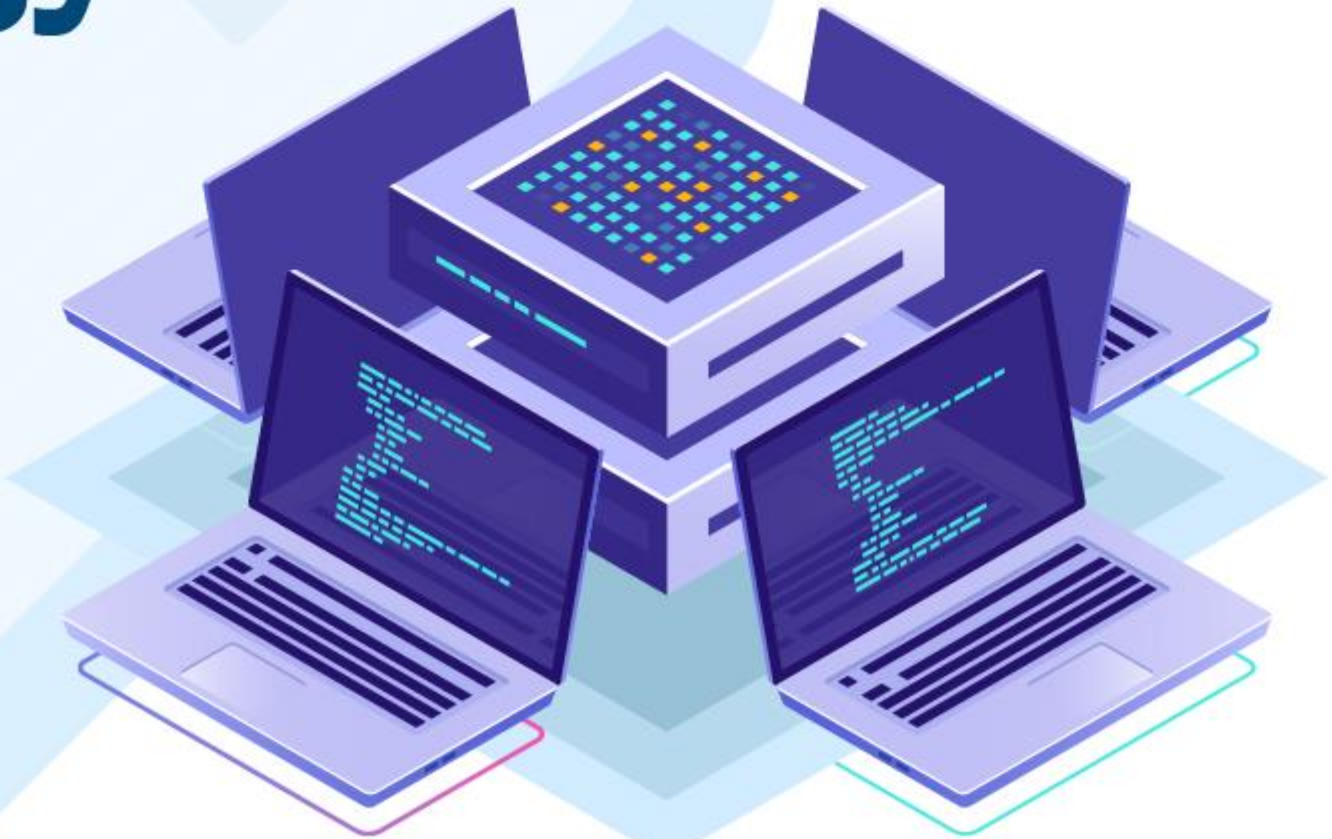
Information Technology

Spring Semester

» Mobile and Sensor Networks

» Dr. Ahmed Abdelreheem

Lec_8



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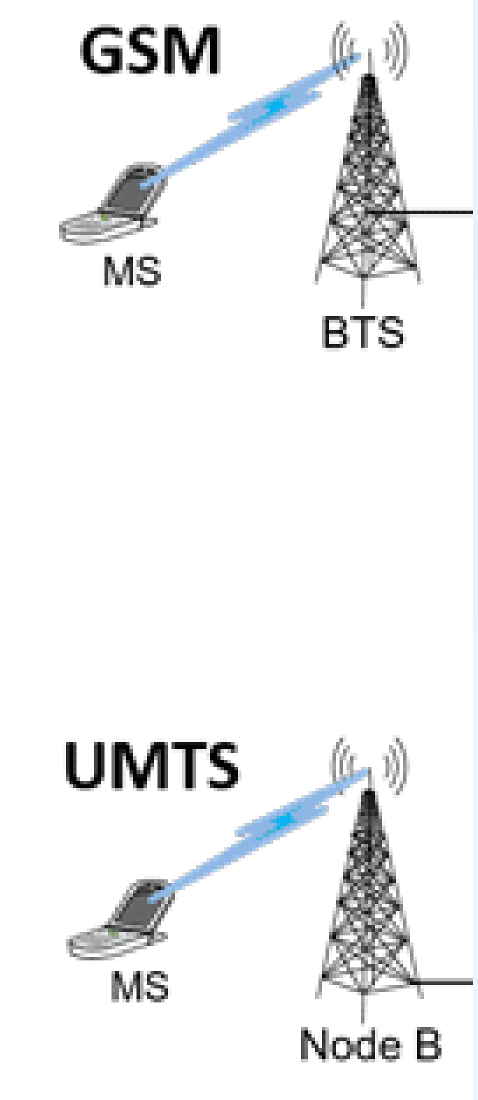
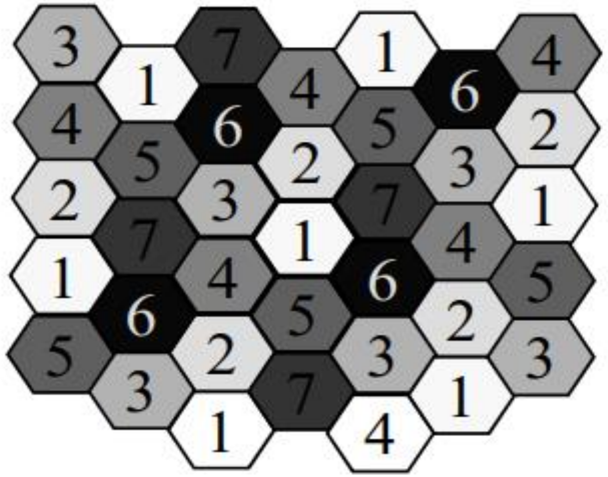
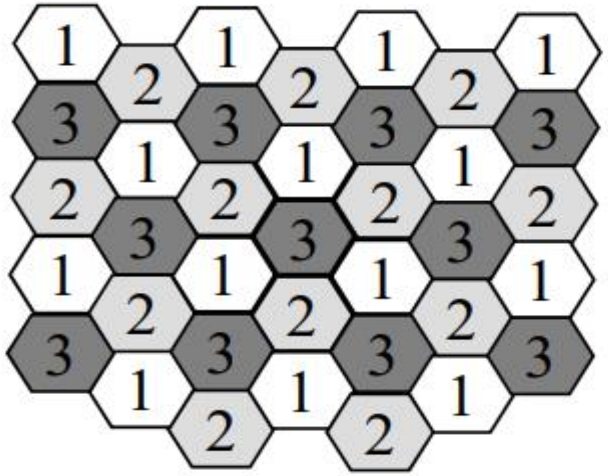

GSM
MS
BTS
UMTS
MS
Node B

Cluster dimensioning

- **All available frequencies are divided into K groups**
- **We assign a group to each cell in order to maximize the distance between 2 cells that use the same group of frequencies**
- **Frequency reuse efficiency = 1/K**
- **Possible K values: K=1,3,4,7,9,12,13, …**



K = 7



K = 3

Multiple Access Technique

- Multiple access techniques are used to allow a large number of mobile users to share the allocated spectrum in the most efficient manner. As the spectrum is limited, so the sharing is required to increase the capacity of cell or over a geographical area by allowing the available bandwidth to be used at the same time by different users.

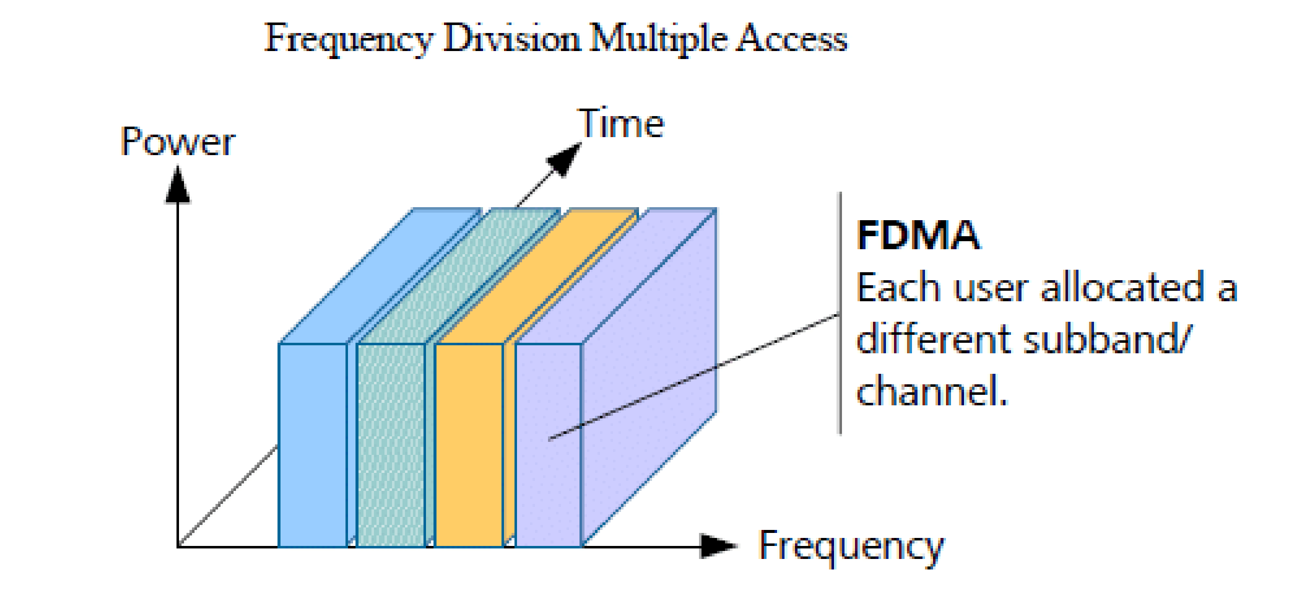
- There are several different ways to allow access to the channel. These includes mainly the following:

1. Frequency division multiple-access (FDMA)
2. Time division multiple-access (TDMA)
3. Code division multiple-access (CDMA)

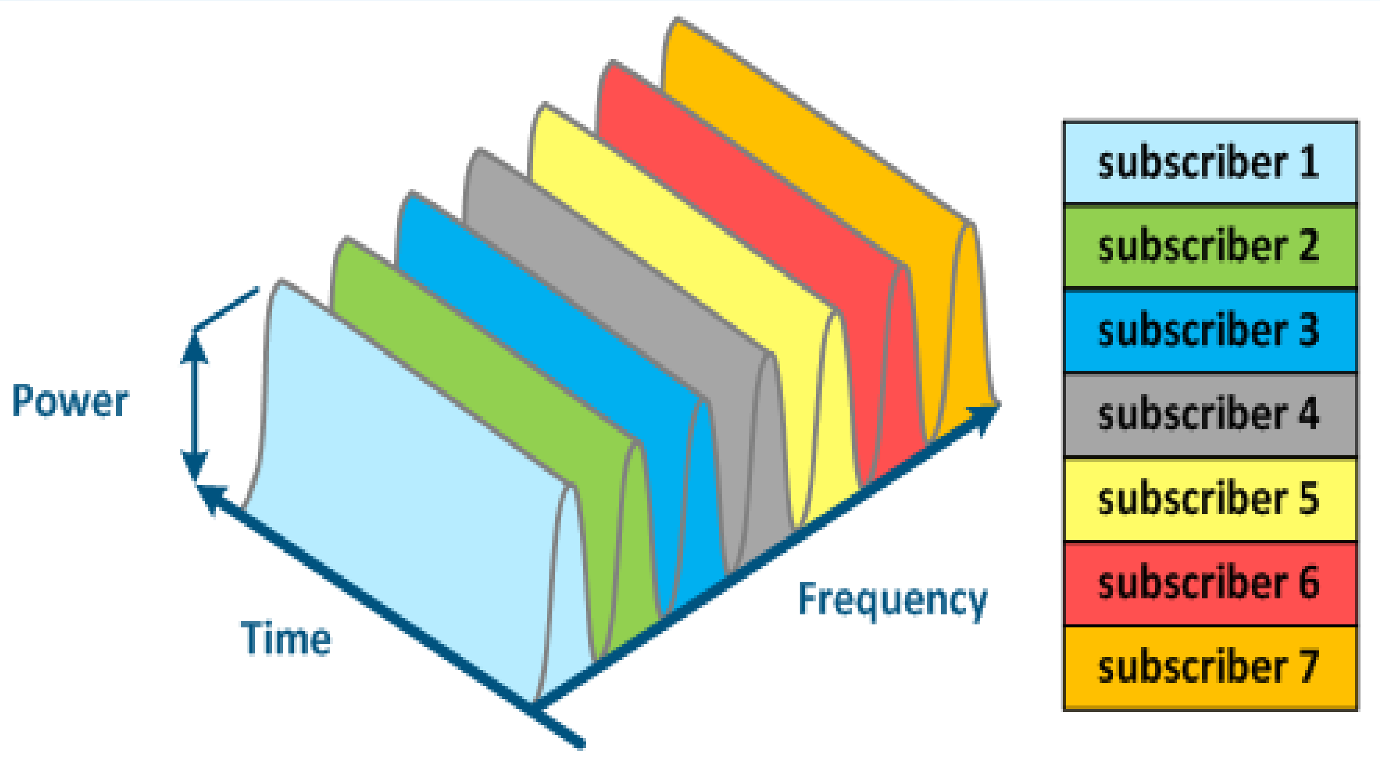
Frequency Division Multiple Access

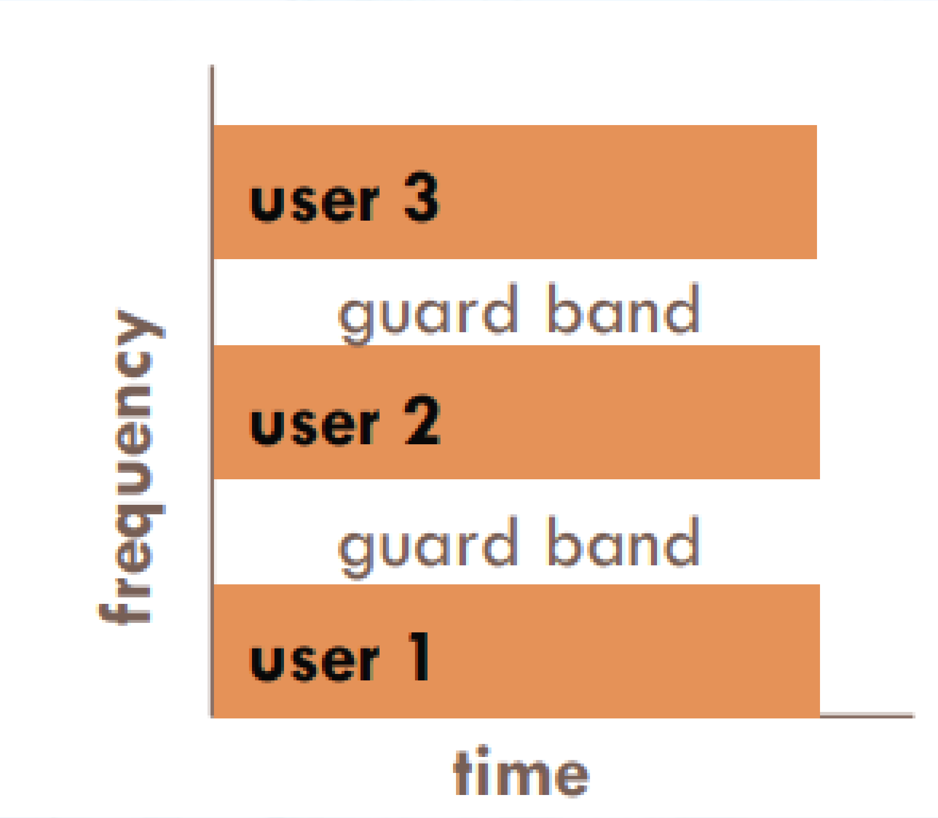
- This was the initial multiple-access technique for cellular systems in which each individual user is assigned a pair of frequencies while making or receiving a call as shown in Figure 8.1. One frequency is used for downlink and one pair for uplink. This is called frequency division duplexing (FDD).

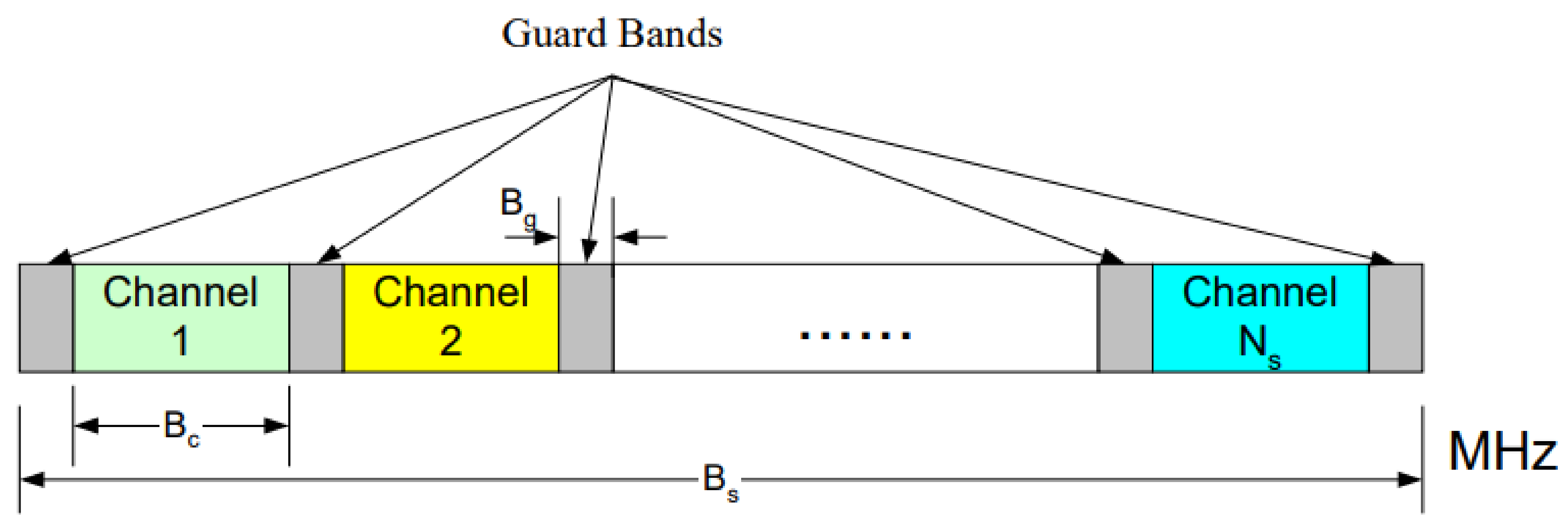
- That allocated frequency pair is not used in the same cell or adjacent cells during the call so as to reduce the co-channel interference. Even though the user may not be talking, the spectrum cannot be reassigned as long as a call is in place. Different users can use the same frequency in the same cell except that they must transmit at different times.



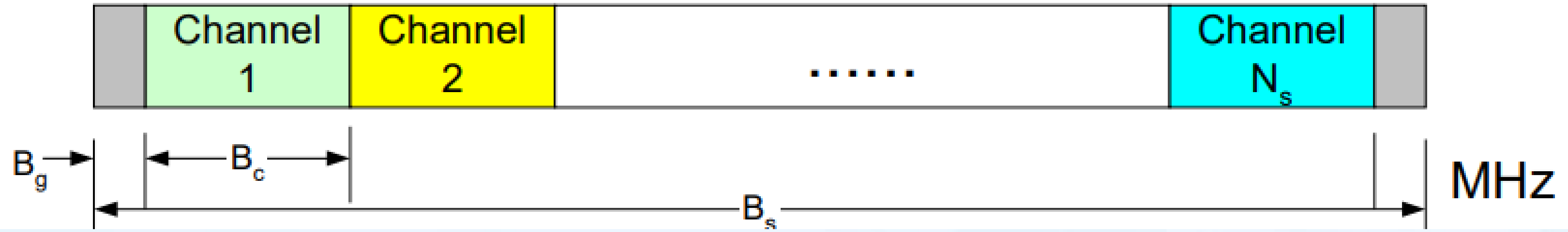
- Separate spectrum into non-overlapping frequency bands
- Assign a certain frequency to a transmission channel between a sender and a receiver
- Different users share use of the medium by transmitting on non-overlapping frequency bands at the same time



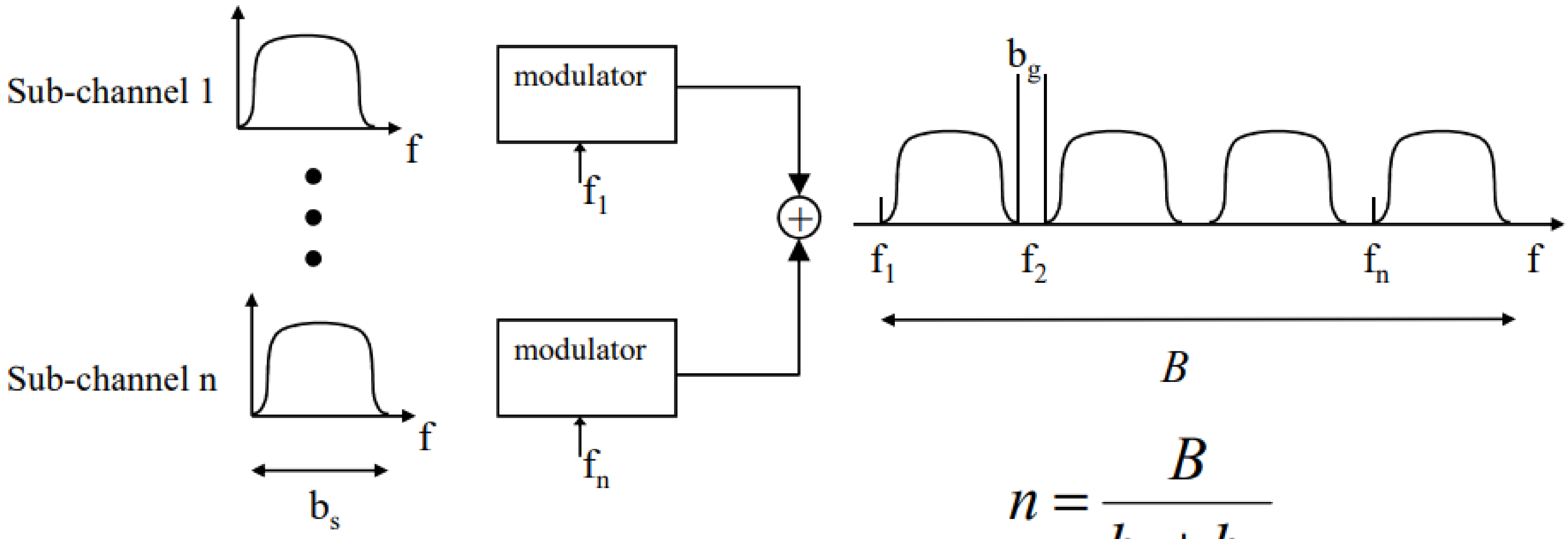




- In a *cluster*, each user is assigned a portion of the available bandwidth



FDM (Frequency Division Multiplexing)



$$n = \frac{B}{b_s + b_g}$$

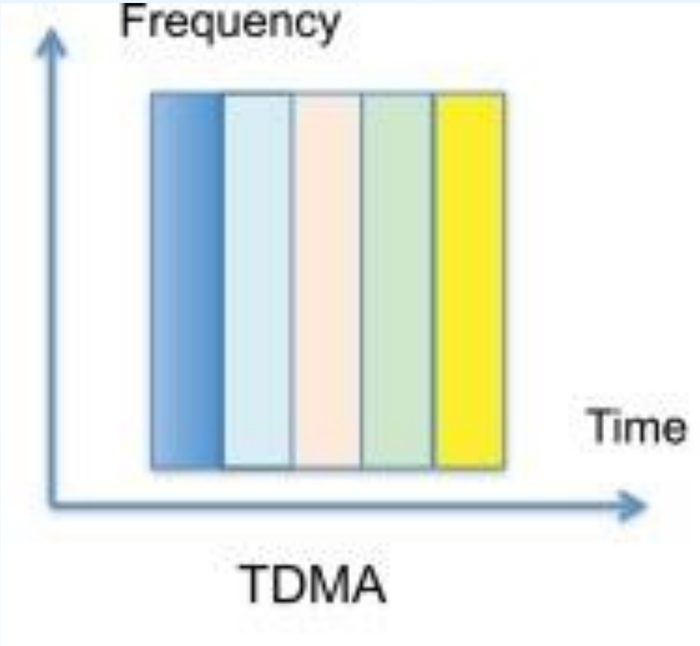
$B = total\ available\ bandwidth\ (f_{max} - f_{min})$

$b_s = signal\ bandwidth$

$b_g = guard\ band$

Time Division Multiple Access

- In digital systems, continuous transmission is not required because users do not use the allotted bandwidth all the time. In such cases, TDMA is a complimentary access technique to FDMA.
- Global Systems for Mobile communications (GSM) uses the TDMA technique.
- In TDMA, the entire bandwidth is available to the user but only for a finite period of time.
- In most cases the available bandwidth is divided into fewer channels compared to FDMA and the users are allotted time slots during which they have the entire channel bandwidth at their disposal



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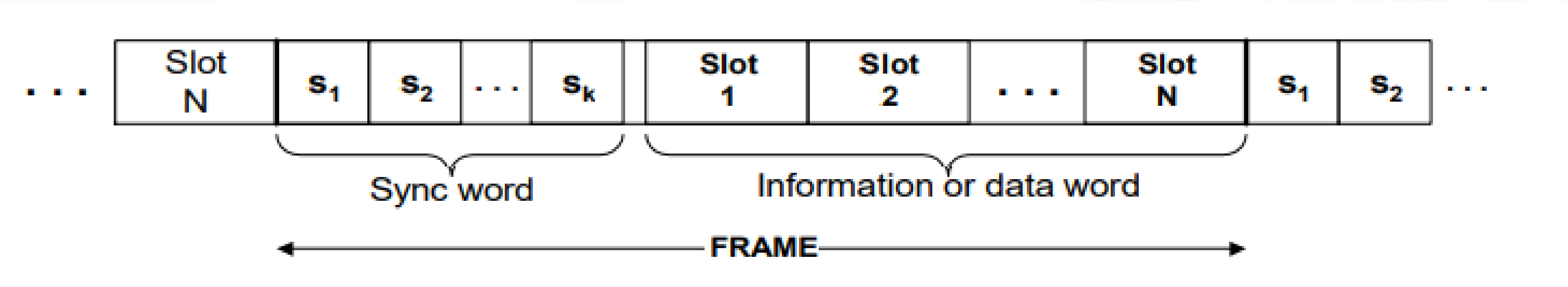
Time Division Multiple Access

- Digitized info from several sources are multiplexed in time and transmitted over a single communication channel
- The communication channel is divided into frames of length T_f
- Each frame is further segmented into N subinterval called slots, each with duration $T_s = \frac{T_f}{N}$, where N is the number of users



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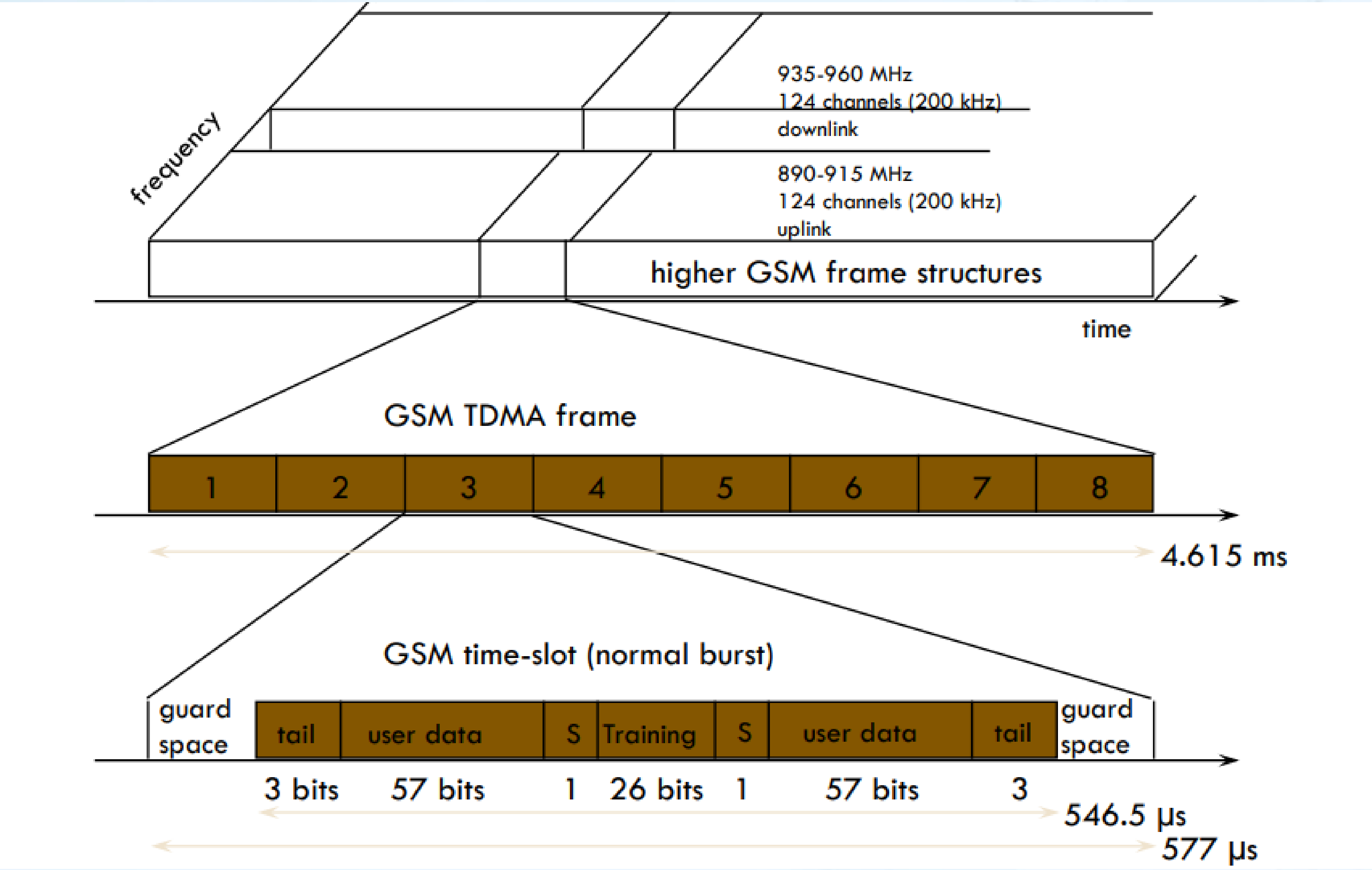
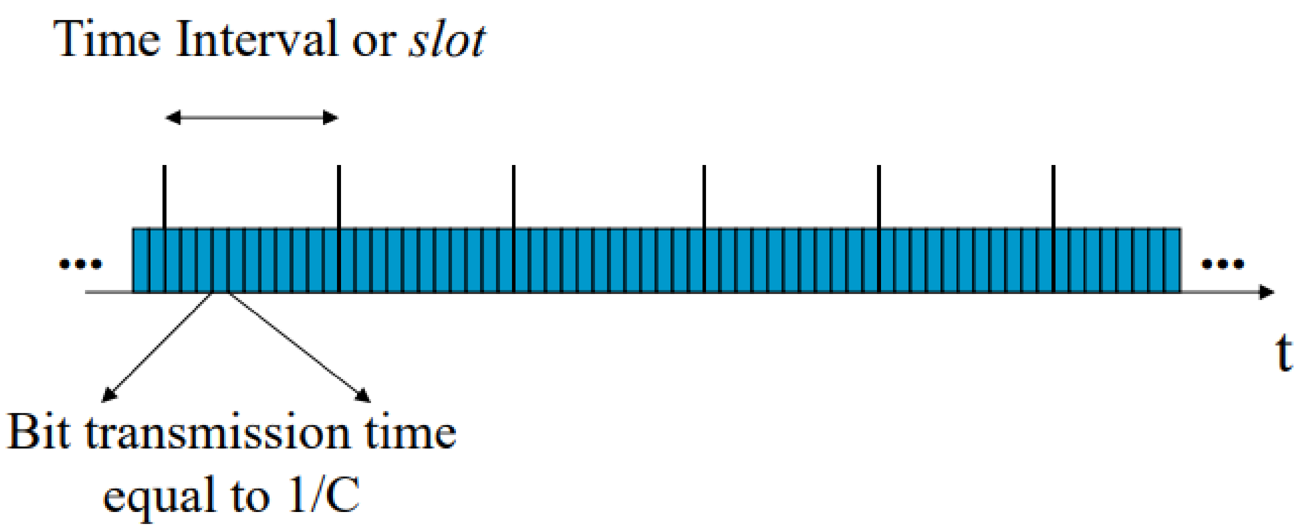
Time Division Multiple Access



TDM (Time Division Multiplexing)

- This technique is used for digital/binary signals (sequencies of 0s - 1s)
- Given a channel with speed/capacity *C* (bit/s), we define time intervals (named *slots*), whose duration is a multiple of the bit duration $t_b = 1/C$



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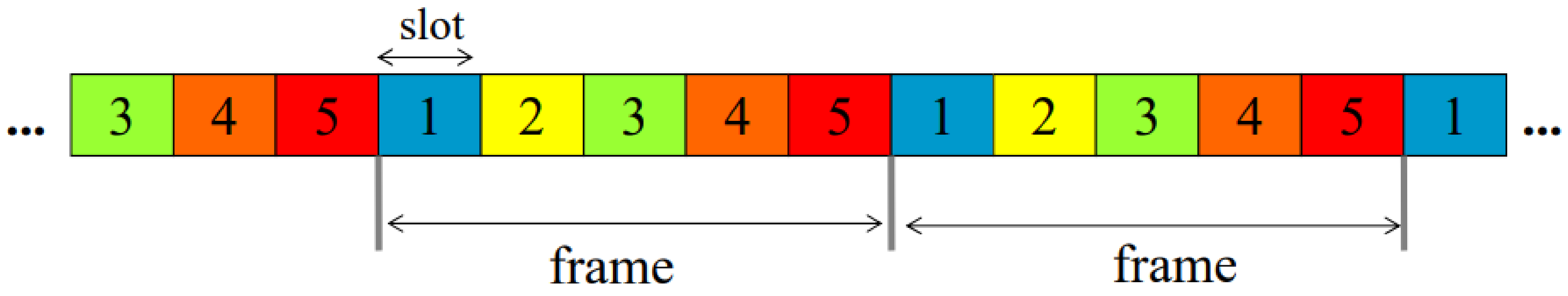
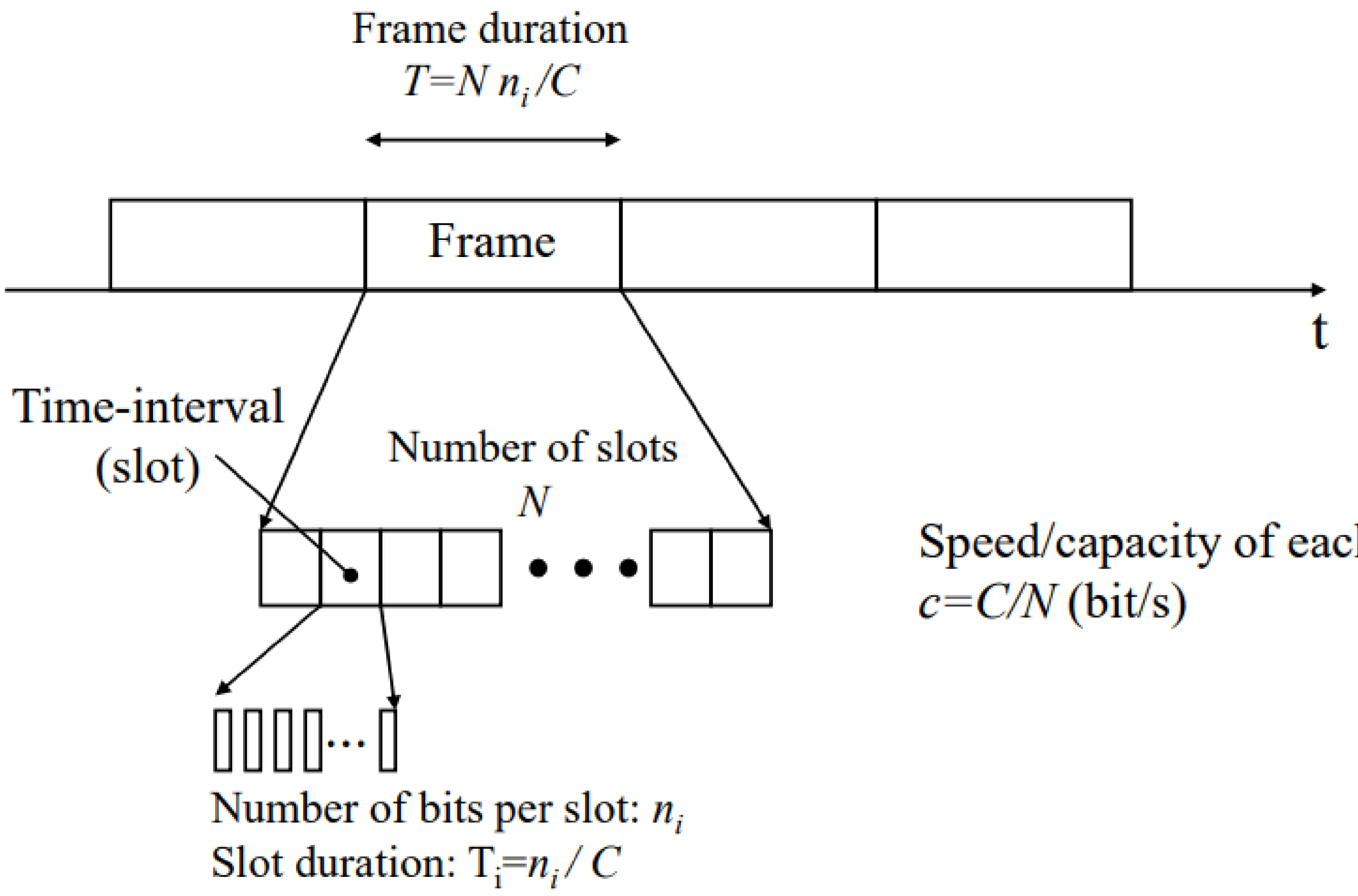
TDM (Time Division Multiplexing)

- Each source/sender can use only a single time slot every *N*
- Hence we define a *frame structure,* where the frame is constituted by *N* consecutive time slots
- If we give a number to each time slot, each source/sender is associated to a time-slot number, and it can transmit only *inside* such slot



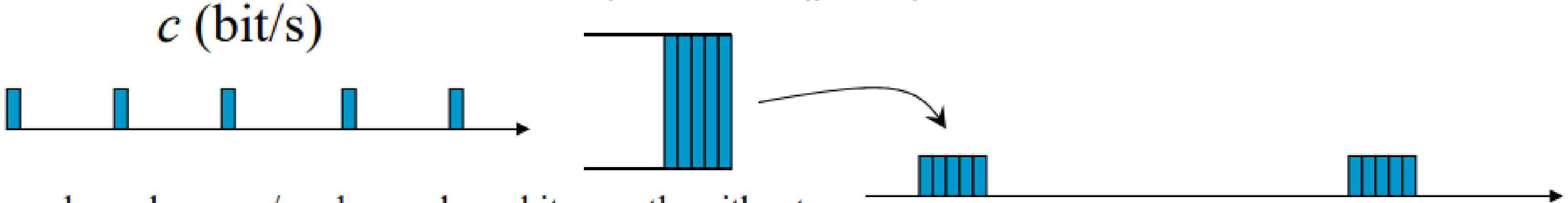
TDM (Time Division Multiplexing)



Speed/capacity of each sub-channel
$c = C/N$ (bit/s)

TDM (Time Division Multiplexing)

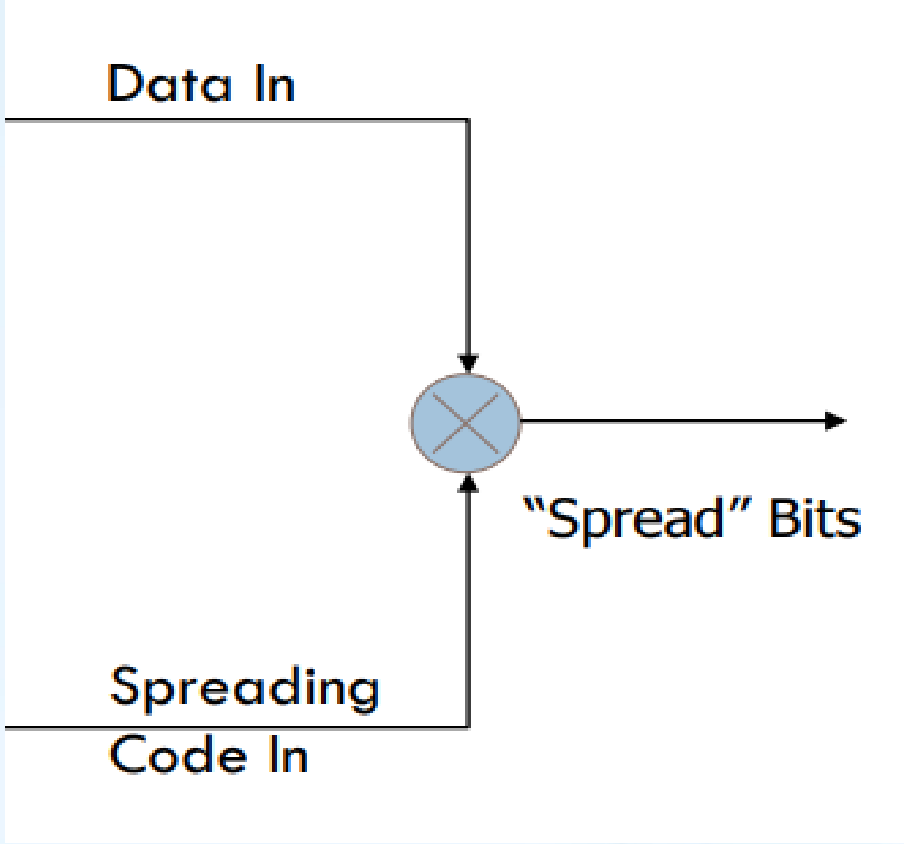
- The choice of the *slot duration* is very important (this is a parameter chosen when the slotted system is designed):
  - n_i number of bits per slot
  - T_i slot duration ($T_i = n_i / C$)
- the sub-channel capacity/speed c <u>does not</u> depend on T_i but <u>only</u> on N ($c = C/N$)
- Time to collect n_i *bits*: $T_a = n_i / c$



<u>Remark</u>: each source/sender produces bits exactly with rate c
The n_i bits that fit in the slot **must** be already available when the slot <u>begins</u>.
Clearly, the source needs n_i / c seconds to produce and accumulate the n_i bits

Code Division Multiplexing

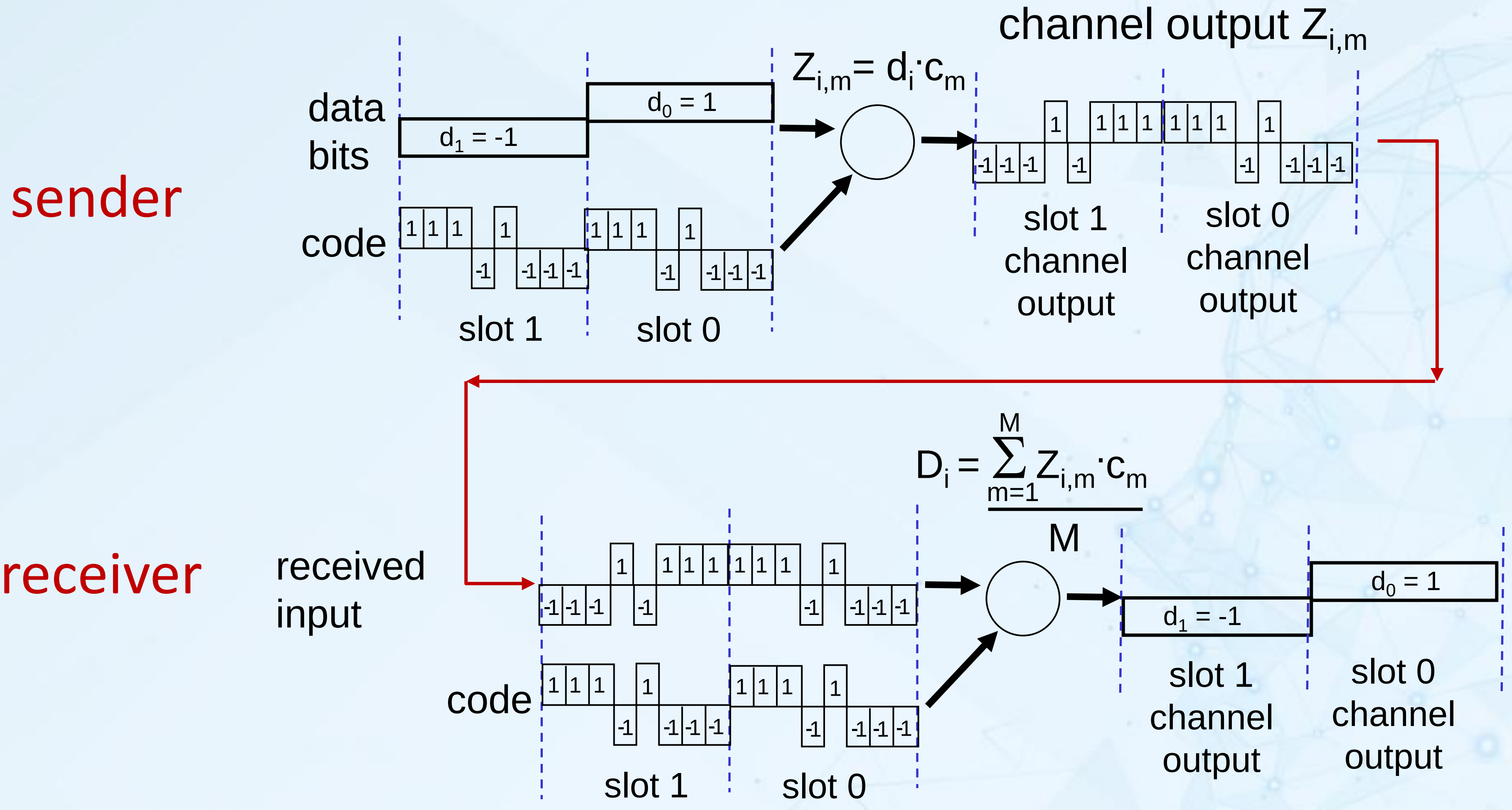
- All users can use same carrier frequency and may transmit simultaneously
- Each user has own unique access spreading codeword which is approximately orthogonal to other users codewords
- CDMA used 3G standards



Code Division Multiple Access (CDMA)

- unique "code" assigned to each user; i.e., code set partitioning
  - all users share same frequency, but each user has own "chipping" sequence (i.e., code) to encode data
  - allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")
- encoding: inner product: (original data) X (chipping sequence)
- decoding: summed inner-product: (encoded data) X (chipping sequence)

CDMA encode/decode

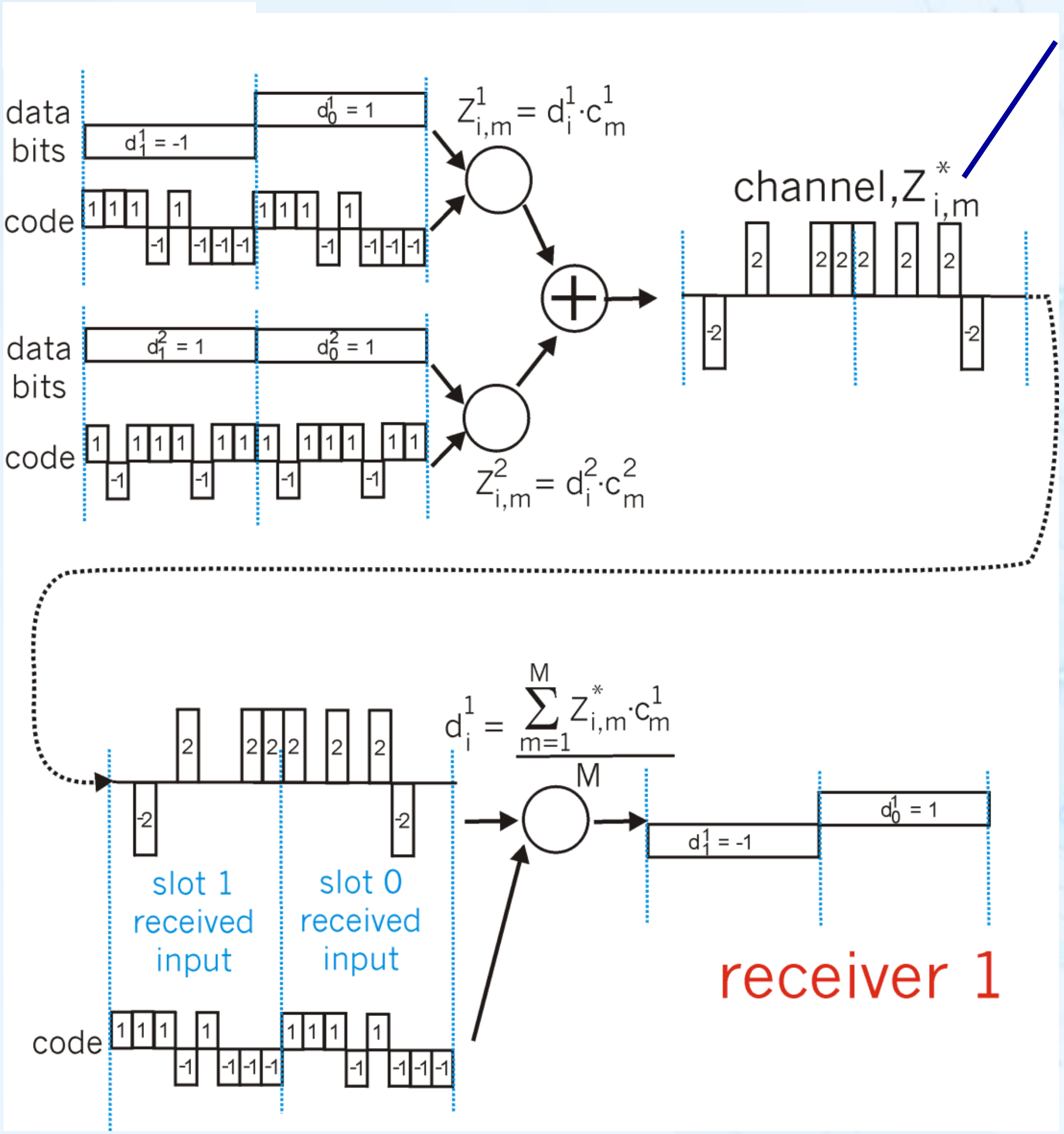


… but this isn't really useful yet!

CDMA: two-sender interference

Sender 1

Sender 2



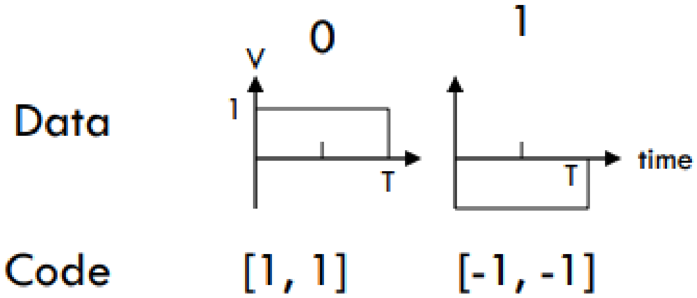
channel sums together transmissions by sender 1 and 2

using same code as sender 1, receiver recovers sender 1's original data from summed channel data!

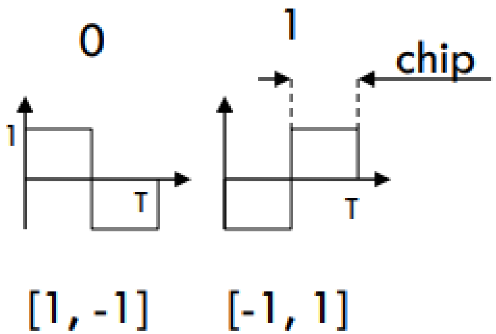
… now *that's* useful!

Code Division Multiplexing

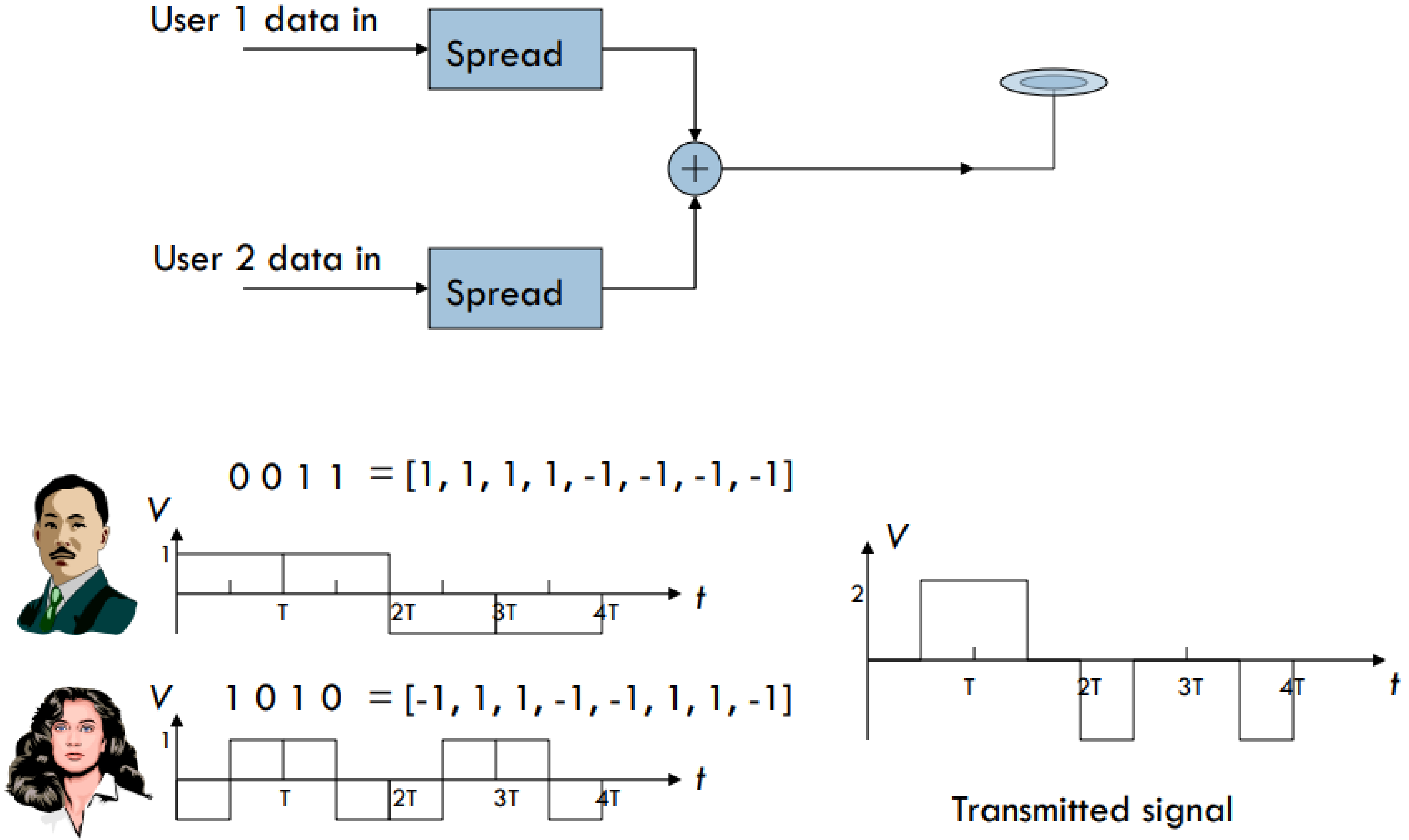
- **Traditional**
- To send a 0, send +1 V for T seconds
- To send a 1, send -1 V for T seconds
- Use separate time slots or frequency bands to separate signals



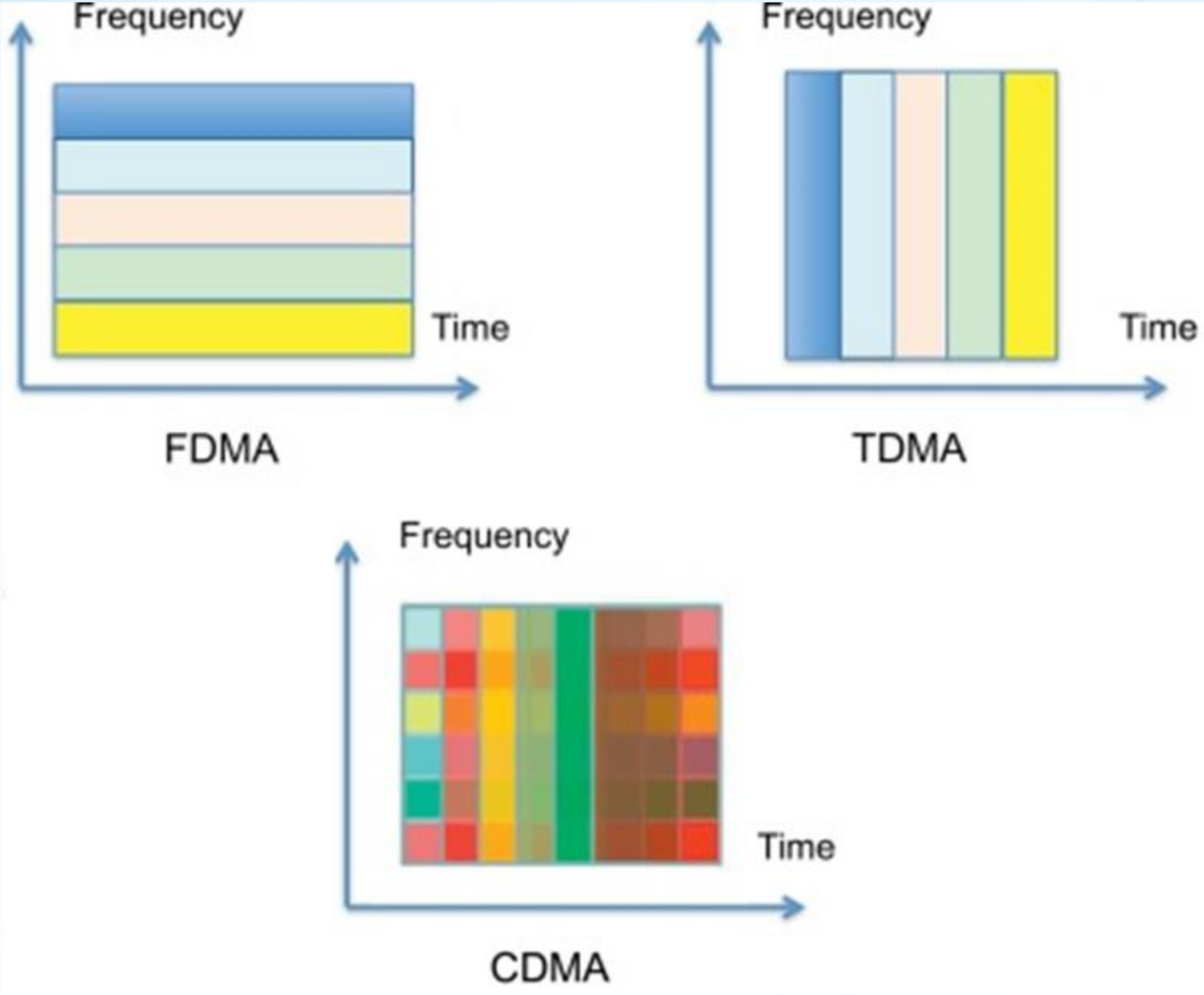
- **Simple CDMA**
- To send a 0, Bob sends +1 V for T seconds; Alice sends +1 V for T/2 seconds and -1 V for T/2 seconds
- To send a 1, Bob sends -1 V for T seconds; Alice sends -1 V for T/2 seconds and +1 V for T/2



Code Division Multiplexing



Transmitted signal

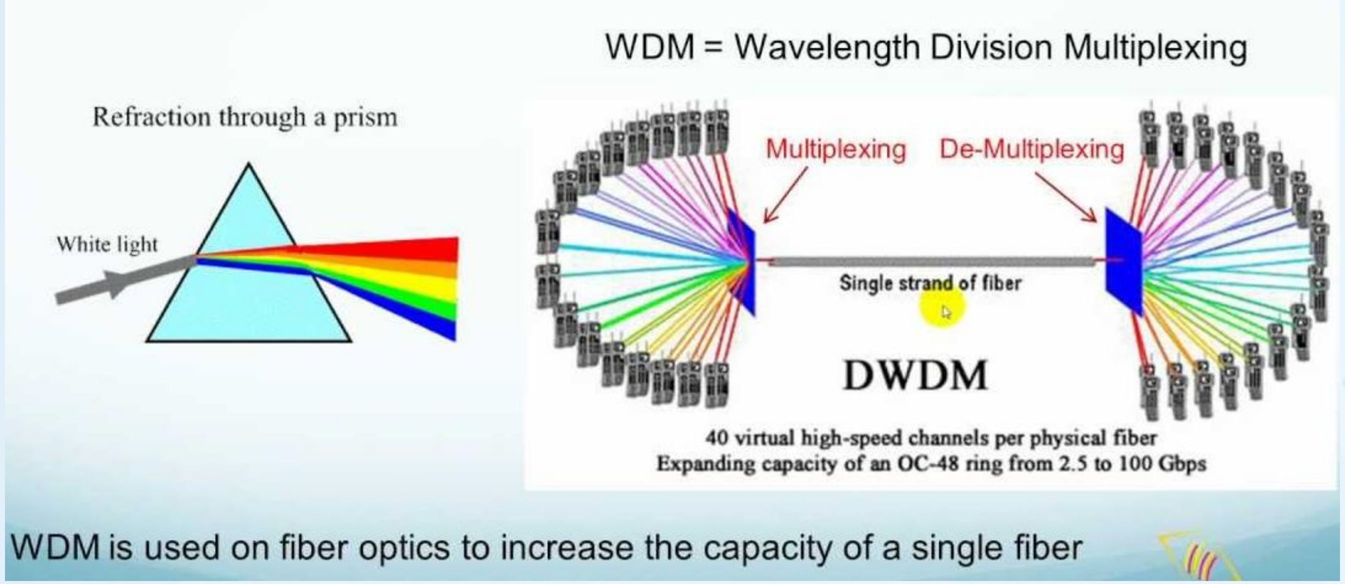


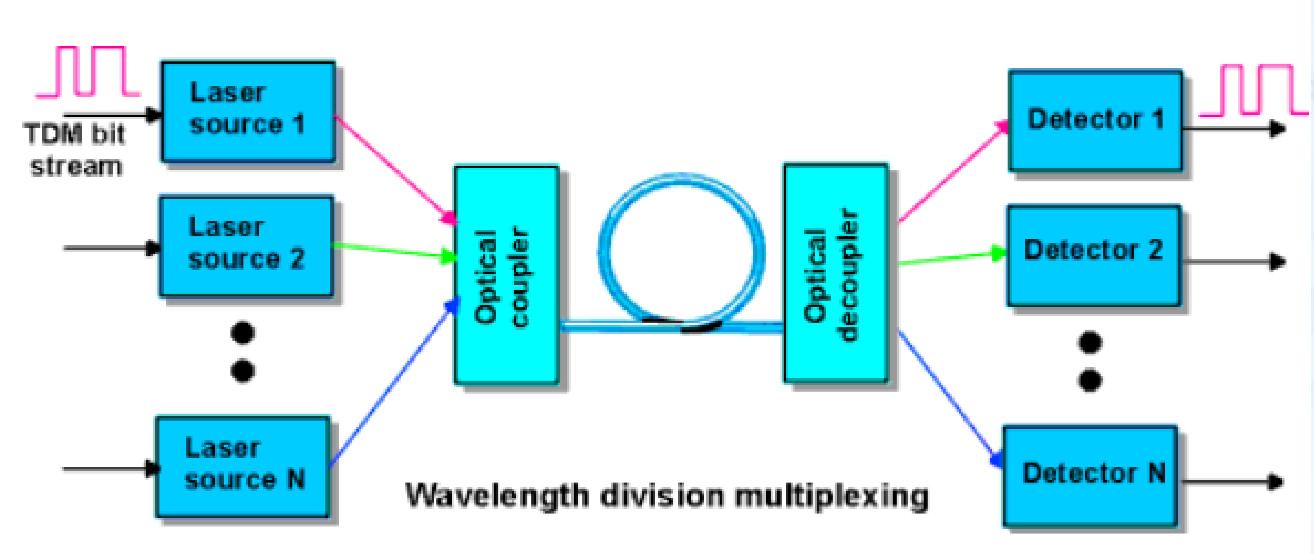
Frequency
Time
FDMA
Frequency
Time
TDMA
Frequency
Time
CDMA

Wavelength Division Multiplexing (WDM)

- **It's the same as FDM; it is called WDM for historical reasons, related to the development of optical fibers**
- **Different signals are modulated using different wavelengths on optical fibers**
- **Each wavelength can carry huge amount of information (5-10 Gbit/s)**
- **Technological limit: related to the stability of LEDs/Lasers used to modulate signals, as well as by the precision of optical filters**
- **We have currently commercial devices with 16 – 128 wavelengths (Dense WDM, DWDM)**

Wavelength Division Multiplexing (WDM)





Duplexing Modes

Simplex

- Information is transmitted in one and only one pre-assigned direction

Half Duplex:

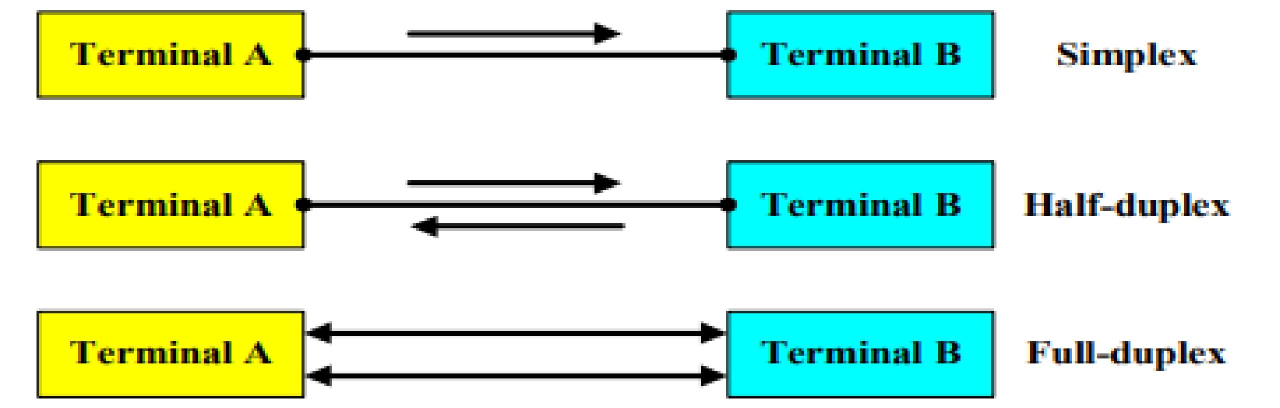
- Transmission of information in only one direction at a time
- Uses simplex operation at both end

Full Duplex

- Simultaneous transmission and reception of info in both directions
- In general, duplex operation require 2 frequencies
- May be achieved by simplex operation of 2 or more simplex at both ends

Duplexing can be implemented in either Frequency or Time domain

- Frequency Division Duplexing (FDD) & Time Division Duplexing (TDD)



Duplexing Modes

- **Simplex**: one way communication (e.g., broadcast AM)
- **Duplex**: two-way communication
  - **TDD**: time division duplex n, Users take turns on the channel
  - **FDD**: frequency division duplex,
    - Users get two channels one for each direction of communication n For example one channel for uplink (mobile to base station) another channel for downlink (base station to mobile)
  - **Half-duplex** in 802.11, a device cannot simultaneously be transmitting and receiving

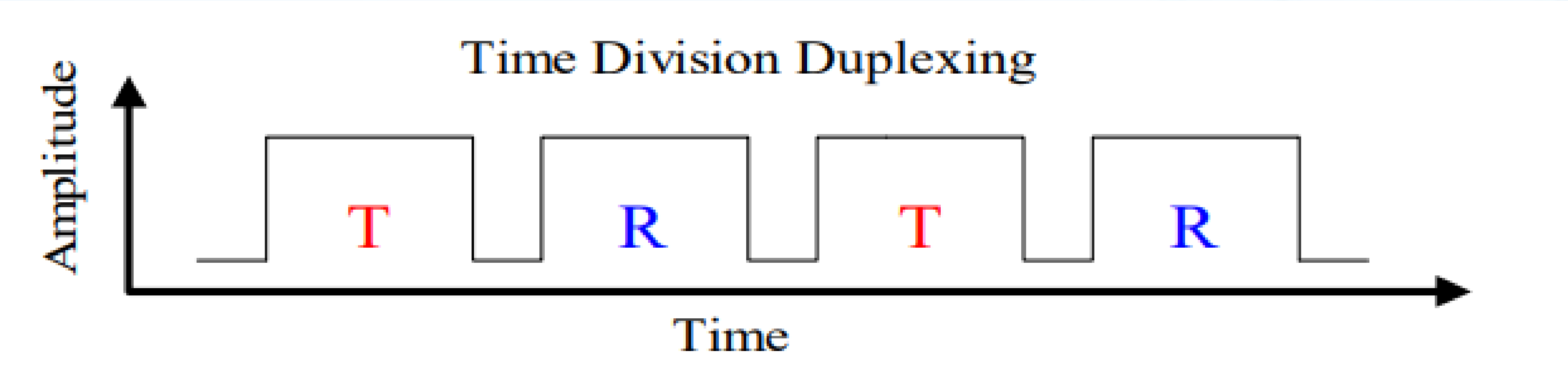
Frequency Division Duplexing (FDD)

- Multiplexes the Tx and Rx in one time slot in which transmission and reception is on 2 different frequencies

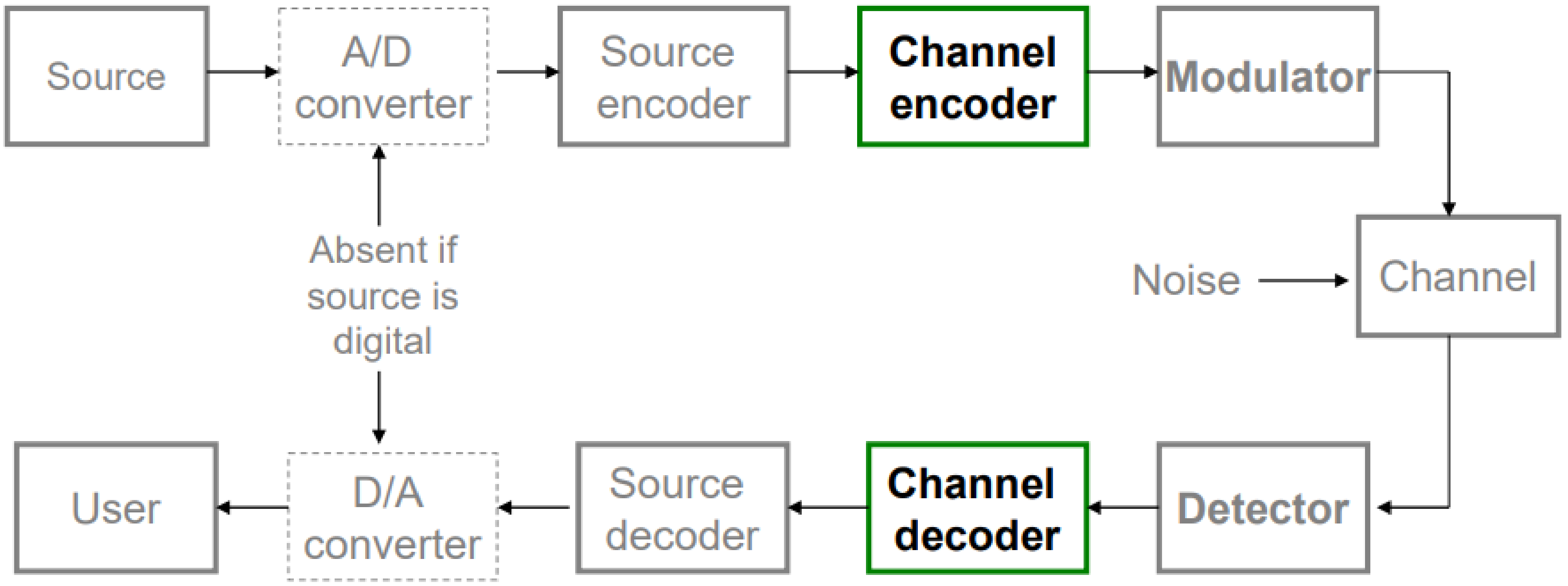
- It provides simultaneous transmission channels for mobile/base station • i.e. each channel has a Forward and a Reverse frequency
- At the base station, separate transmit and receive antennas are used to accommodate the two separate channels
- At the mobile unit, a single antenna (with duplexer) is used to enable transmission and reception
- To facilitate FDD, sufficient frequency isolation of the transmit and receive frequencies is necessary
- FDD is used exclusively in analog mobile radio systems

Time Division Duplexing (TDD)

- Multiplexes the Tx & Rx in one frequency at different time slots
- A portion of the time is used to transmit and a portion is used to receive
- TDD is used, for example, in a simple 2-way radio where a button is pressed to talk and released to listen
- TDD is only possible for digital transmission



Channel Coding



The purpose of channel coding is:-

- To protect information from channel noise, distortion and jamming which is the subject of error detection and correction codes.
- To protect information from 3rd party "enemy" which is the subject of encryption scrambling.

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QUESTIONS?