Multiple Access : CDMA

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Agenda

- CDMA: features
- Basic principle
- Second generation CDMA
- Third generation CDMA
- 4G standards

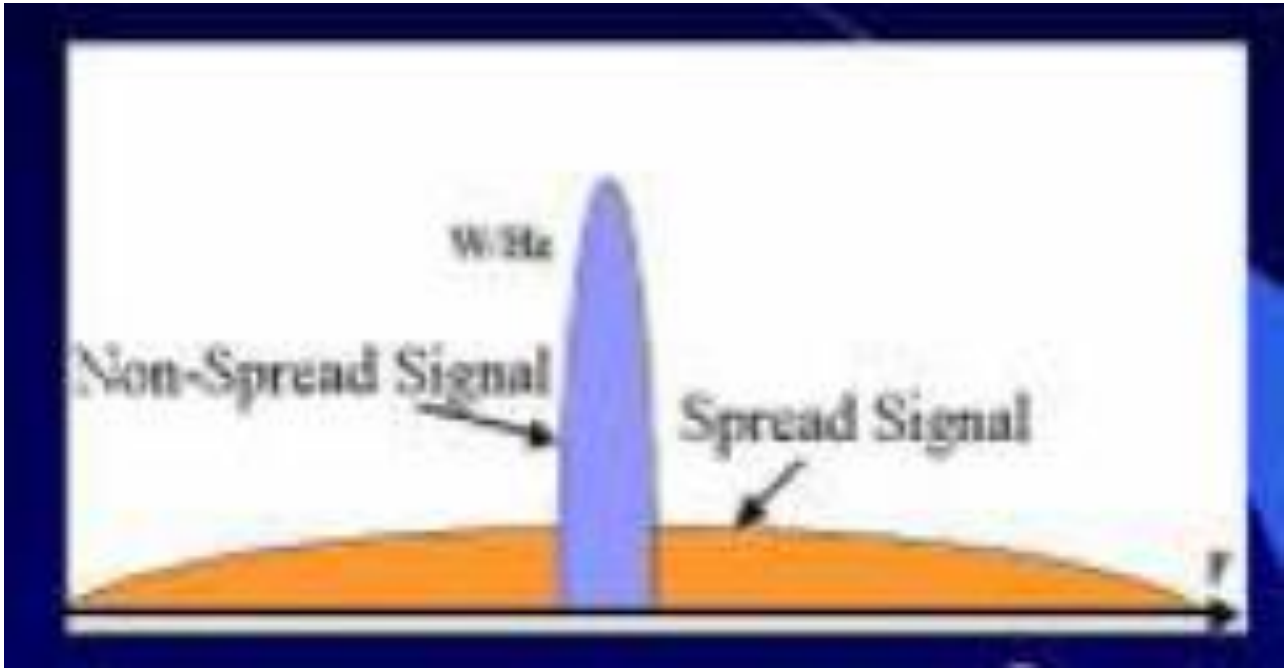
CDMA

- Wireless communication technology that uses spread spectrum communication
- Three ways to spread the bandwidth of the signal
  - Frequency hopping
  - Time hopping
  - Direct sequence

CDMA features

- All users use same frequency and may transmit simultaneously
- Narrowband massage signal multiplied with wideband spread signal
- Each user has its own pseudo code
- To detect at the receiver end receiver must know the transmitter codeword.

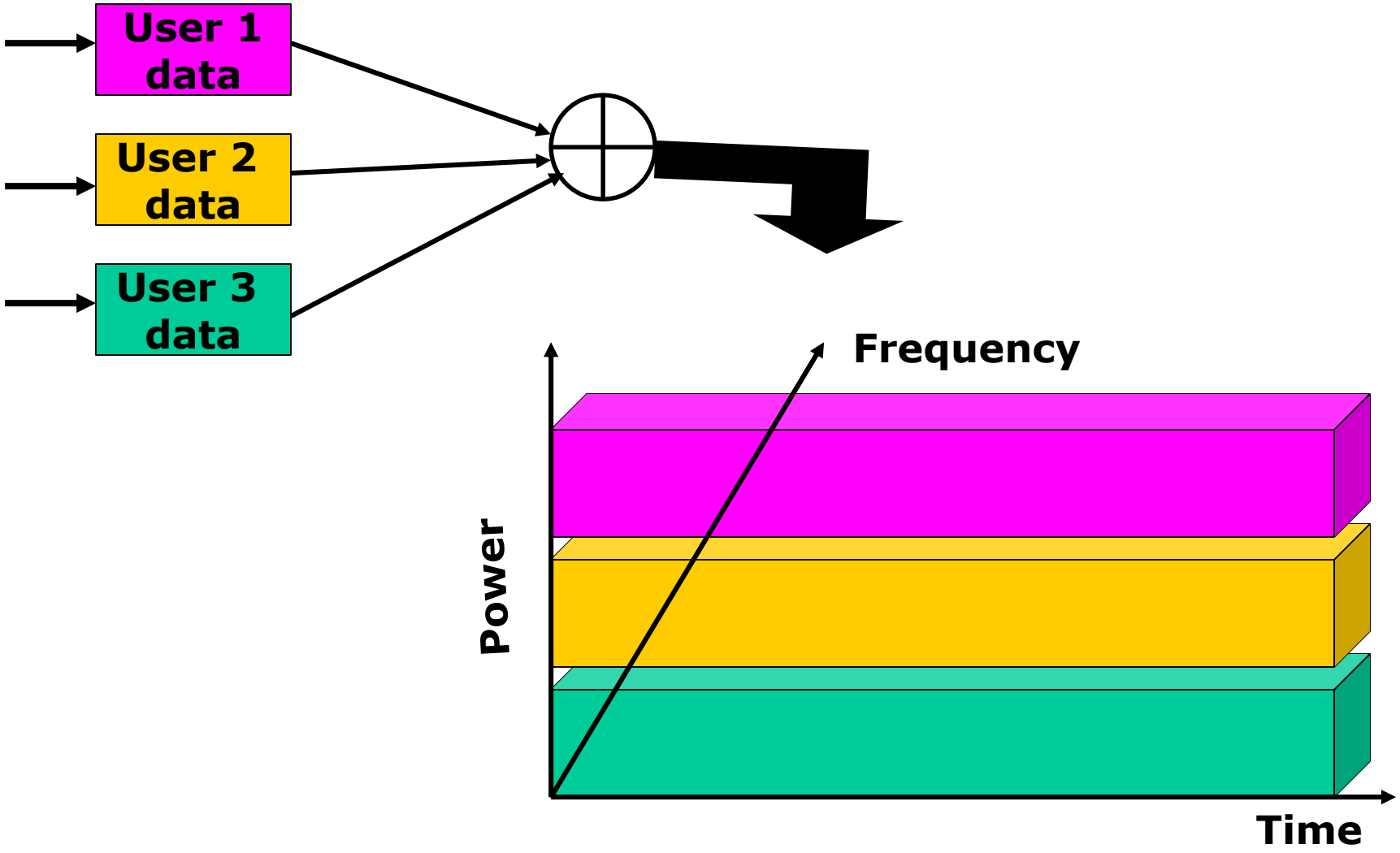
Spread Spectrum



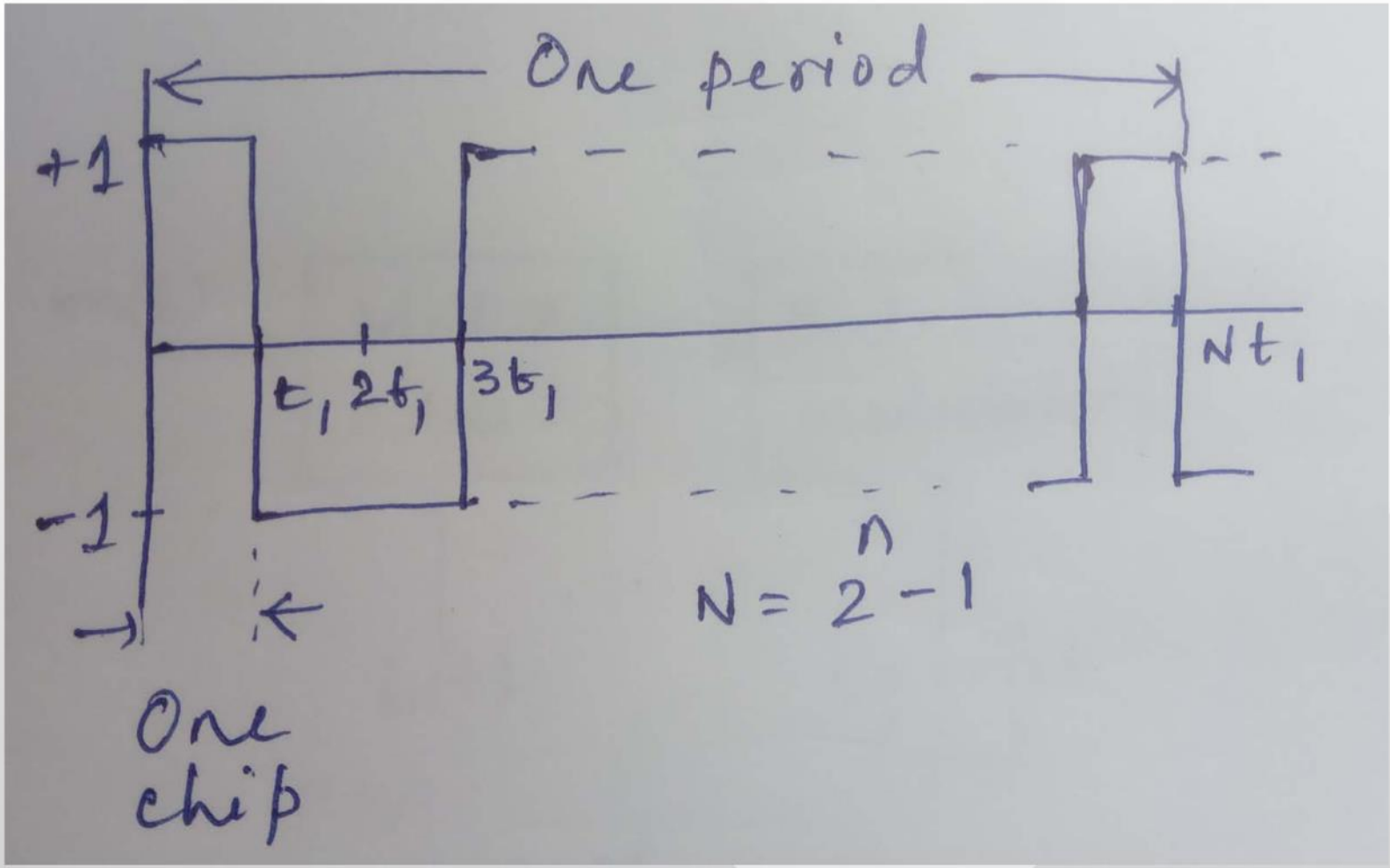
Pros and cons of CDMA

- Advantages:
  - Frequency diversity, spread out over large bandwidth, less immune to noise burst, selective fading
  - Multipath resistance, less interference
  - Privacy, each user has unique code
  - Graceful degradation
- Disadvantages:
  - Self-jamming, spreading sequences are not orthogonal
  - Near-far problem
  - Soft handoff, more complex than hard handoff

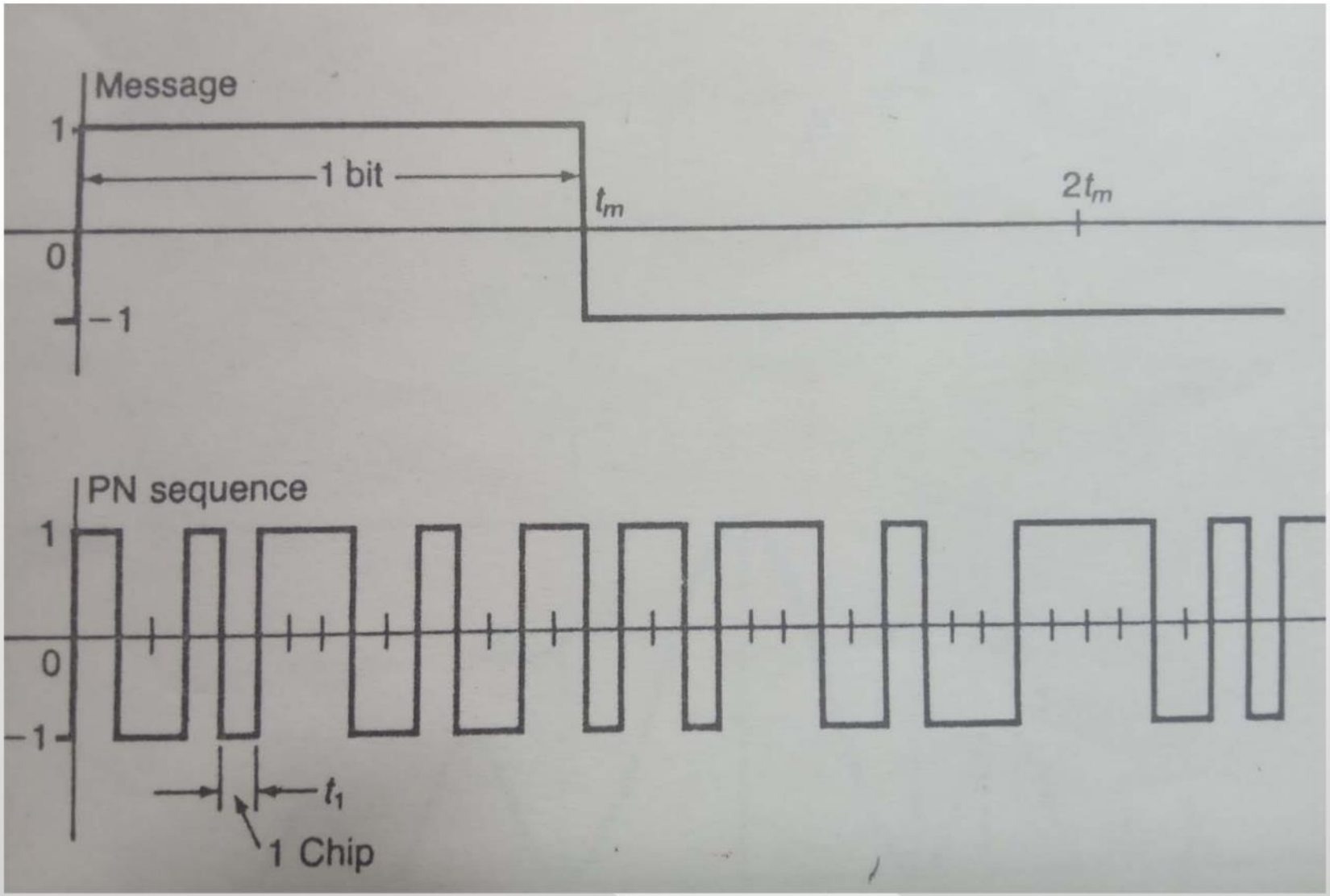
CDMA example



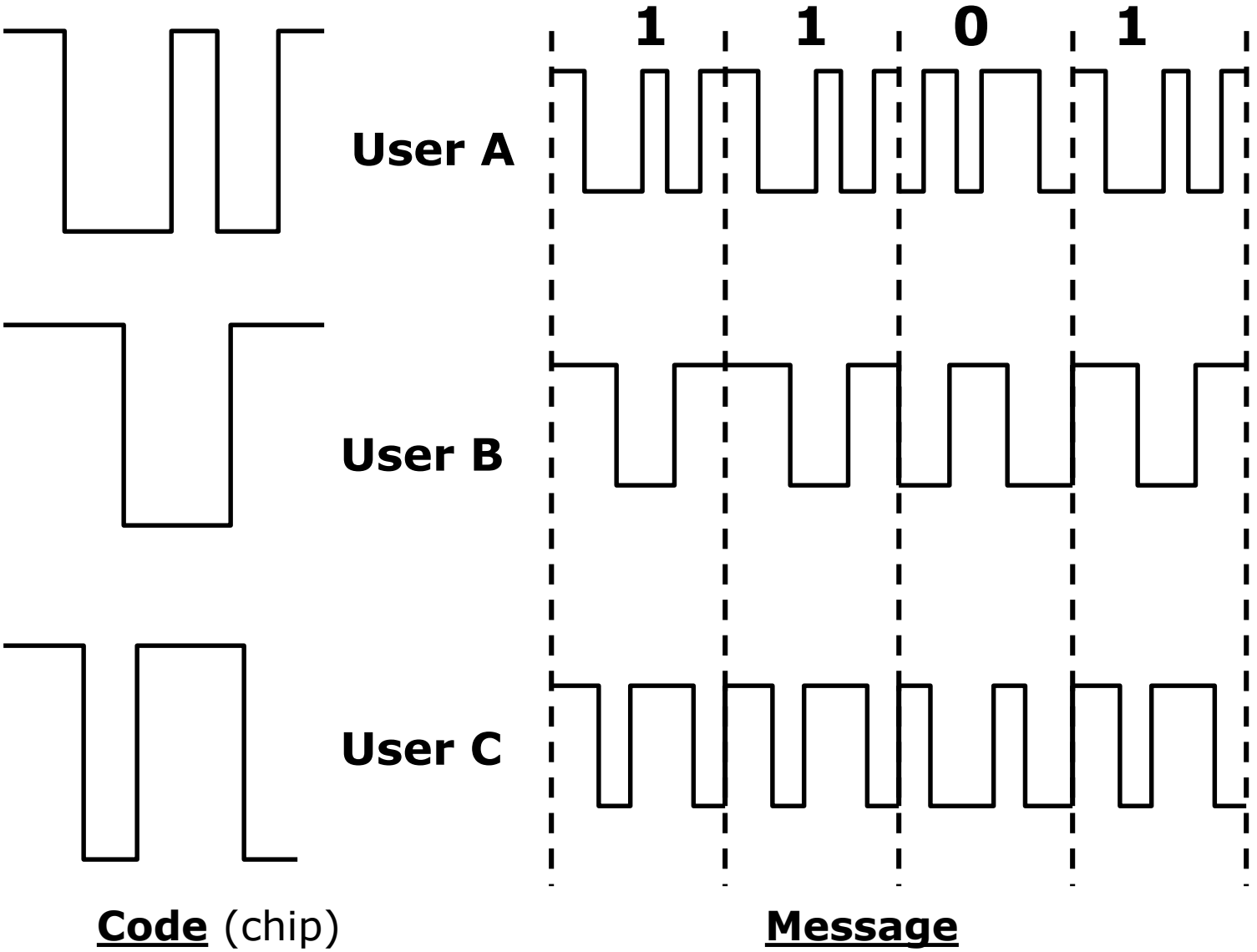
Periodic Binary PN Sequence



Relation between PN code sequence and binary message



CDMA example



CDMA example

User A	1	-1	-1	1	-1	1
User B	1	1	-1	-1	1	1
User C	1	1	-1	1	1	-1

User Code
c = <c1, c2, c3, c4, c5, c6>

Transmit (bit 1)	1	-1	-1	1	-1	1	
Received codeword	1	-1	-1	1	-1	1	
Multiplication	1	1	1	1	1	1	=6

Transmission from A

Transmit (bit 0)	-1	1	1	-1	1	-1	
Received codeword	1	-1	-1	1	-1	1	
Multiplication	-1	-1	-1	-1	-1	-1	=-6

Transmission from A

CDMA example

User A	1	-1	-1	1	-1	1
User B	1	1	-1	-1	1	1
User C	1	1	-1	1	1	-1

Transmit (bit 1)	1	1	-1	-1	1	1	
Received codeword	1	-1	-1	1	-1	1	
Multiplication	1	-1	1	-1	-1	1	=0

Transmission from B, receiver attempts to recover A's transmission

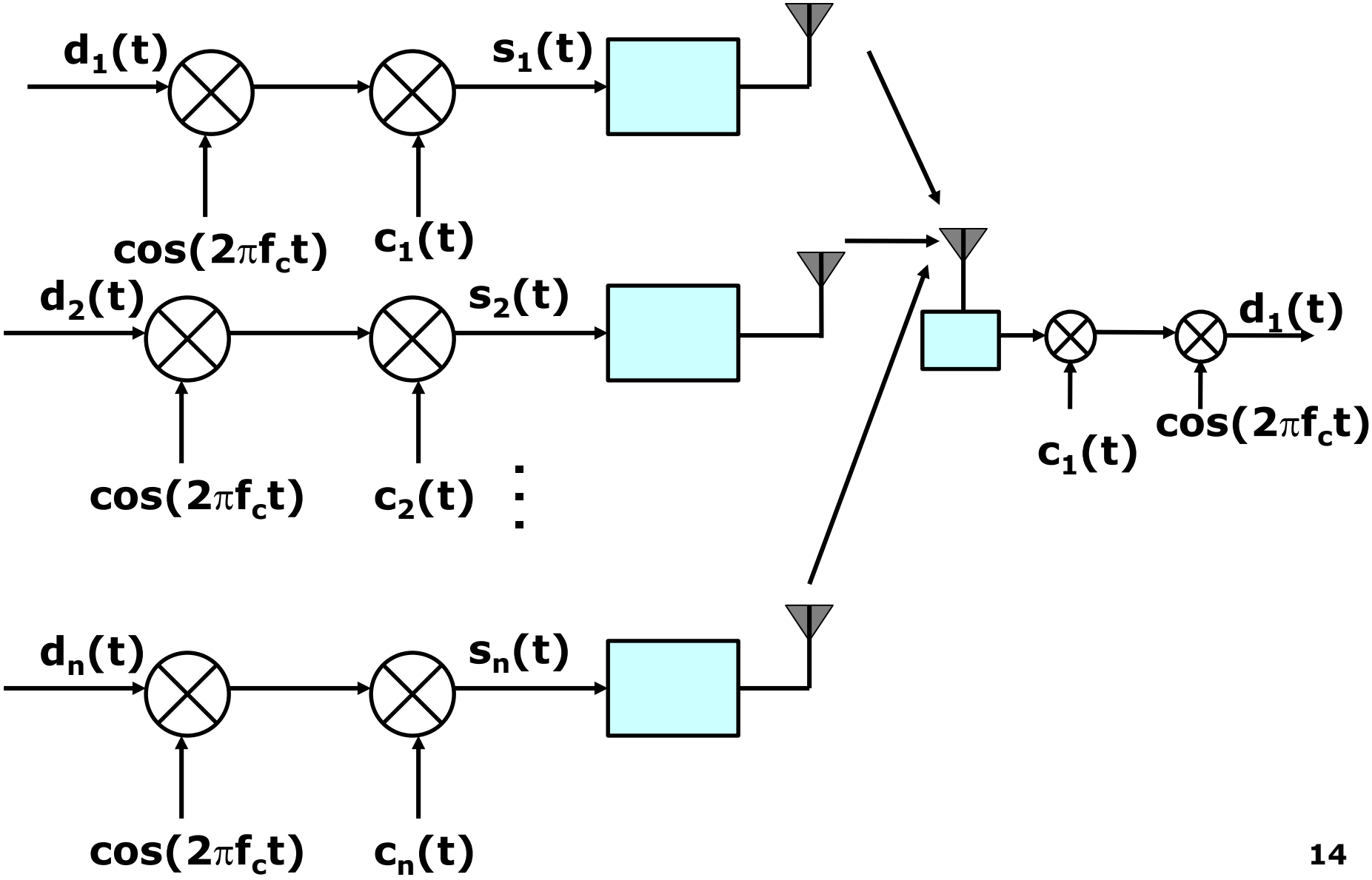
Transmit (bit 1)	1	1	-1	1	1	-1	
Received codeword	1	1	-1	-1	1	1	
Multiplication	1	1	1	-1	1	-1	=2

Transmission from C, receiver attempts to recover B's transmission

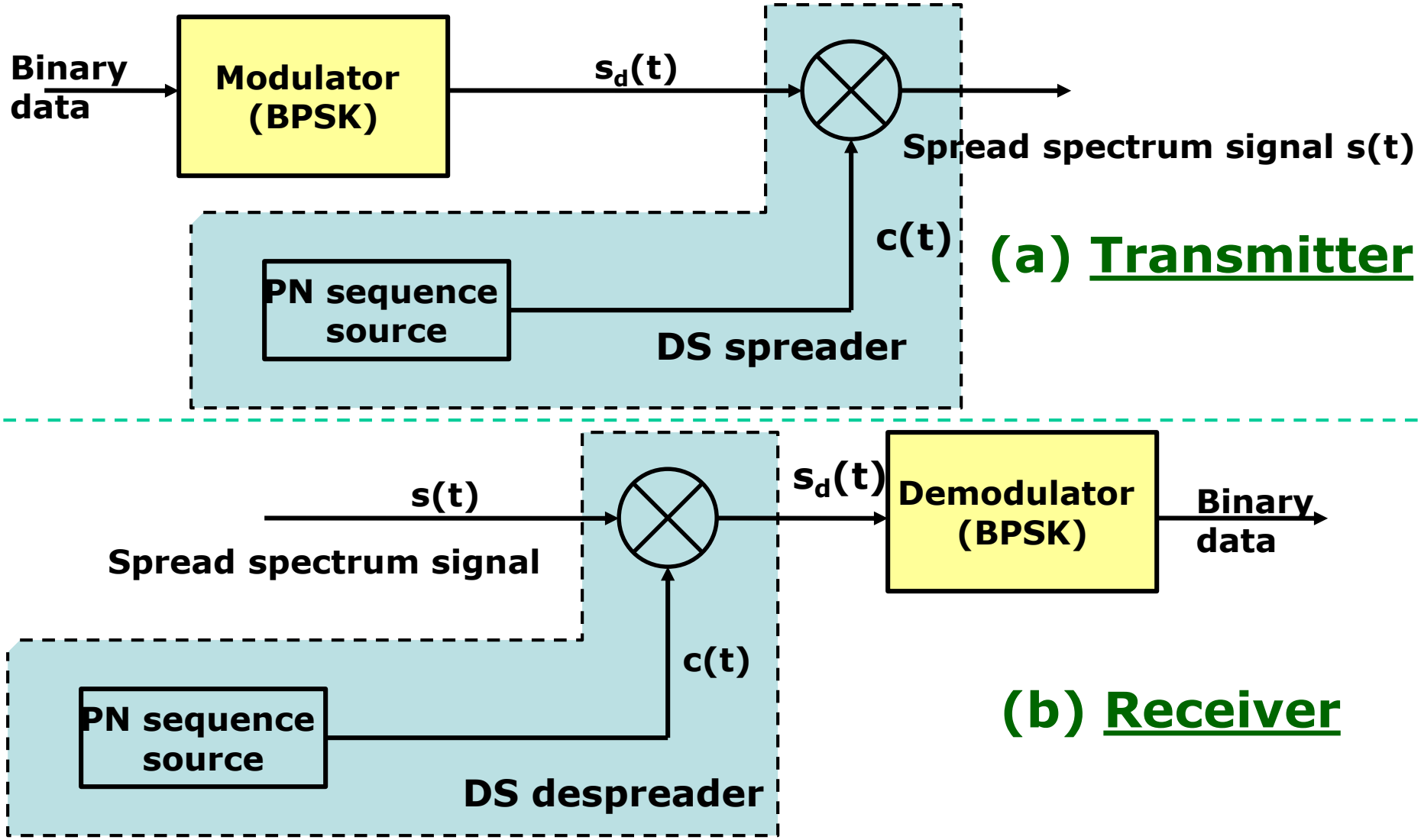
Transmission from B and C, receiver attempts to recover B's transmission

B (data 1)	**1**	**1**	**-1**	**-1**	**1**	**1**	
C (data 1)	**1**	**1**	**-1**	**1**	**1**	**-1**	
Combined signal	**2**	**2**	**-2**	**0**	**2**	**0**	
Received codeword	**1**	**1**	**-1**	**-1**	**1**	**1**	
Multiplication	**2**	**2**	**2**	**0**	**2**	**0**	**=8**

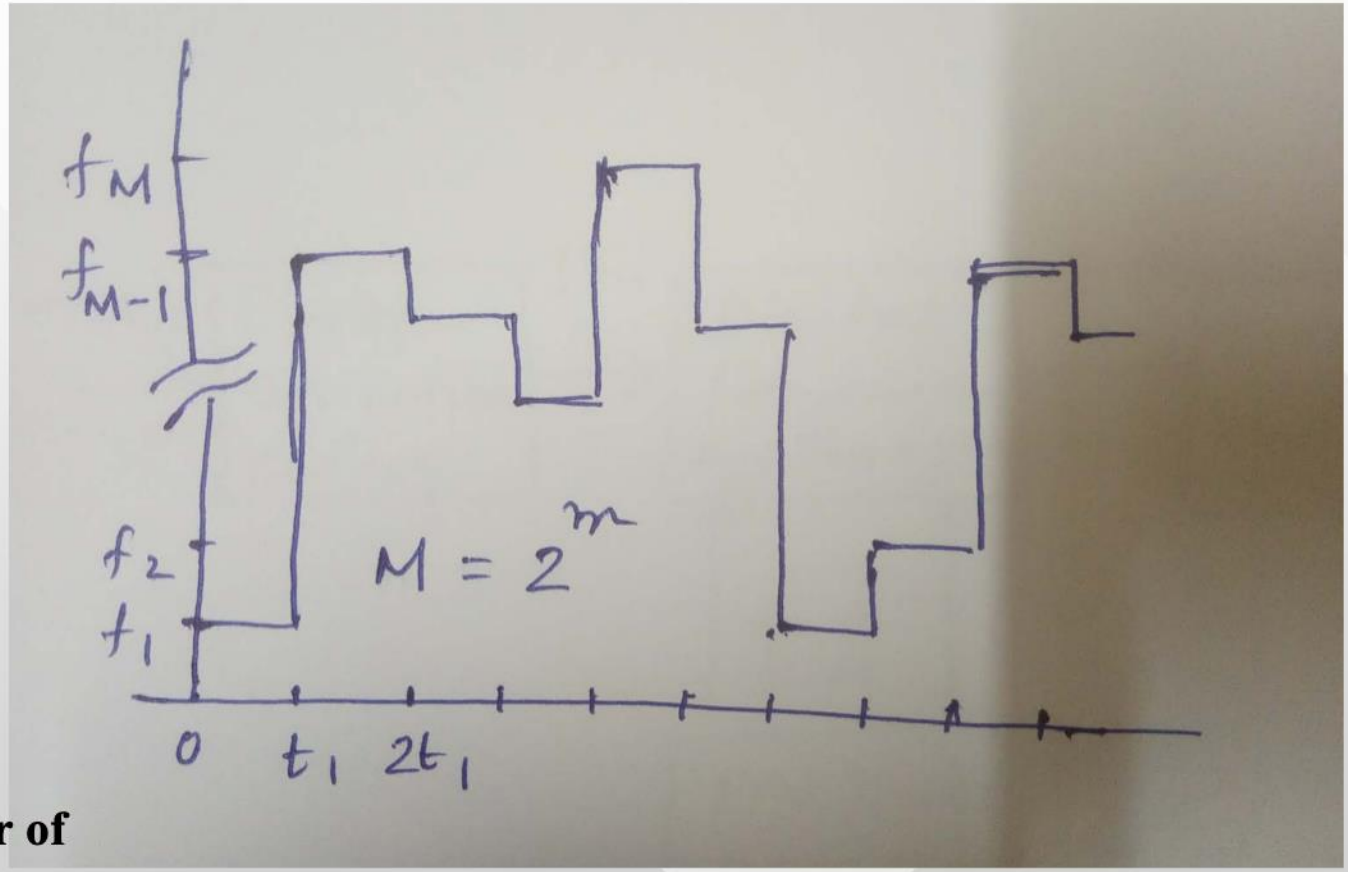
CDMA DSSS


$d_1(t)$
$s_1(t)$
$\cos(2\pi f_c t)$
$c_1(t)$
$d_2(t)$
$s_2(t)$
$\cos(2\pi f_c t)$
$c_2(t)$
$d_1(t)$
$c_1(t)$
$\cos(2\pi f_c t)$
$d_n(t)$
$s_n(t)$
$\cos(2\pi f_c t)$
$c_n(t)$

Direct sequence spread spectrum systems



Frequency hop spread spectrum

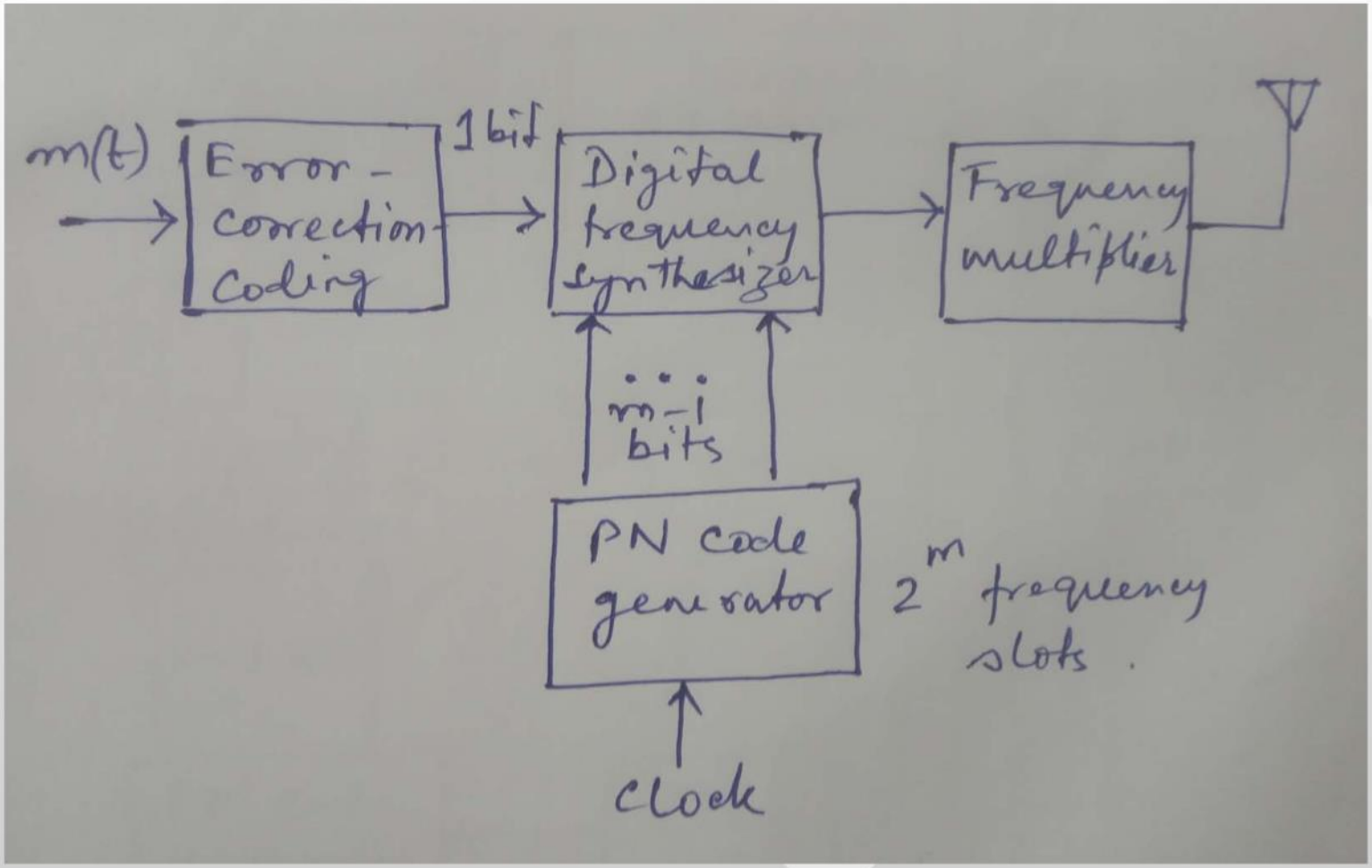


M = number of frequency
m = number of bits in a message

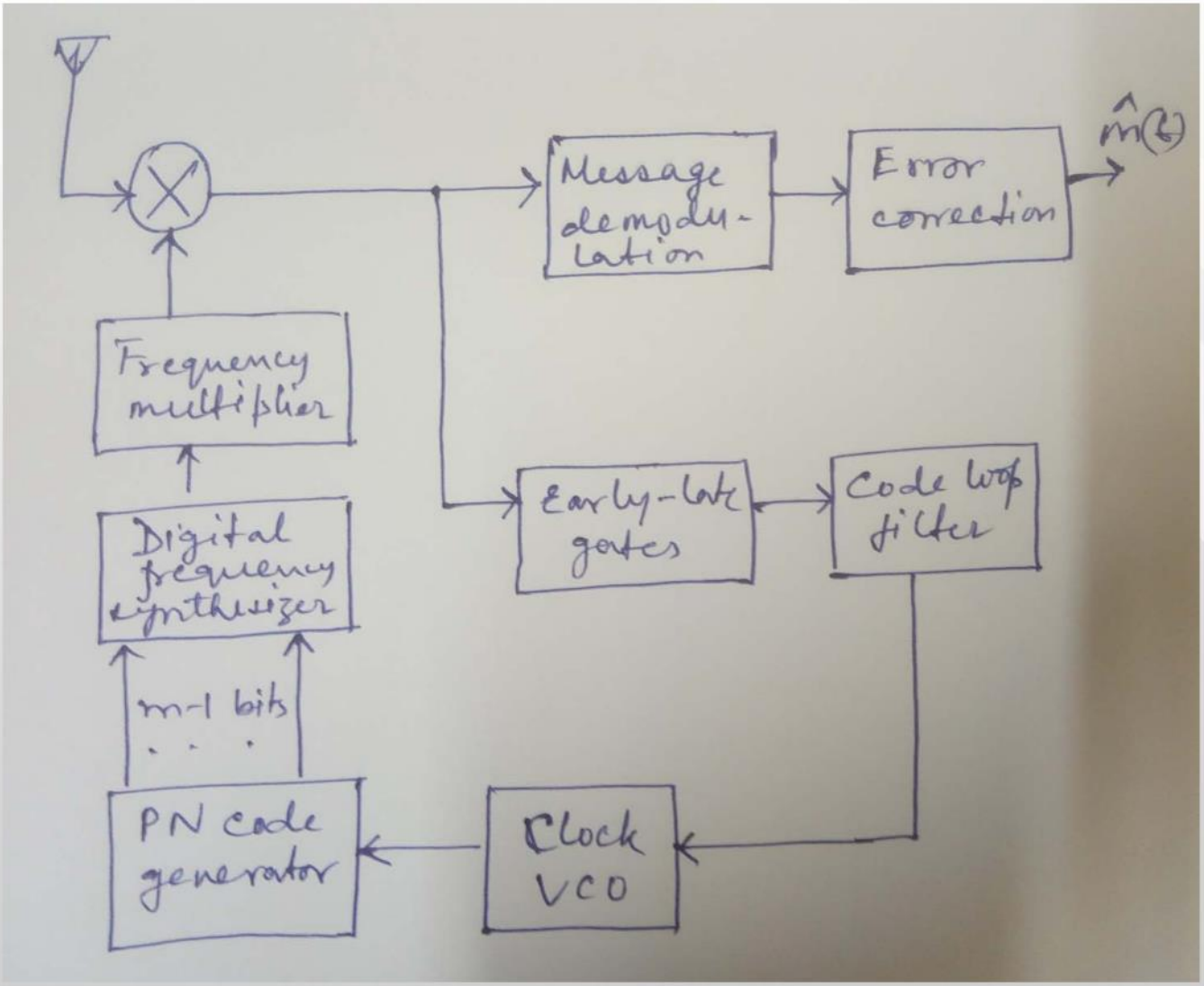
Frequency hop spread spectrum

- In frequency-hopping signal, the frequency is constant over one time chip, but changes from chip to chip
- Fast hop: frequency hopping takes place at a rate
  that is greater than the message bit rate
- Slow hop: frequency hop is less than the message bit rate
- For fast hop, $t_1 = t_m/k$, t_1 is time chip, t_m is massage bit time, k = 1,2,3 ...

Frequency-Hopping Transmitter



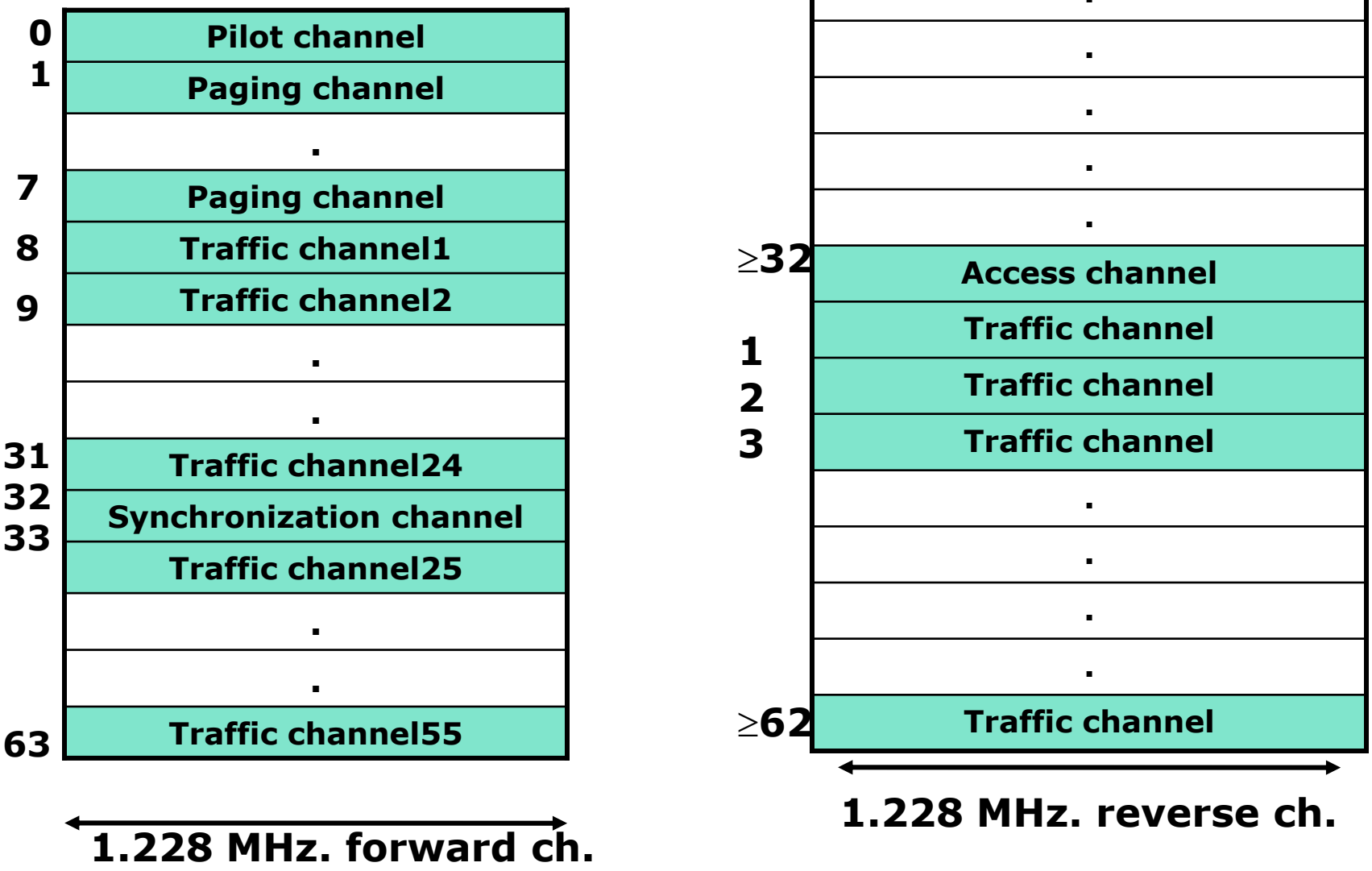
Frequency-Hopping Receiver



Second Generation CDMA

IS-95

- *Second generation CDMA* scheme primarily deployed in North America
- 64 logical CDMA forward channel each of 1.228MHz. bandwidth
- IS-95 forward link
  - Pilot (channel 0)
  - Synchronization
  - Paging
  - Traffic
- IS-95 reverse link
  - Access
  - Traffic

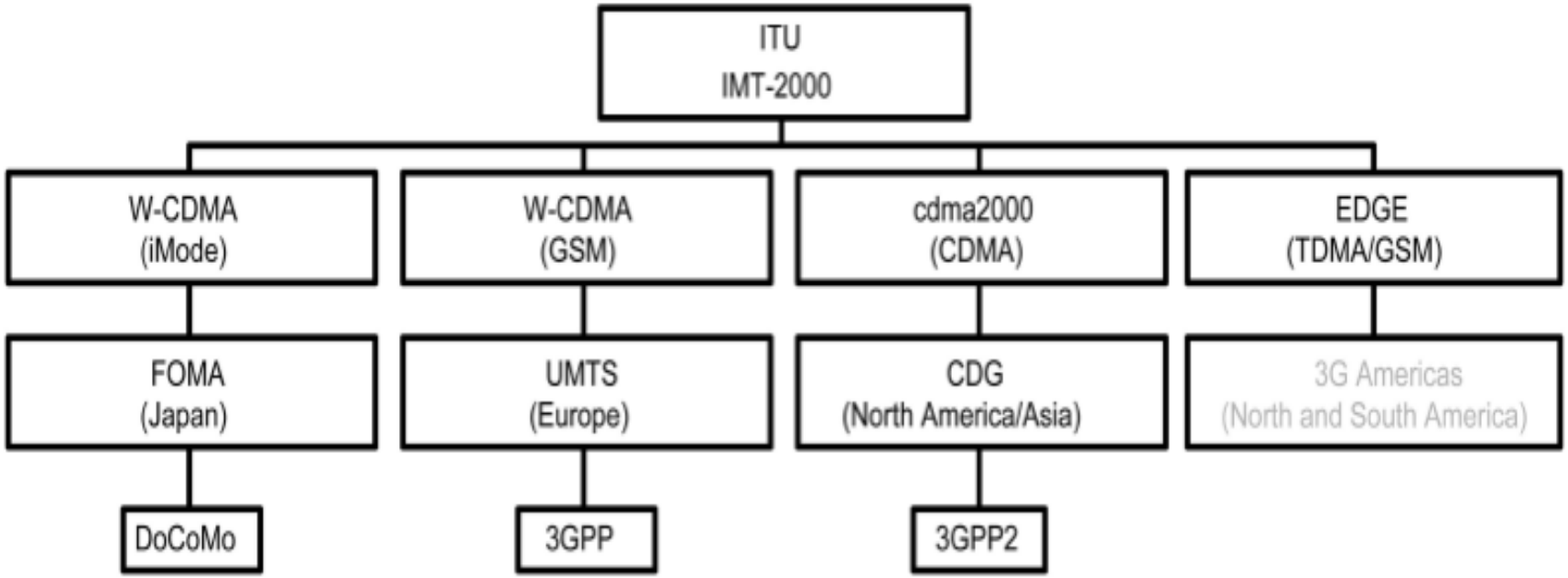

0
Pilot channel
1
Paging channel
.
7
Paging channel
8
Traffic channel1
9
Traffic channel2
.
.
31
Traffic channel24
32
Synchronization channel
33
Traffic channel25
.
.
63
Traffic channel55
1.228 MHz. forward ch.
1
Access channel
2
Access channel
.
.
.
.
.
≥32
Access channel
Traffic channel
1
Traffic channel
2
Traffic channel
3
.
.
.
.
≥62
Traffic channel
1.228 MHz. reverse ch.

Third generation systems (IMT*-2000)

- Aim is to produce high speed communication to support multimedia, data and video in addition to voice
- Voice quality comparable to PSTN
- **144kbps data rate** available to vehicles
- **384kbps** available to pedestrian
- **2.048Mbps** for office use
- Symmetric and asymmetric data transmission
- Support circuit switched and packet switched data traffic
- Efficient use of available spectrum
- Flexibility to allow new services and technologies

*International Mobile Telecommunication

3G development groups worldwide



W-CDMA Parameters

Channel B.W.	5 MHz
Forward RF channel structure	Direct spread
Chip rate	3.84 Mcps
Frame length	10 ms
No. of slots/frame	15
Spreading modulation	Balanced QPSK (forward) Dual channel QPSK(reverse) Complex spreading circuit
Data modulation	QPSK BPSK
Coherent detection	Pilot symbol

Reverse channel multiplexing	Time multiplexing
Multirate	Various spreading and multicore
Spreading factor	4 to 256
Power control	Open and fast code loop (1.6 KHz)
Spreading (forward)	Variable length orthogonal sequence for channel separation Gold sequence for cell and user separation
Spreading (reverse)	Same as forward, different time shift in I and Q channels
Handover	Soft

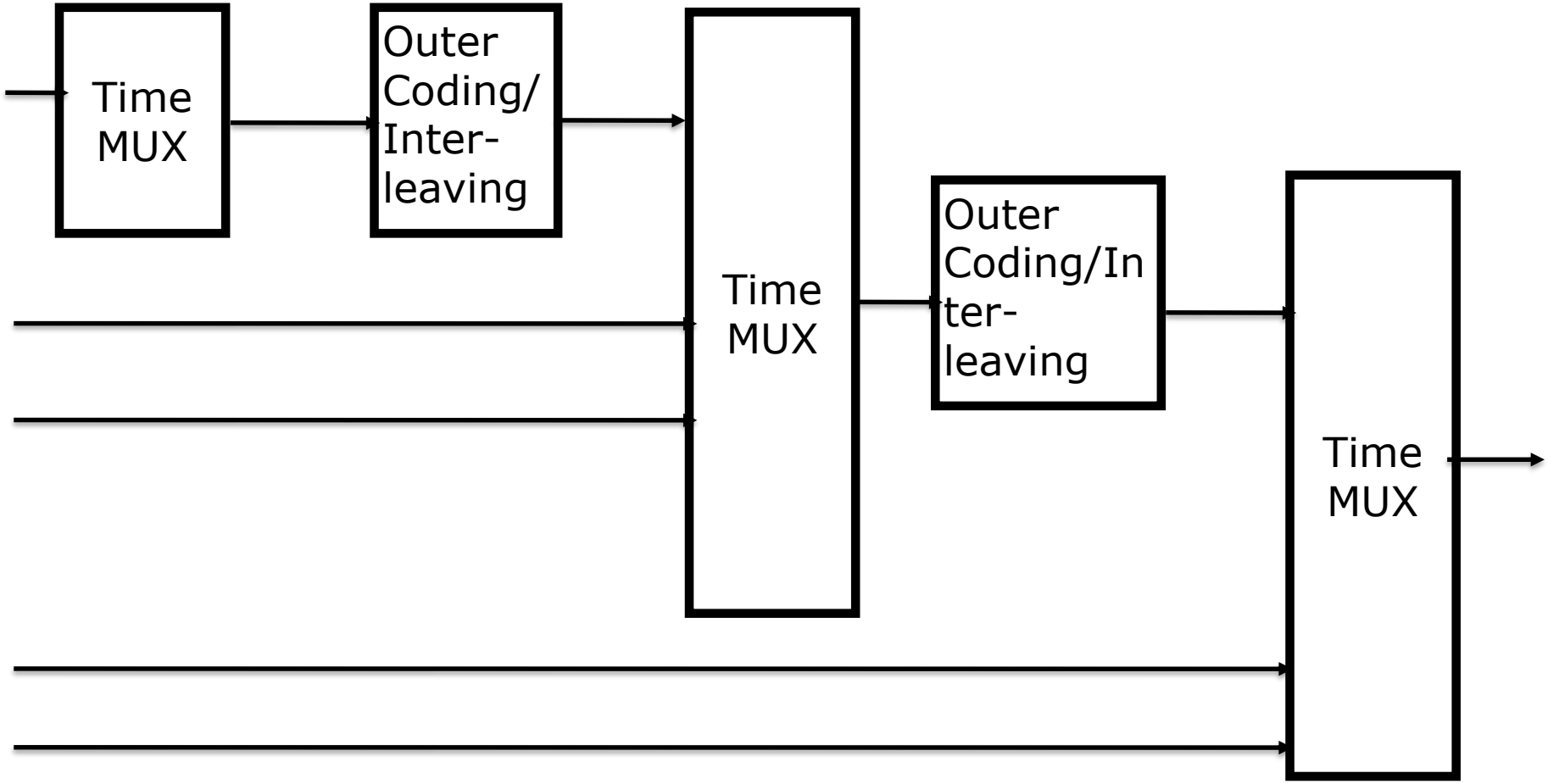
CDMA design considerations

- Bandwidth
  - Bandwidth for channel limited to 5 MHz.
- Chip rate
  - Depends on data rate, need for error control, bandwidth limitation
  - Chip rate 3 Mcps or more
- Multirate
  - Multiple fixed data-rate logical channels to a given user
  - Supports multiple simultaneous application

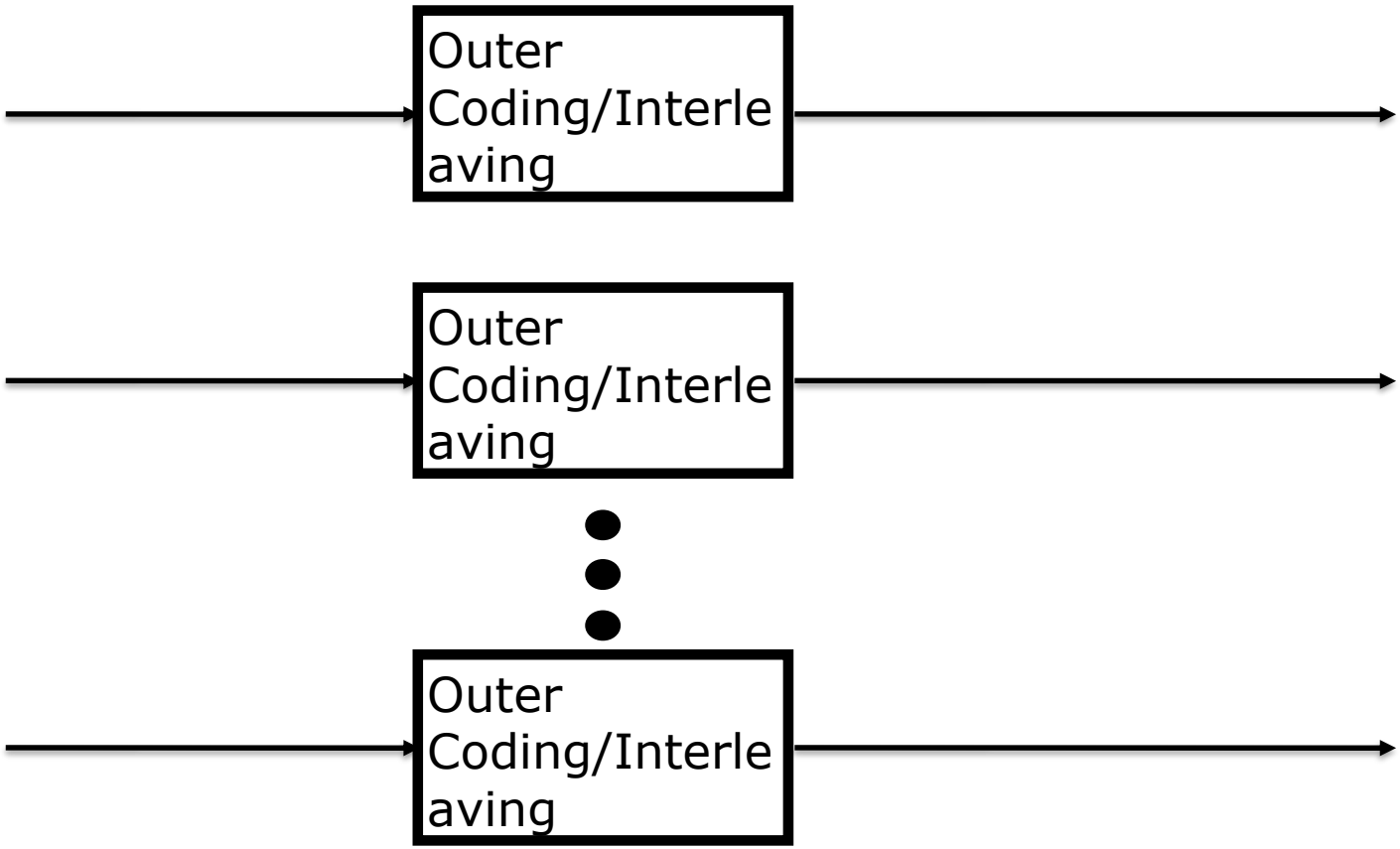
Multirate: TDMA and CDMA

- Different number of slots per frame are assigned to achieve different data rate within a single CDMA channel
- Multiple CDMA codes with separate coding and interleaving, mapped to separate CDMA channels

Time Multiplexing



Code Multiplexing

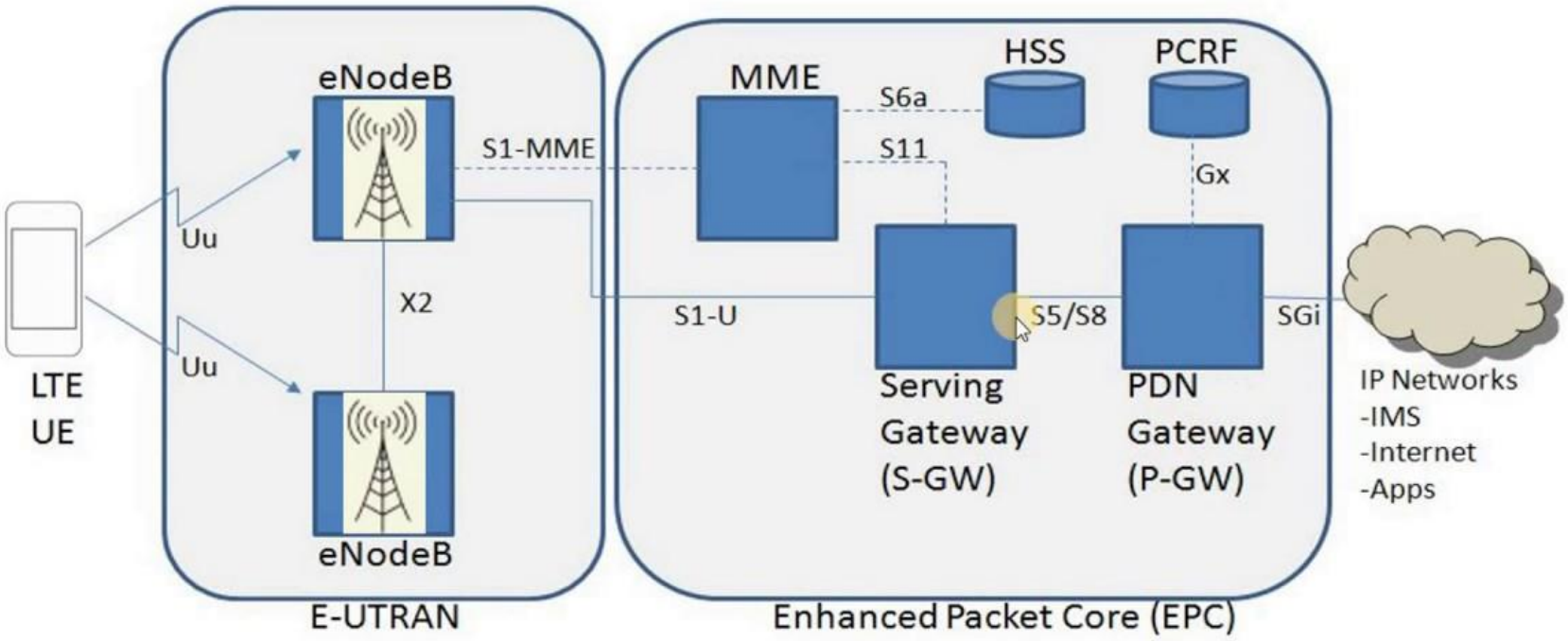


4G Standards

- UTRA (Universal Terrestrial Radio Access) is a 3rd generation system
- 3GPP technologies, launched a project in Dec. 2004 called Long Term Evolution (LTE) to study requirements for a new air interface called Evolved UTRA (EUTRAN)
- LTE is using OFDMA (Orthogonal Frequency Division Multiple Access) in downlink (evolved NodeB (eNodeB) => User Equipment (UE)) and SC-FDMA (Single Carrier- Frequency Division Multiple Access) in uplink (UE => eNodeB)
- While UMTS (at least FDD and 3,84Mcps TDD) used a channel bandwidth of 5MHz, LTE allows 6 different channel bandwidths: 1,4/3/5/10/15/20MHz
- Developments of the 4th generation of mobile communication system with LTE advanced

https://www.etsi.org/technologies/mobile/4G

4G | LTE ARCHITECTURE



..... → Signal

——— → Traffic

4G-LTE Architecture

1. MME→ Mobility management entity
2. HSS→ Home subscriber server, a central repository of information for network nodes
3. PCRF→ Policy and charging rules function, allocation of network resources for the IP Multimedia Systems network

Challenges of LTE Advanced

- Support of wider bandwidth: aggregation of multiple component carriers with up to 20MHz bandwidth
- Spatial multiplexing: DL up to 8 layers, UL up to 4 layers
- Coordinated multiple point transmission and reception: to improve the coverage of high data rates, the cell-edge throughput and/or to increase system throughput
- Relaying functionality: to improve the coverage of high data rates, coverage of new area, group mobility, temporary network deployment

Thank You!