Networks and Distributed Systems

Lecture 23 – Mobile Communication basics

History of Wireless Communication

- Many people used communication before in different forms:
  - Light, flags (Semaphore)
  - Signaling towers in China (206 BC)
  - Smoke signals in Greece (150 BC)

History of Wireless Communication

- Beginning of electromagnetic wave communication:
  - 1831 Faraday demonstrated electromagnetic induction
  - 1864 J. Maxwell proposed the theory of electromagnetic fields, wave equations
  - 1876 Alexander Graham Bell invented the telephone
  - 1895 Guglielmo Marconi demonstrated for the first time wireless transmission

Guglielmo Marconi sends message from England to Newfoundland

Dec 12. The Italian physicist Guglielmo Marconi, who sent wireless telegraphic messages across the English Channel from Dover, England, to Boulogne, France, on March 29, 1899, repeated his experiment today over the Atlantic Ocean, a distance of 2,232 miles.

In order to carry out this experiment, Marconi set up a 164-foot-high antenna in Poldhu, Cornwall, England. Then, he erected a receiver in St. John's, Newfoundland, Canada. In spite of the earth's curvature, he received a Morse signal corresponding to the letter "S" from the Poldhu station across the ocean.

When Marconi realized the importance of his first discoveries in 1895, he asked the Italian Minister of Telecommunication to help him. But the minister found that Marconi's experiments were too extravagant. That's why Marconi went to England, where he won the support of Sir William Peace, the Postmaster General, who immediately understood the significance of the young Marconi's work. Thanks to Peace's perspicacity and the help of Professor Adolf Slaby, Marconi could hit his target today (— 2/22/03).

Guglielmo Marconi and his first wireless.

History of Wireless Communication

- 1911 mobile transmitter on Zeppelin
- 1926 Transmission on a train from Hamburg to Berlin
- 1924 first car radio
- 1940s first mobile communication system started in the US and in the 50s in Europe

History of Wireless Communication

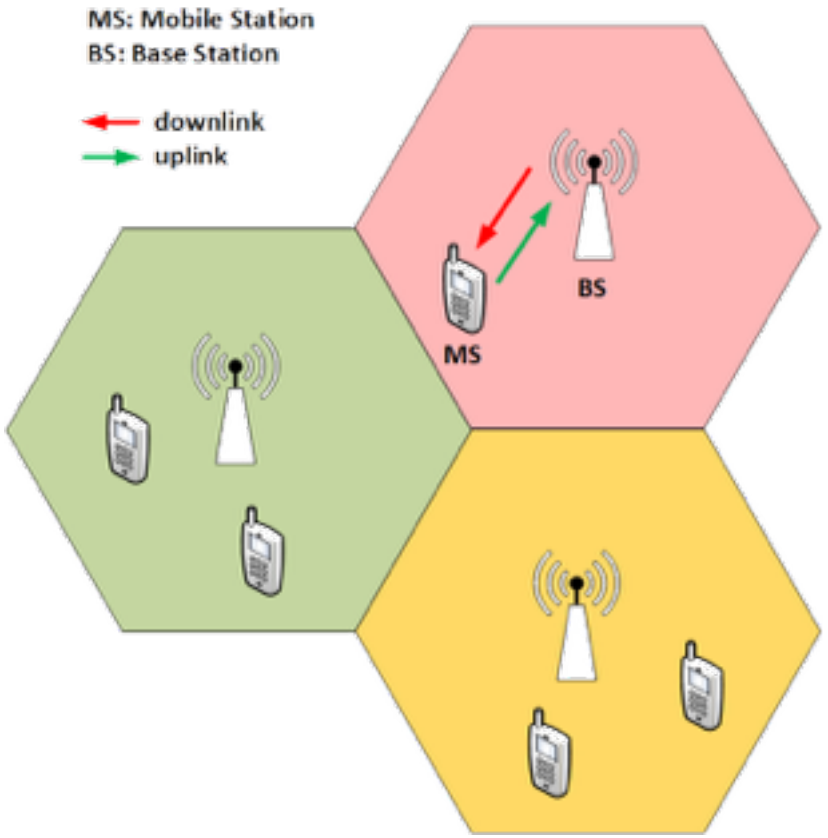
- 1987 Formation of the GSM association
- 1990 Freezing phase 1 of the GSM specification
- 1998 UMTS specifications started
- 2001 Start operation of the first 3G network in Japan
- 2004 LTE was proposed
- 2008 LTE standard was finalized

Mobile Comm. Basic Terms

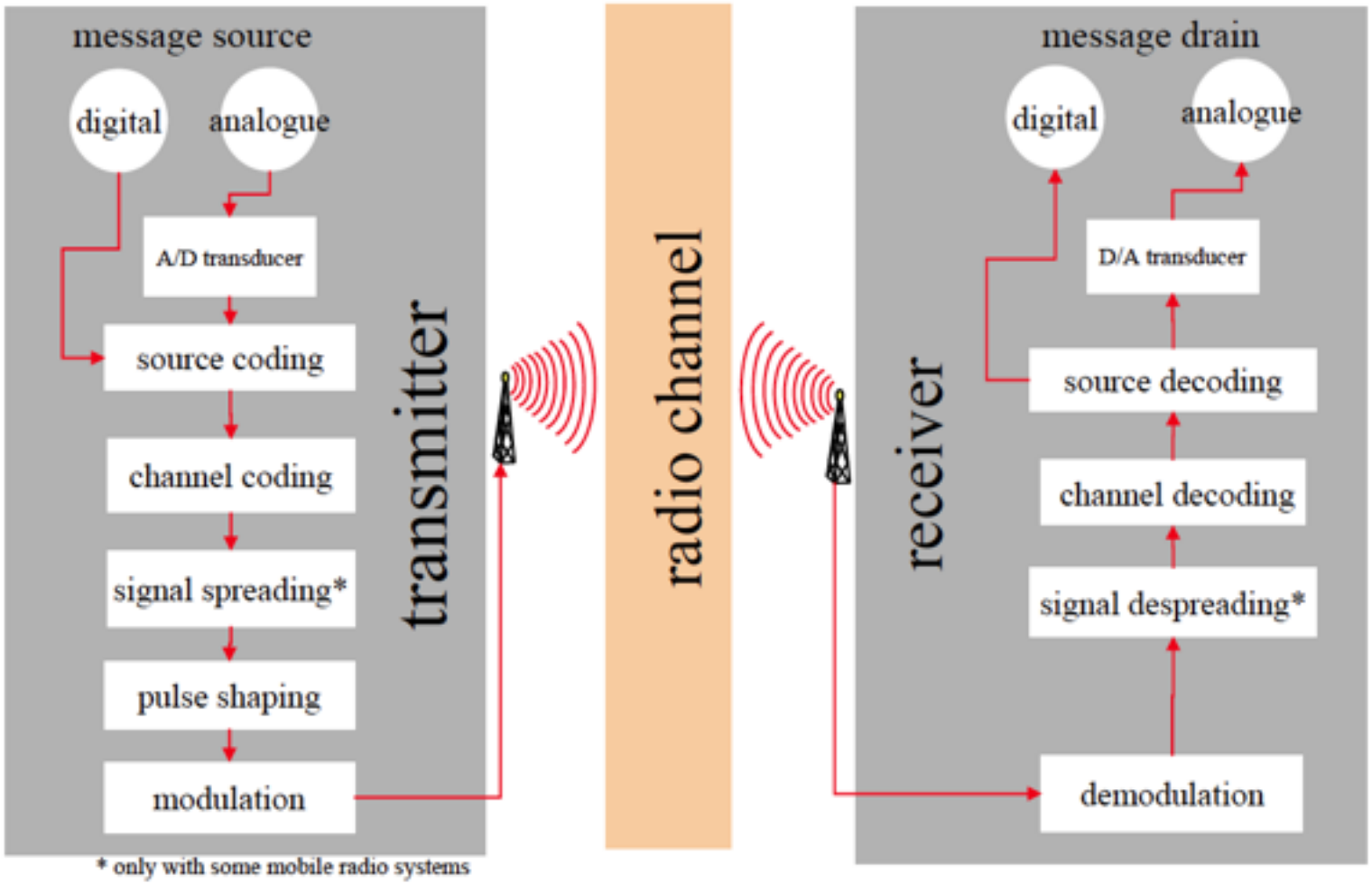
- There are three main components of a mobile radio network:
  - A telecommunication system
  - Mobility
  - Radio channel

Cellular Mobile Radio Networks

- Consists of one or several fixed radio Base Stations (BS)
- Each BS covers a certain area called radio cell
- Transmission from BS to MS is called downlink
- Transmission from MS to BS is called uplink



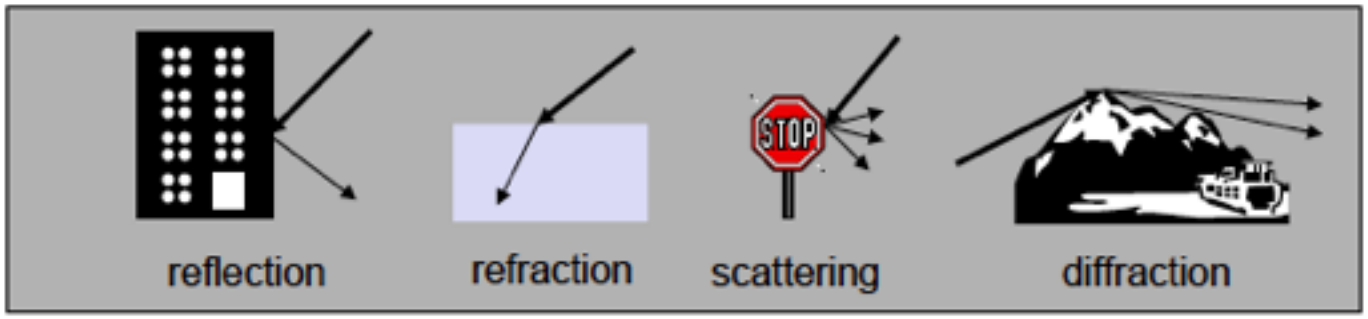
Radio Comm. System components



Signal Propogation

- Propagation in free space always like light (straight line)
- Receiving power in free space proportional to 1/d.
  (d = distance between sender and receiver)

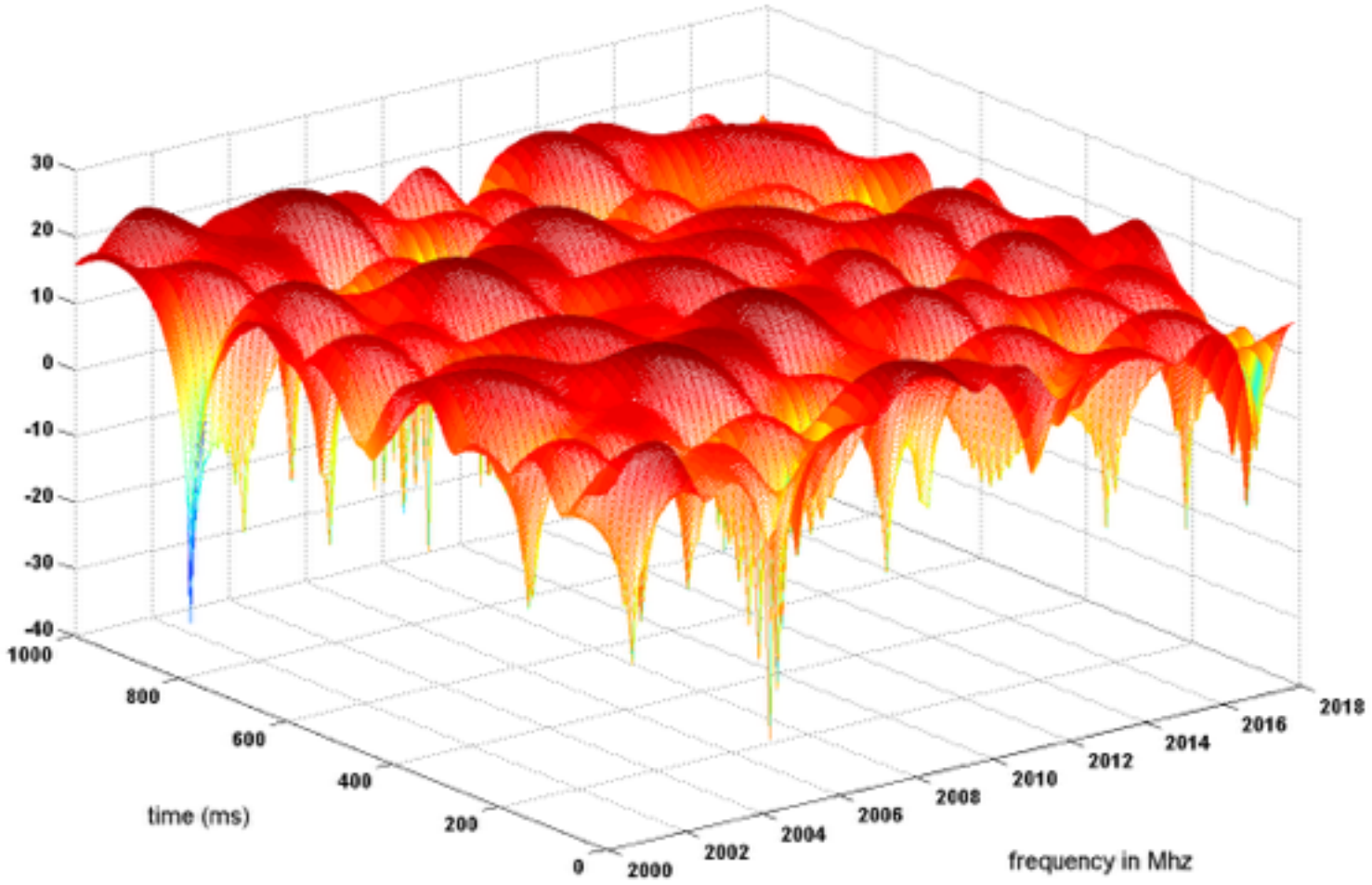
- Sources of distortion
  - Reflection/refraction – bounce of a surface; enter material
  - Scattering – multiple reflections at rough surfaces
  - Diffraction – start “new wave” from a sharp edge
  - Doppler fading – shift in frequencies (loss of center)
  - Attenuation – energy is distributed to larger areas with increasing distance



Radio Channel

- The signal sent from the sender undergoes several effects:
  - Path-loss: the signal is attenuated with distance
  - Slow fading: due to the change of the propagation environment (shadowing)
  - Fast fading: due to the superposition of different phases (scattering)

Radio Channel



SINR

Signal-to-Interference-Noise-Ratio: is the quality of the transmission, i.e., the ratio of the received signal to the interference and noise

$$SINR = P / (I + N)$$

P: received power

I: Interference power of other simultaneous transmissions

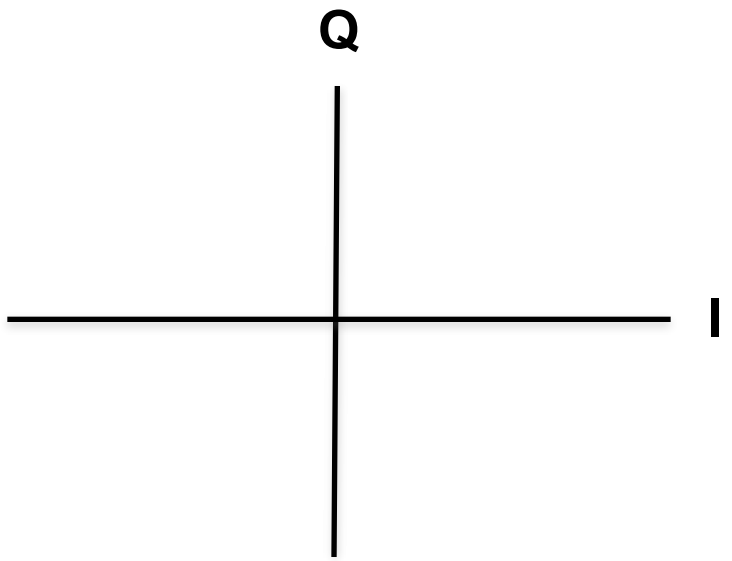
N: background noise power

Modulation

- Transformation of the signal into the frequency domain (carrier frequency)
- Conversion of the signal to an electromagnetic wave with high carrier frequency
- Modulation techniques used in mobile communications:
  - Binary Phase Shift Keying (BPSK)
  - Quadrature Phase Shift Keying (QPSK)
  - Quadrature Amplitude Modulation (QAM)

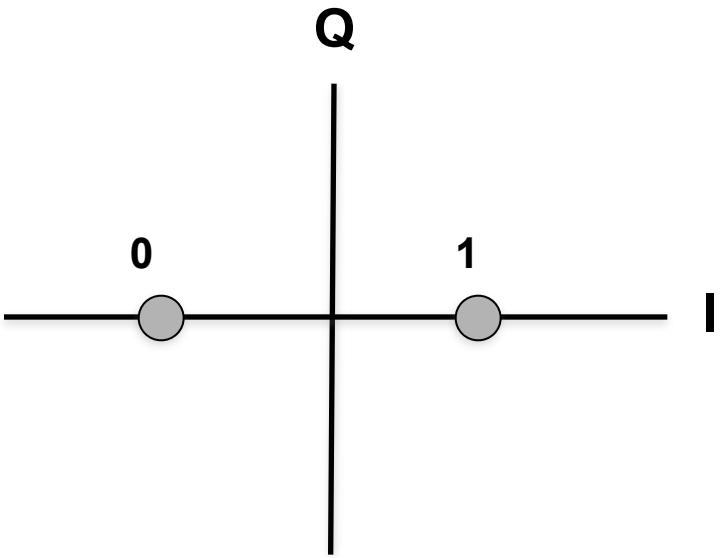
Constellation Diagram

- Represents the transmitted symbol with complex number and modulating a cosine and sine carrier signal with the real and imaginary parts
  - In-Phase axis or I
  - Quadrature axis or Q



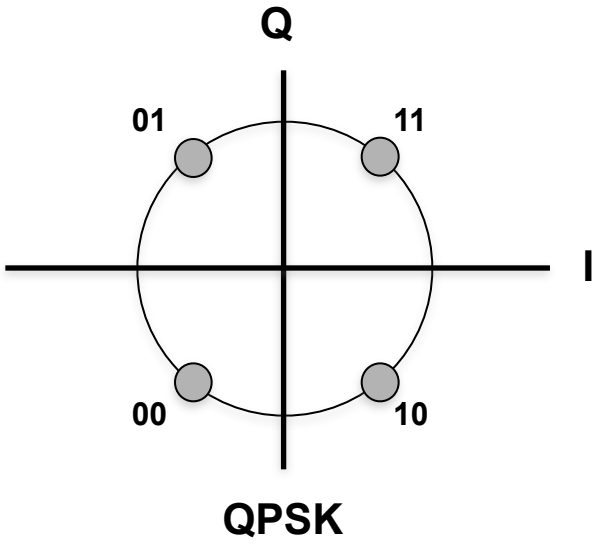
BPSK (Binary Phase-shift Keying)

- The simplest form of PSK.
- Uses two phases that are separated by 180°

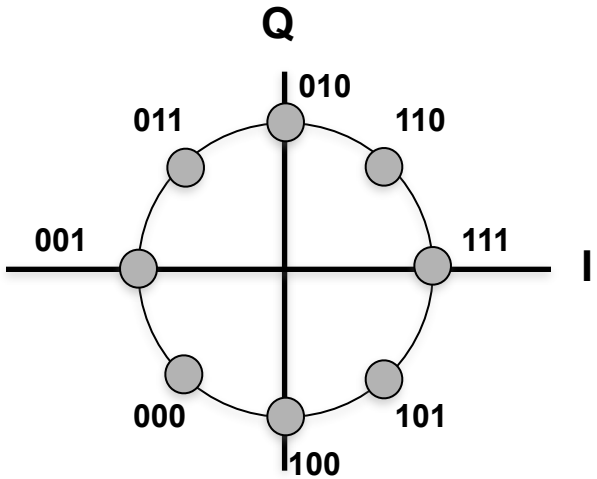


QPSK and M-QAM

- Quadrature Phase Shift Keying (QPSK)
- Quadrature Amplitude Modulation (QAM)

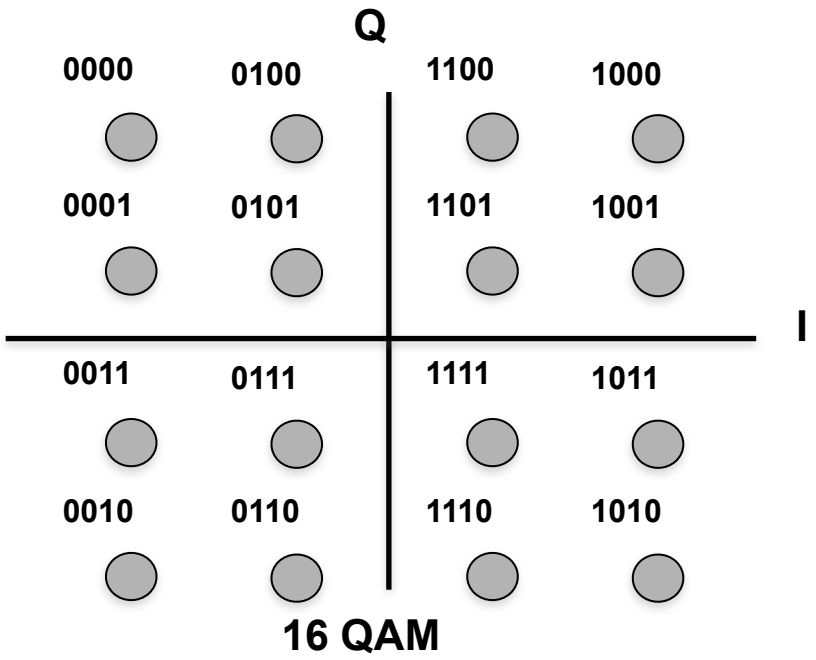


QPSK



8 QAM

16 QAM


Q
0000
0100
1100
1000
0001
0101
1101
1001
I
0011
0111
1111
1011
0010
0110
1110
1010

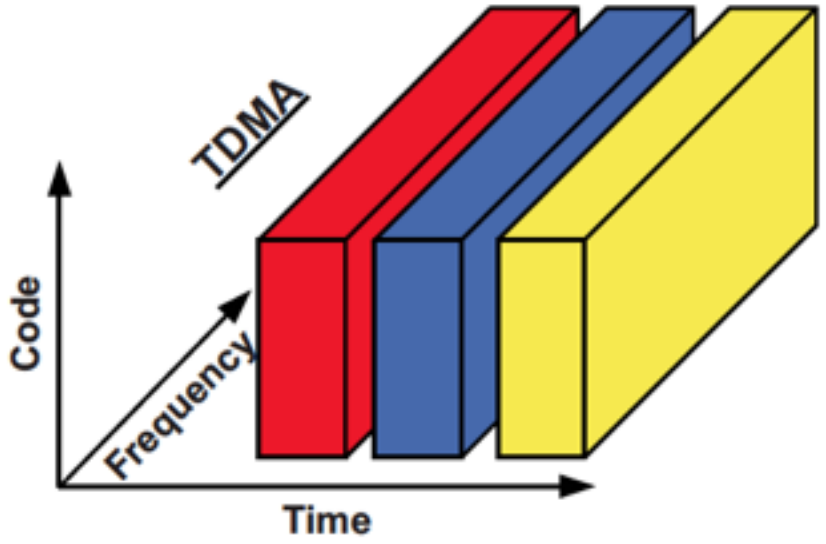
16 QAM

Multiple Access Schemes

- A way used to access the radio channel
- Limited number of radio channels → need Multiple Access
- Common schemes used in mobile comm. Systems:
  - Frequency Division Multiple Access (FDMA)
  - Time Division Multiple Access (TDMA)
  - Code Division Multiple Access (CDMA)
  - Orthogonal Frequency Division Multiple Access (OFDMA)
  - Space Division Multiple Access (SDMA)

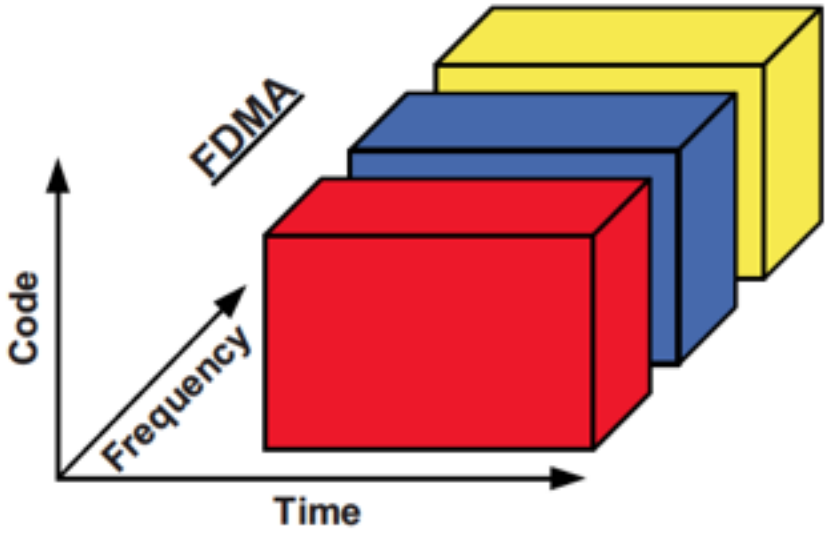
Time Division Multiple Access (TDMA)

- Used in GSM (2G)
- Splitting the frequency carrier into N time slots
- All users use the same frequency
- Different users gains access to the frequency at different time periods



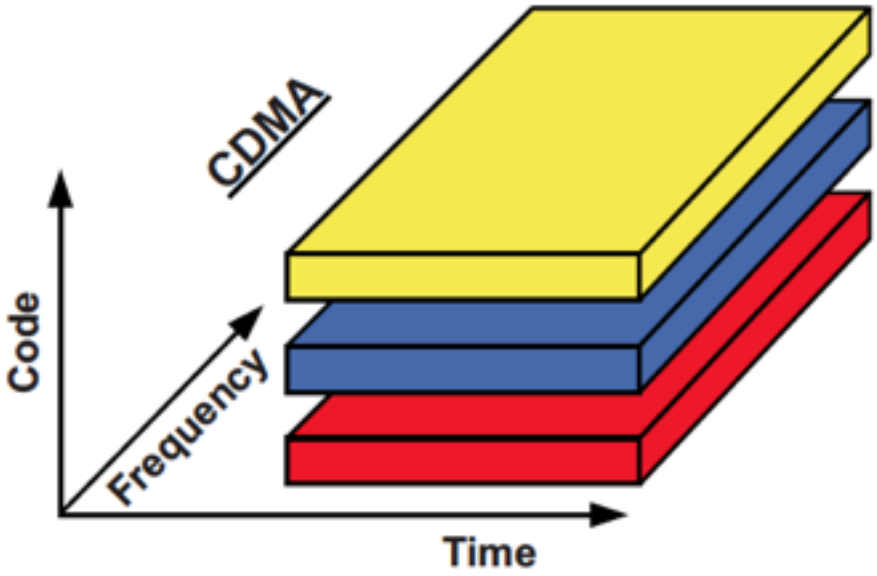
Frequency Division Multiple Access (FDMA)

- Splitting the frequency into N sub-bands
- Every sub-band is used by one user/connection
- In GSM, uplink is assigned different carrier frequency that the downlink (Frequency Division Duplex FDD)



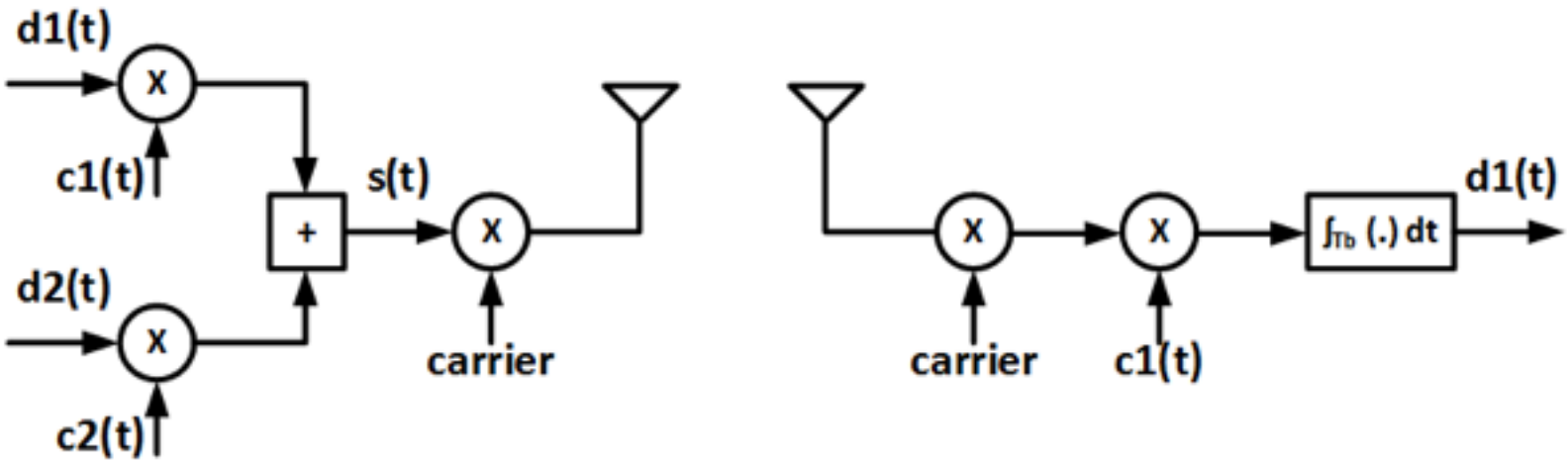
Code Division Multiple Access (CDMA)

- Used in UMTS (3G)
- All users send at the same time and with the same frequency
- Users are separated by codes



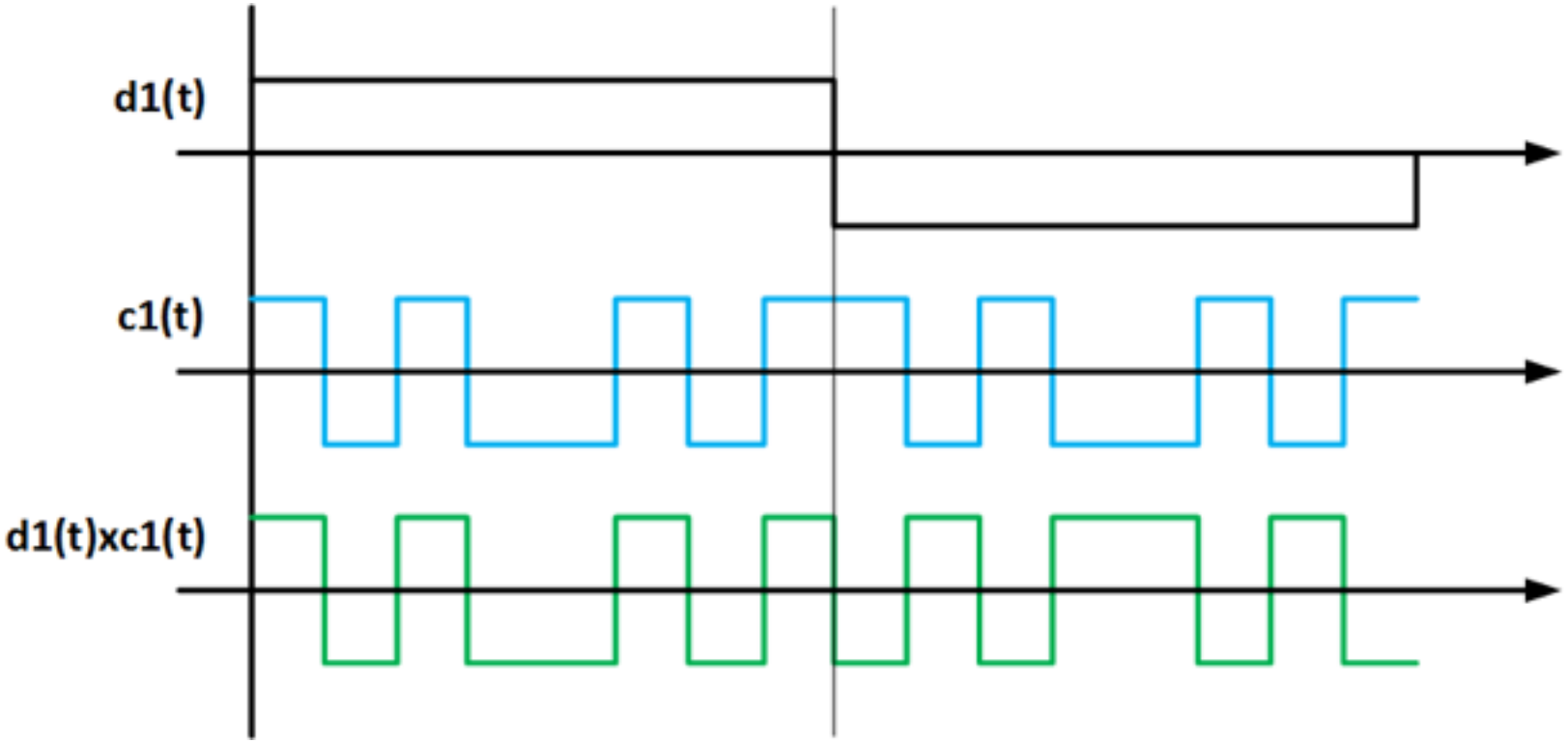
CDMA

- Each user has a unique code c(t) with a symbol size (Tc) smaller than the data symbol (Tb)
- Each user data is multiplied by its code and then everything is summed together

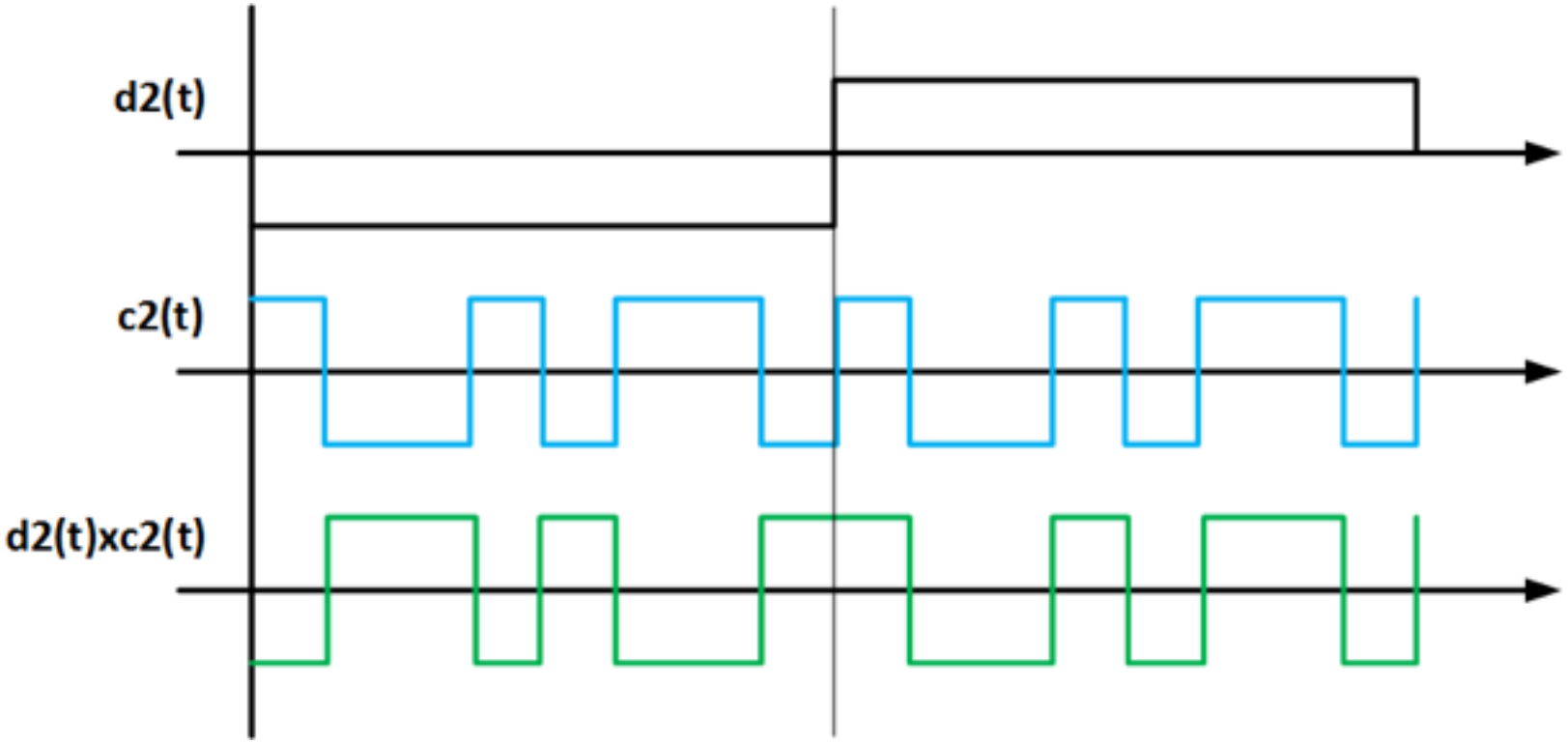


CDMA example

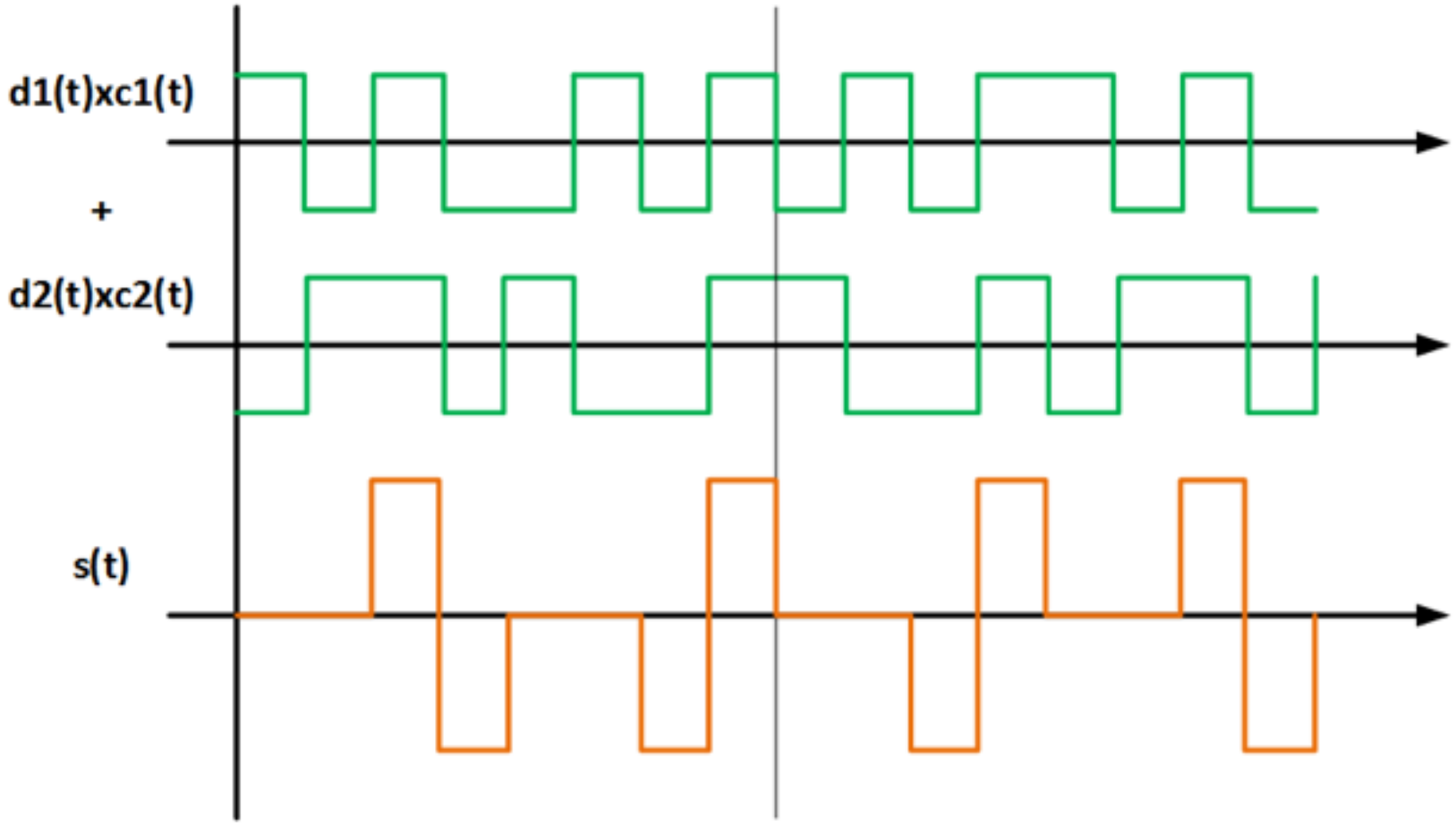
User 1



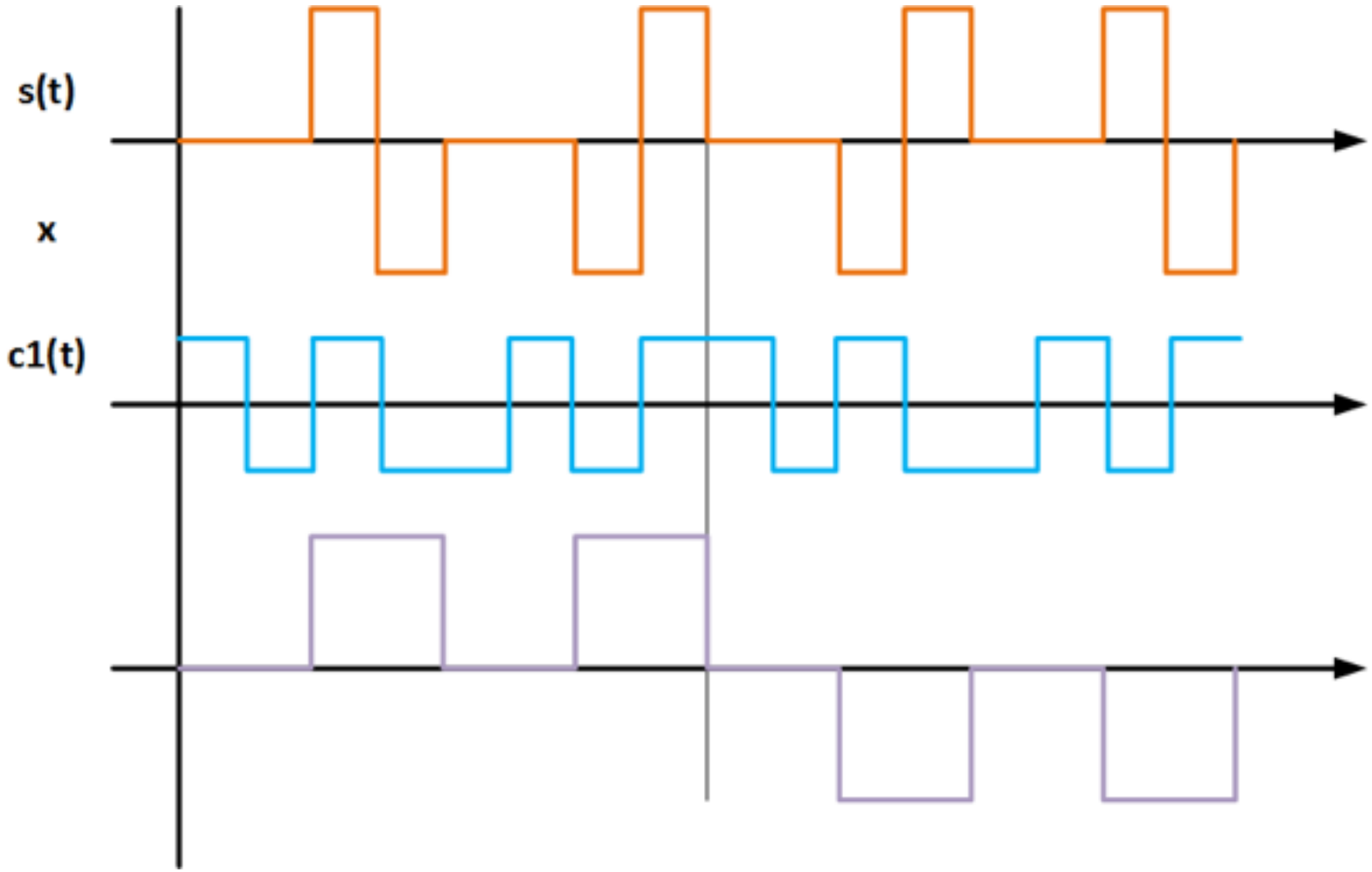
User 2



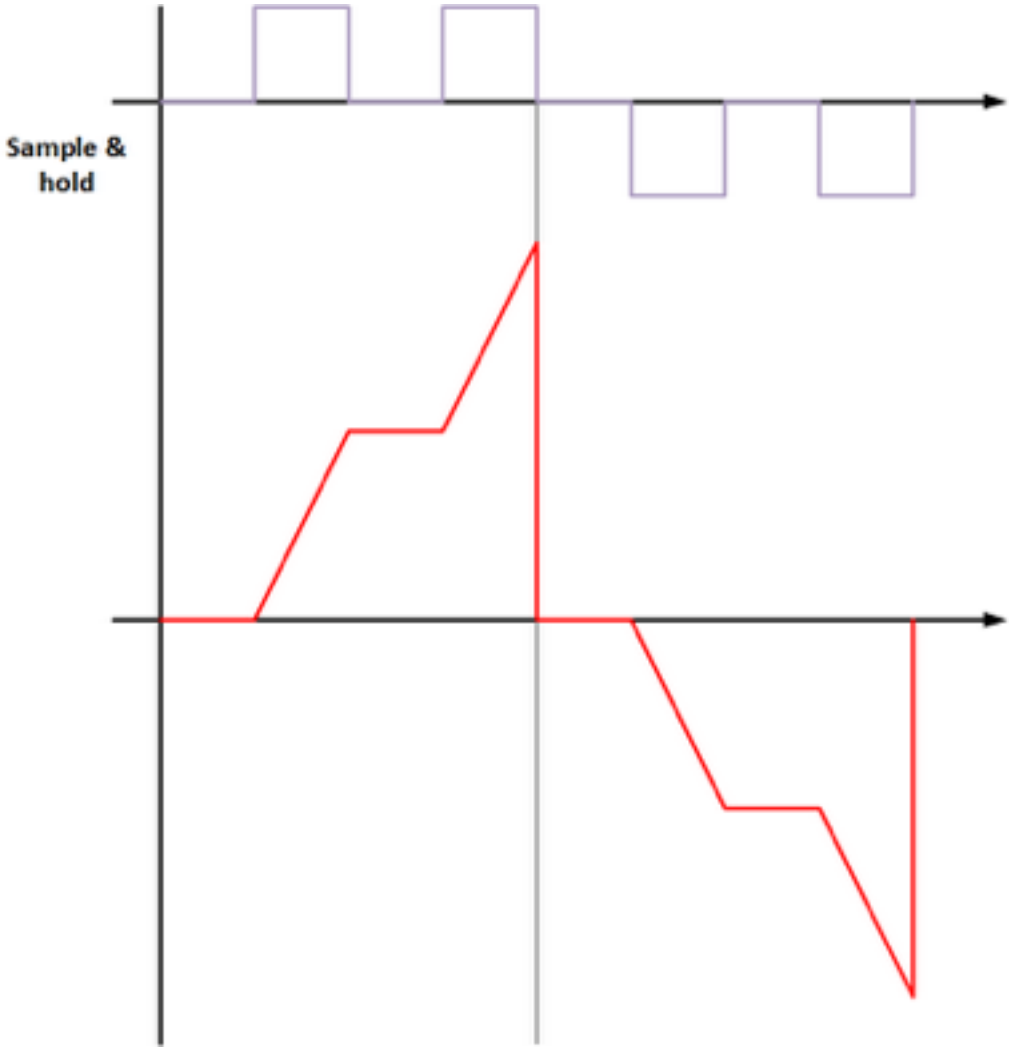
Transmitted Signal (superposition)



User 1 receiver



Sample and Hold



OFDMA (used in LTE 4G)

- The resources are divided into time and frequency dimensions
- The frequency is divided into smaller sub-bands each with a sub-carrier
- Each different block can be assigned to a different user