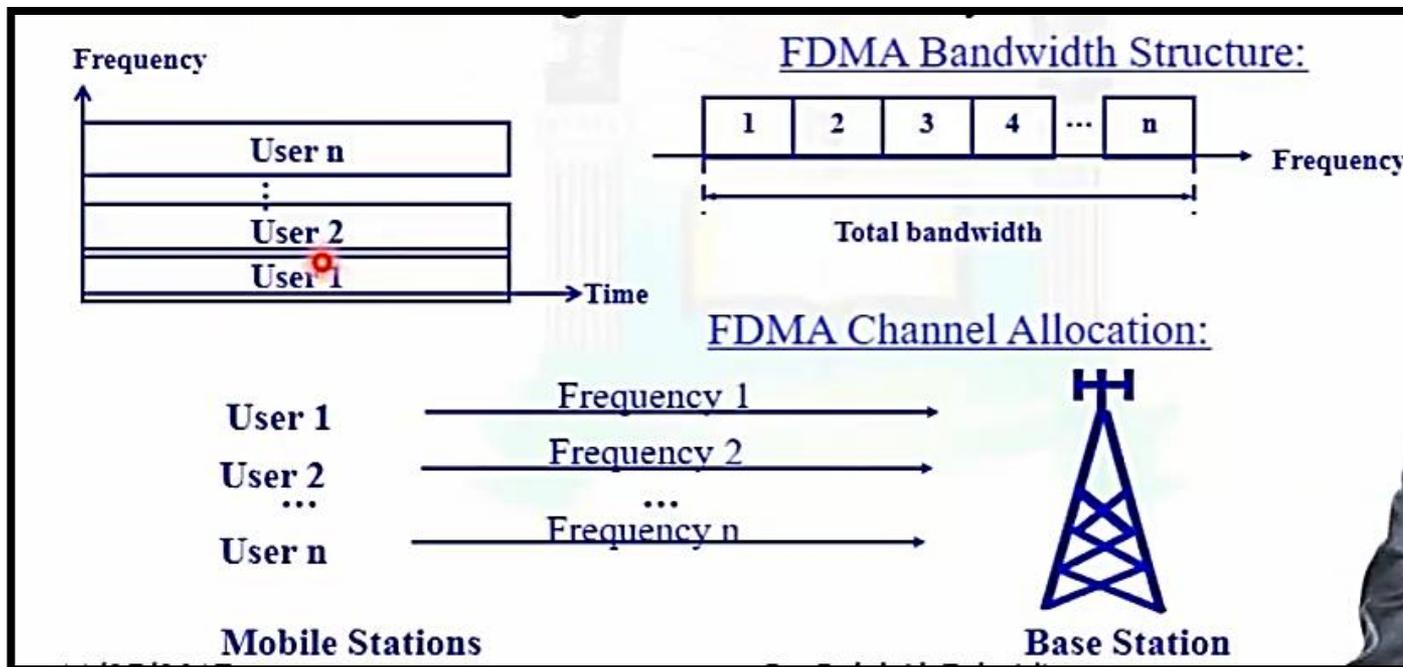
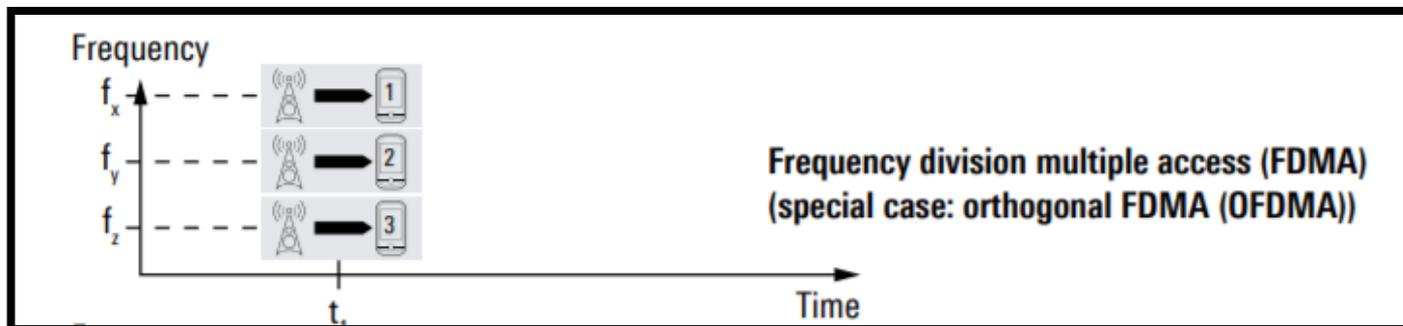


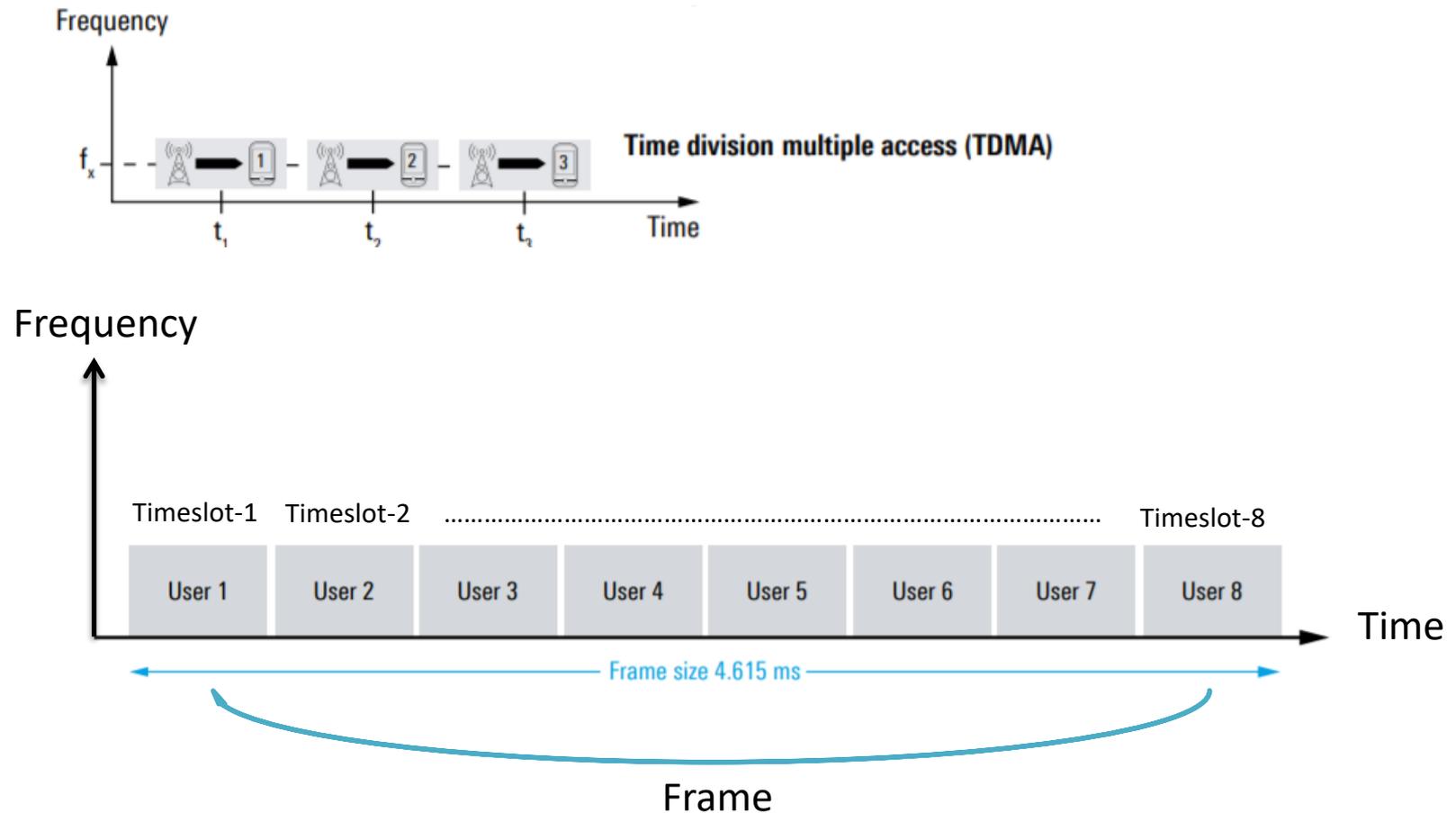
Frequency division multiple access (FDMA) allows multiple devices to access the network using different frequency channels.

- In **FDMA**, the allocated frequency band is divided into a number of sub-bands, called channels and one channel is allocated by the BS to each user.
- **FDMA** is used in all first generation Cellular Systems



Time division multiple access (TDMA) allows multiple devices to access the network using different timeslots of a given frequency channel.

- **TDMA** has been widely used in 2G digital cellular networks.
- **TDMA in GSM(2G)** splits time up into eight timeslots for the uplink and downlink. Therefore, one **200 kHz channel** of GSM can support eight users, each user in a **577 ms slot** that comprises a **4.616 ms TDMA frame**. An uplink frame is shown in Fig. 5. A similar allocation is made in the downlink frame.

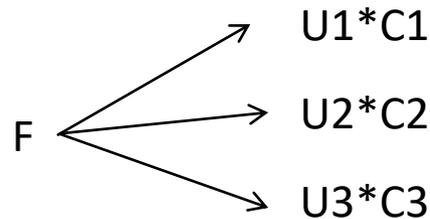


Code division multiple access (CDMA): involves the use of a wideband frequency channel with different users using different orthogonal codes. Using different orthogonal codes, interference between the signals is minimal.

- **CDMA uses** a Direct Sequence Spread Spectrum (DSSS) property where the transmitter and the receiver must use the same spreading code to transmit data.
- **3G networks** such as the universal mobile telecommunications system (UMTS) use CDMA.



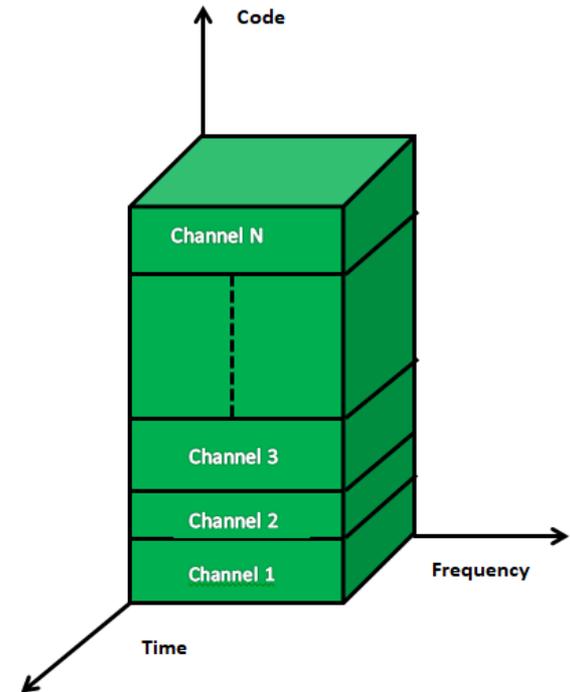
$$(U1 * C1 + U2 * C2 + U3 * C3)$$



F = Frequency
 U = User
 C = Code

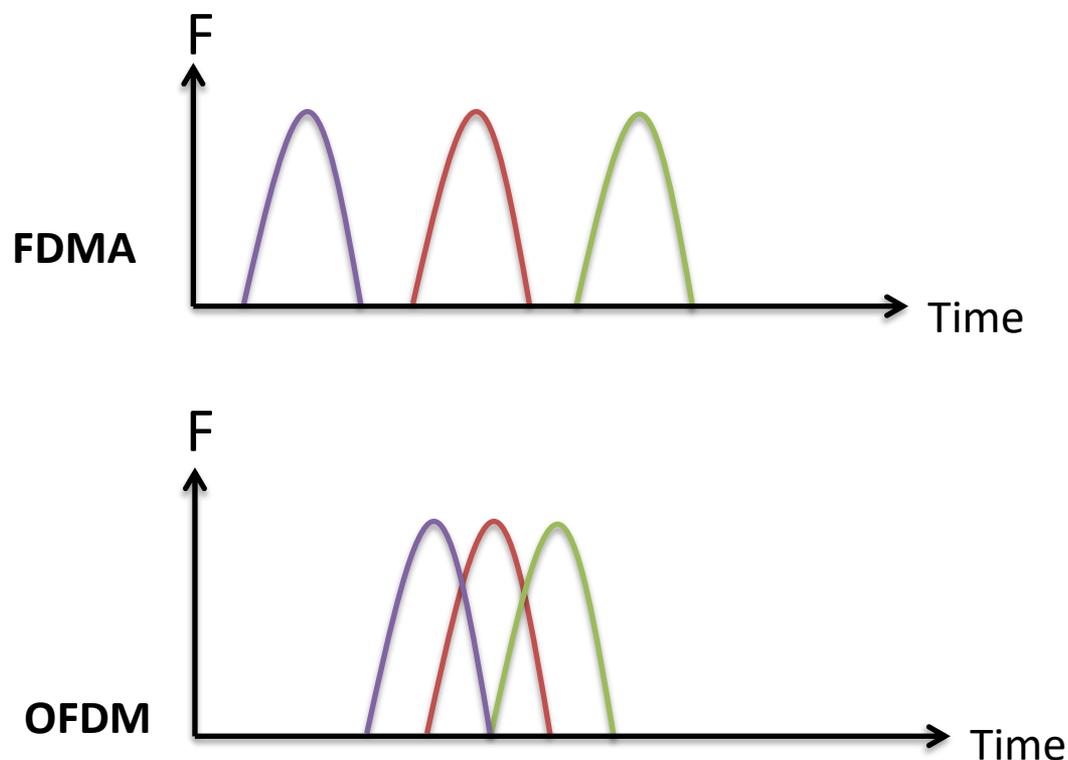
Characteristics of CDMA

- It allows more users to connect at a given time and thus provides improved data and voice communication capacity.
- A full spectrum is used by all the channels in CDMA.
- CDMA systems make the use of power control to eliminate the interference and noise and to thus improve the network quality.
- CDMA encodes the user transmissions into distinct and unique codes in order to secure its signals.
- In CDMA systems all the cells can thus use the same frequency.
- CDMA systems have a soft capacity. Thus there is no particular limit to the number of users in a CDMA system but with increase in the number of users the performance degrades.



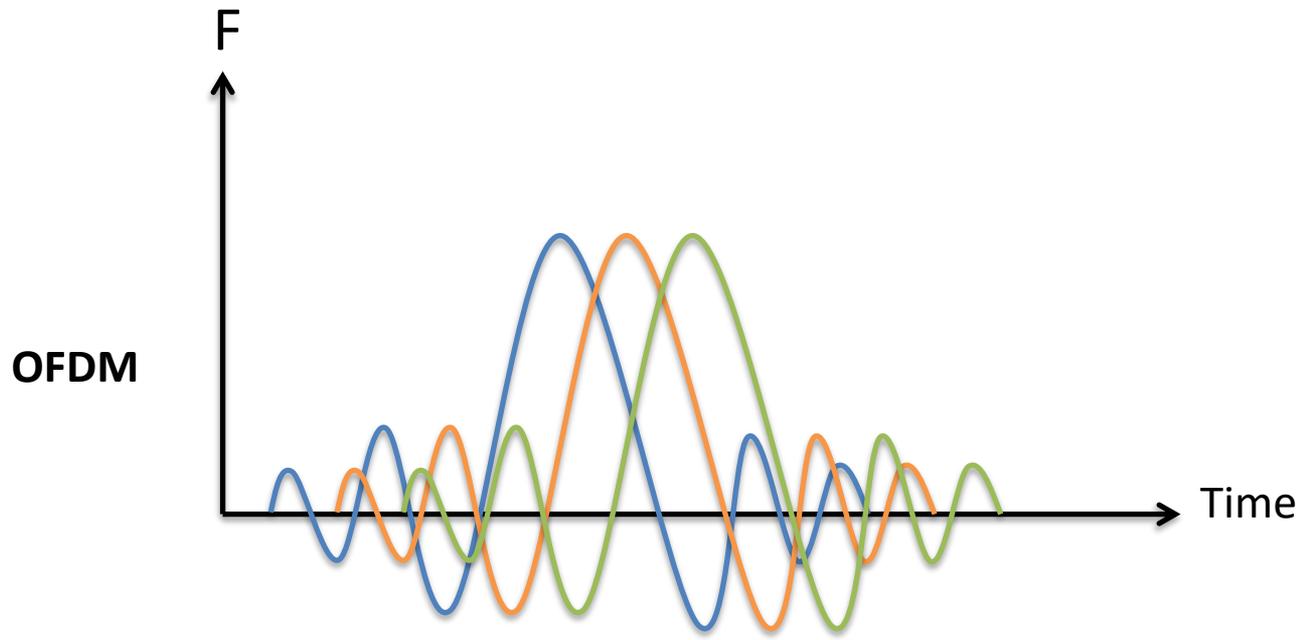
OFDM:

In OFDM (Orthogonal Frequency Division Multiplexing) systems the original bandwidth is subdivided into multiple subcarriers. Each of these subcarriers can then be individually modulated. Typically in OFDM systems we can have hundreds of subcarriers with a constant spacing between them (15KHz on the LTE case). Since the multiple subcarriers in OFDM are transmitted in parallel, it's possible for each one to transmit with a lower symbol rate.



With **OFDM** , many different signals can be sent over the same medium, at the same time. Each signal uses a different basis function. By using the basis function given, the sender and recipient will then see their signal better, the other signals will be clearly separated.

OFDM is a very popular multiplexing method used for many of the latest Wireless and telecommunication standards such as 4G and 5G cellular phone Technologies and many others.



An example of OFDM, with 3 different signals