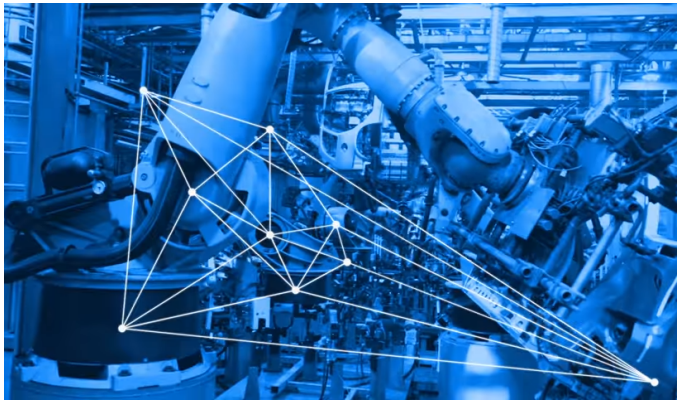
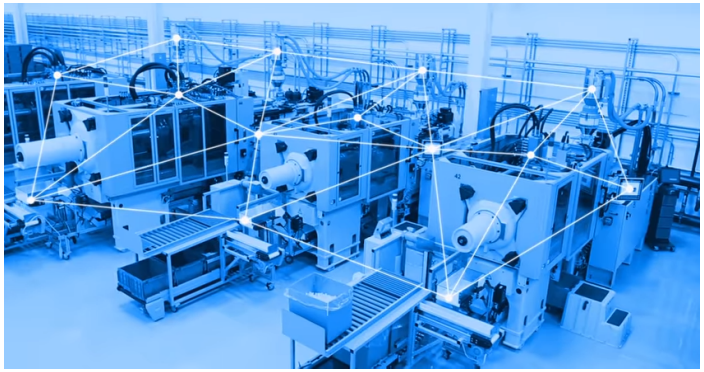
Network topology

- **Mesh applications: many to many communication**





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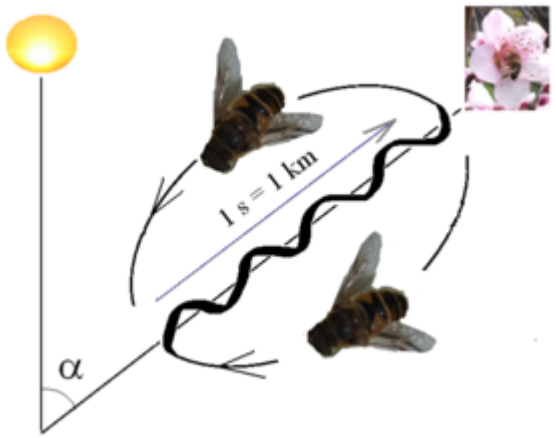
What is ZigBee?

- used to create personal area networks with small, low-power digital radios: home automation, medical device data collection.
- is a low-power, low data rate, and close proximity (i.e., personal area) wireless ad hoc network.
- Named after zigzag dance of the honeybees, where direction of the dance indicate the location of food.



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Applications

- **IoT**
- **Industrial Automation: monitors various parameters and critical equipment.**
- **Home Automation: controlling home appliances remotely: lighting system control, heating and cooling system control, etc.**
- **Smart Metering: energy consumption response, pricing support, security over power line, etc.**
- **Smart Grid monitoring: involve remote temperature monitoring, fault locating, etc.**

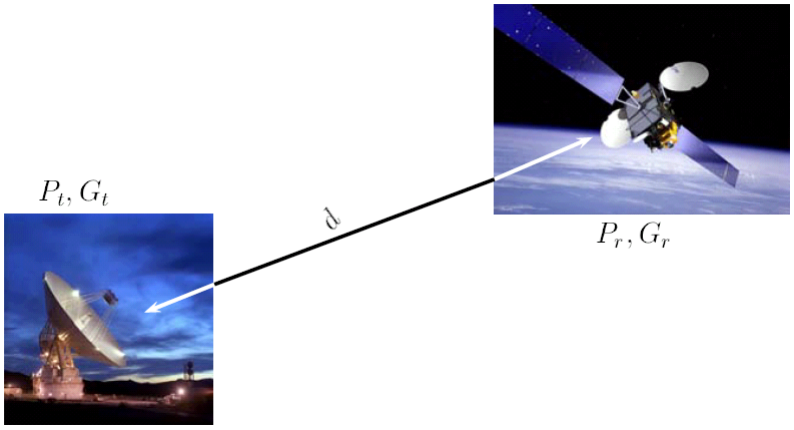
Workshop

- **XBee shields with Arduino:**
  - **Two students.**
  - **Sender: send messages using switches.**
  - **Receiver: receive data and decoded to turn three LED on/off. You are free to choose which LED turns on/off.**
  - **Xbee addresses are already configured using XCTU.**
  - **Addressing: 200, 100, etc are the receivers (LED side), and 201 or 101 is the transmitter (switches).**
  - **Switch on the shield:**
    - **On select when uploading Arduino program.**
    - **On Serial when transmitting and receiving.**

End of lecture

Rest of slides are for additional background information.

- **Receive power**



Line of Sight (LOS) situation

- **High gain: improved S/N, S/(N+I)**
- **P_r = received power**
- **P_t : transmit power**
- **R : distance between the transmitter and receiver.**
- **$\lambda = c/f$: wavelength.**
- **G_{ot} , G_{or} Gain of transmit and receive antennas respectively.**
- **LOS: where Tx and Rx see each other in some kind of eye contact.**

$$P_r = P_t \left(\frac{\lambda}{4\pi R} \right)^2 G_{0t} G_{0r}$$

$$\downarrow$$

$$Free - space\ loss\ factor$$

Double distance: 6dB losses

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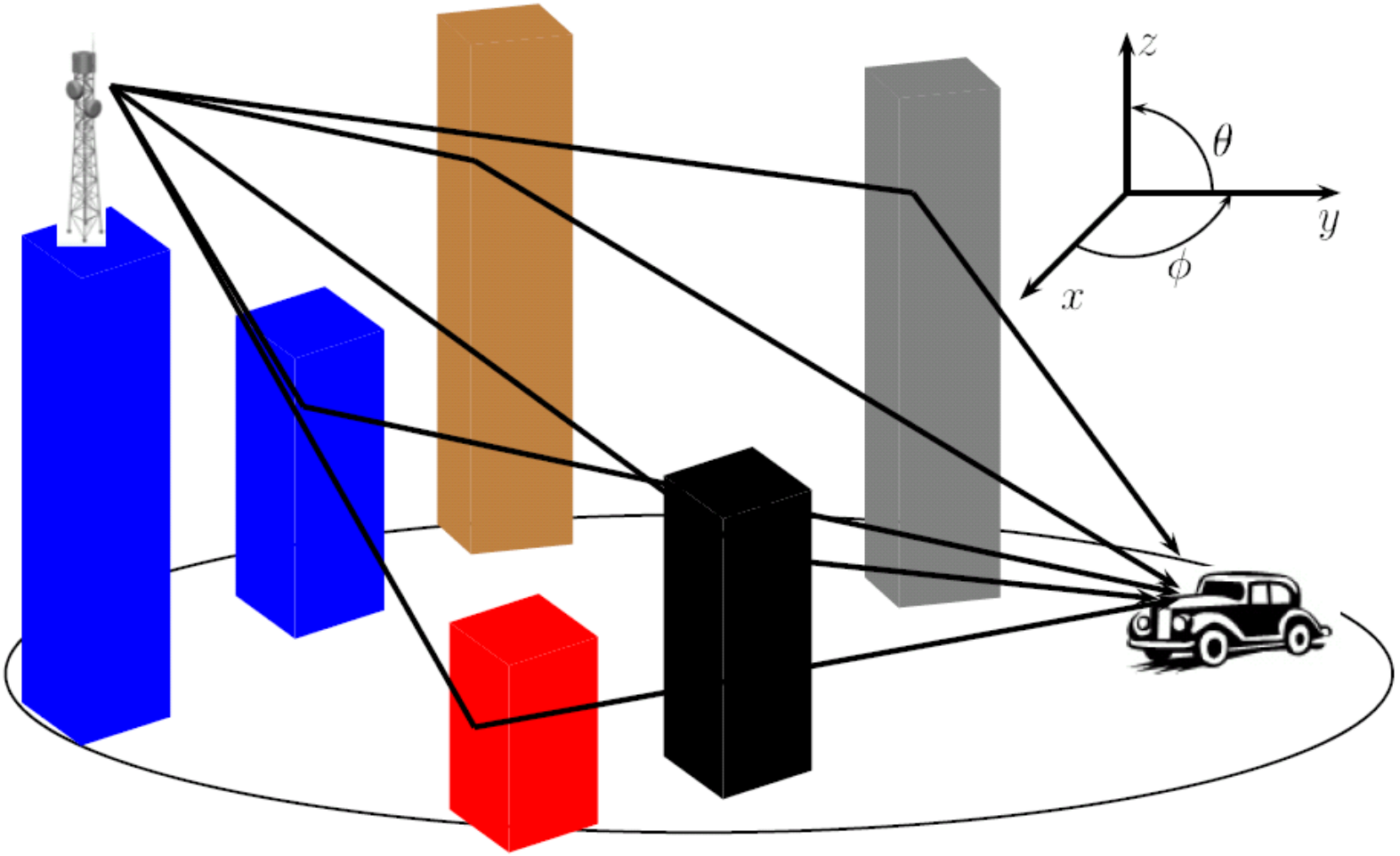

Reflection and scattering of EM waves

• Dynamic Range: sensitivity

- **The dynamic range of a radio receiver is essentially the range of signal levels over which it can operate.**
- **The low end of the range is governed by its sensitivity whilst at the high end it is governed by its overload or strong signal handling performance.**
- **ZigBee:**
  - **for 1mW transmit power: -97dBm**
  - **For 50mW: -102dBm**
- **Bluetooth:**
  - **4dBm output transmitter, -80dBm typical receive sensitivity**

- **Dynamic Range: sensitivity**
  - **Distance = 5km**
  - **Frequency = f = 5.8GHz**
  - **Tx power = 23dBm**
  - **Antenna Gain = 24dBi**

$$P_{dB} = 10 * \log_{10}(P)$$

$$P_{dBm} = 10 * \log_{10}\left(\frac{P}{1mW}\right)$$

$$P_r(dBm) = P_t(dBm) + G_{0t}(dB) + G_{0r}(dB) + 10 * \log_{10}\left[\left(\frac{\lambda}{4\pi R}\right)^2\right]$$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{5.8 \times 10^9} = 0.0517m$$

$$10 * \log_{10}\left[\left(\frac{\lambda}{4\pi R}\right)^2\right] = 10 * \log_{10}\left(\frac{0.0517}{4\pi \times 5 \times 10^3}\right)^2 = -121.70dB$$

$$P_r(dBm) = 23 + 24 + 24 - 121.70 = -50.7$$

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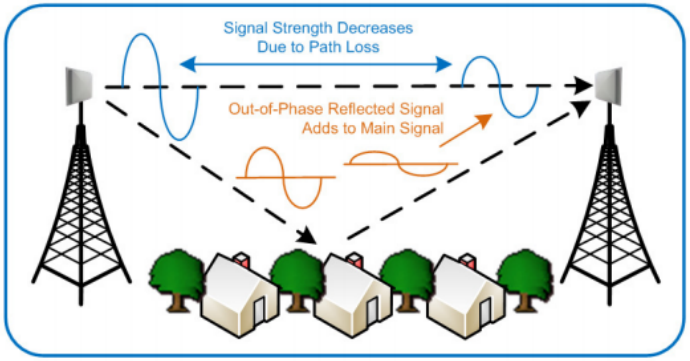
- **Dynamic Range: sensitivity**
- **Link margin or fade margin**



- **Quality Of Service (QOS): guarantee communication**

Time Availability (%)	Fade Margin (dB)
90	8
99	18
99.9	28
99.99	38
99.999	48

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- **Dynamic Range: sensitivity** $P_r\left(dBm\right) = -50.7$

- **Link margin or fade margin = Receiver power – Receiver sensitivity**

- **Receiver sensitivity of TR-Plus-24 used at the receiver is -72dBm**

- **Link margin or fade margin = -50.7 – (-72dBm)=21.3dB**

- **Thus 99% of time guarantee communication**

Time Availability (%)	Fade Margin (dB)
90	8
99	18
99.9	28
99.99	38
99.999	48