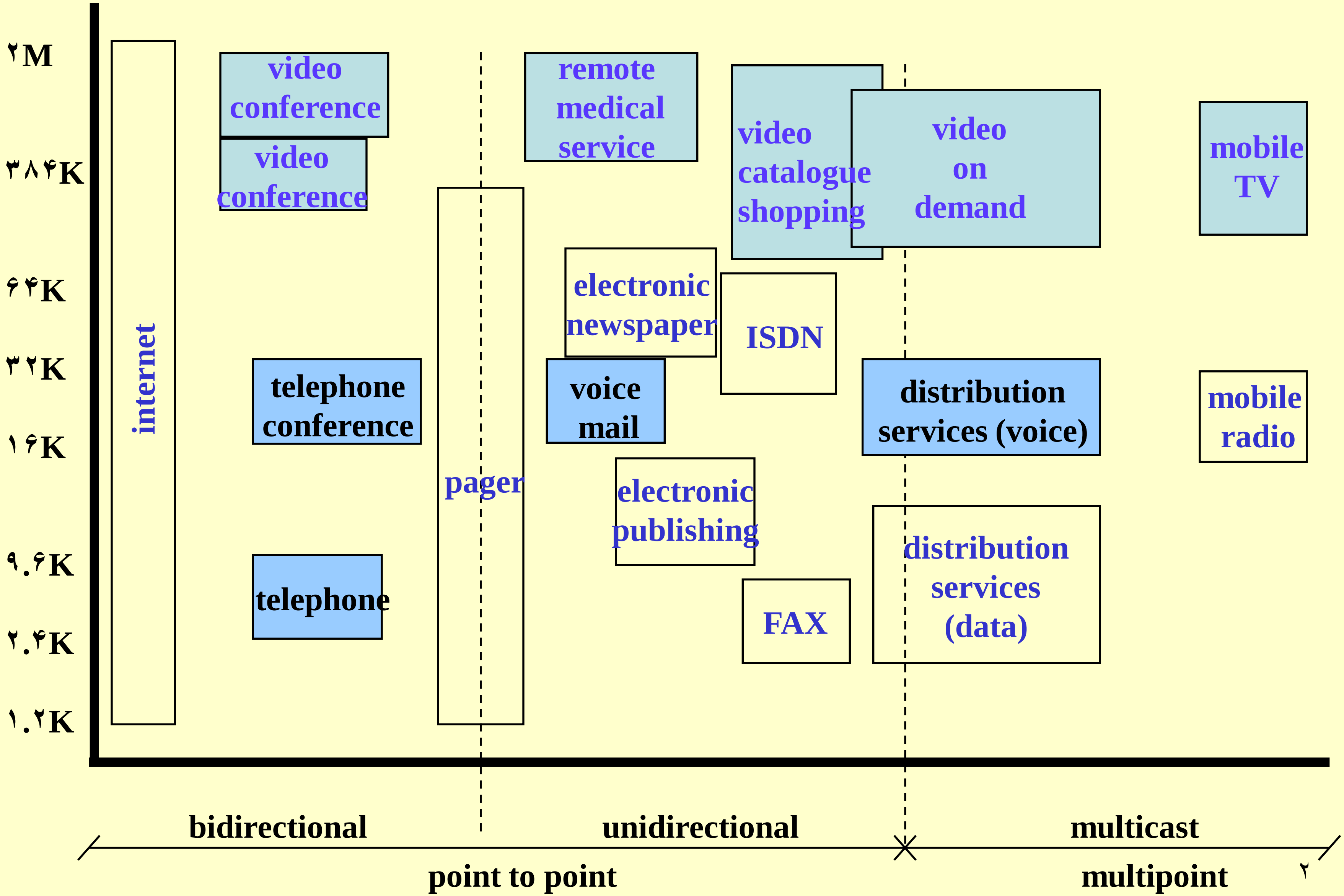
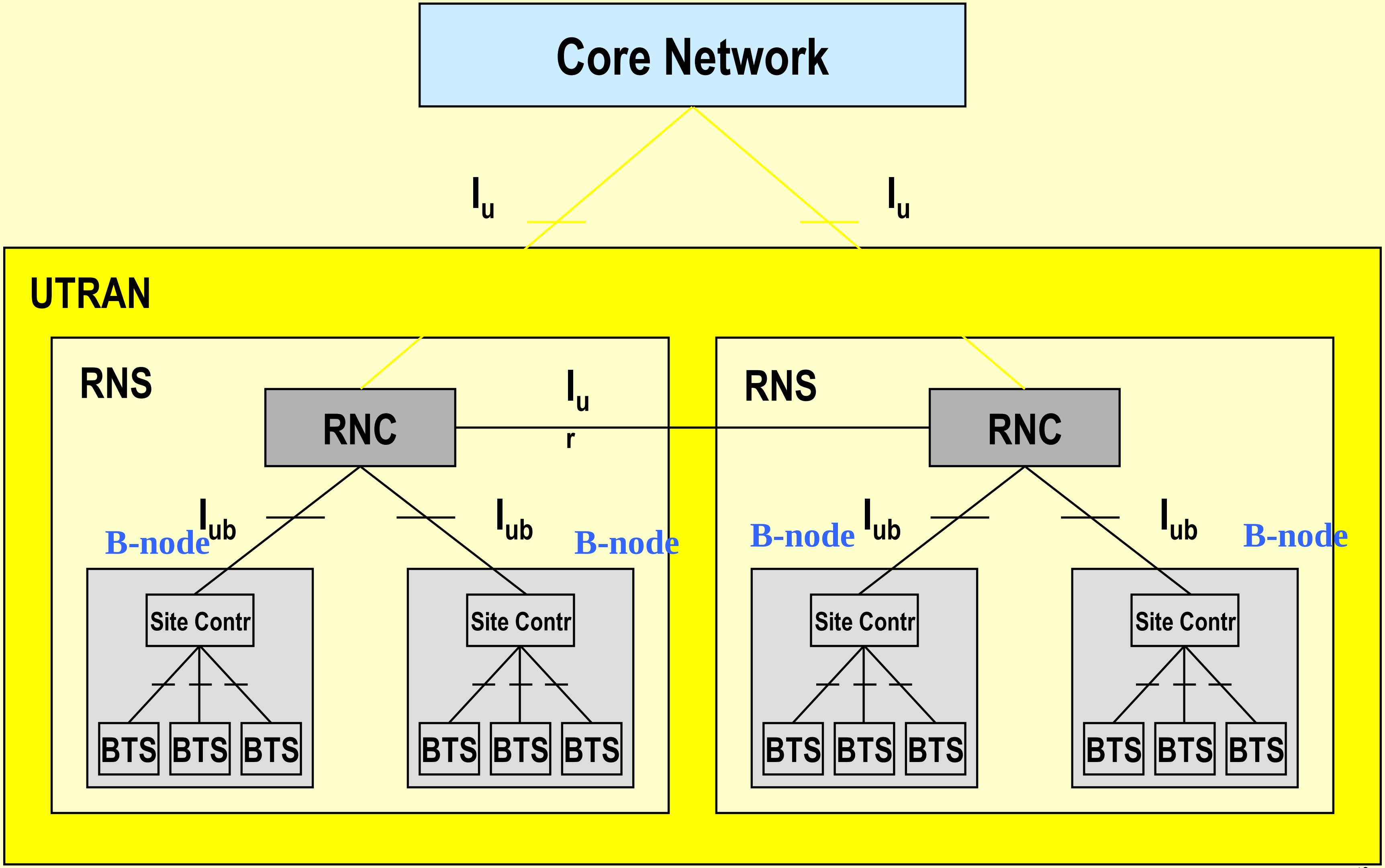
Introduction to WCDMA and WCDMA Dimensioning for UMTS

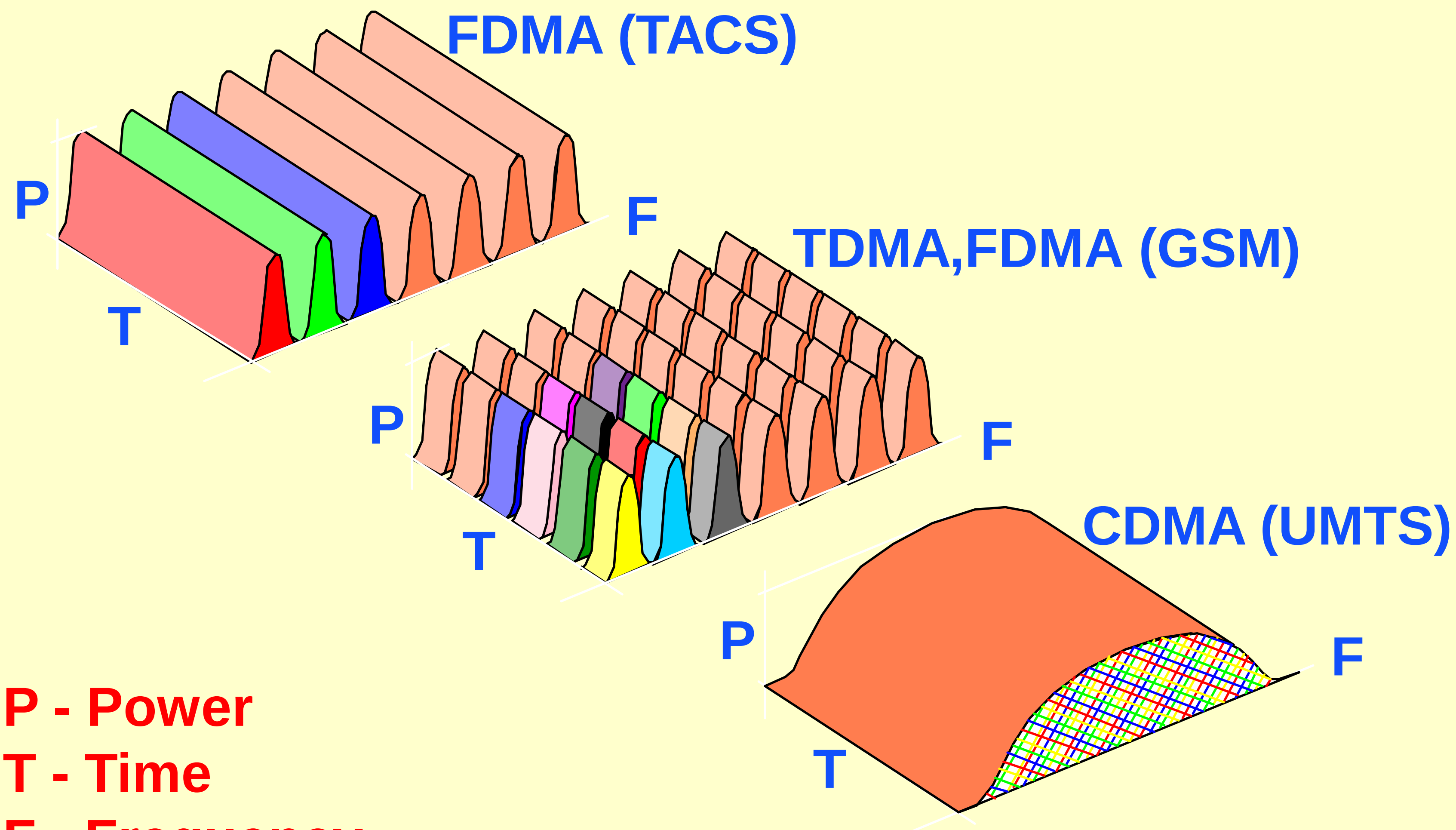
Third generation services



UTRAN (UMTS Terrestrial Radio Access Net) Architecture



Access techniques for mobile communications



P - Power
T - Time
F - Frequency

W-CDMA (Wide Band CDMA)

Key features

- Improved **capacity** and coverage (over second generation); thus, backward compatible
- High degree of **service flexibility**: multiple, parallel services per connection; efficient pkt access

Basics of Spread Spectrum and CDMA

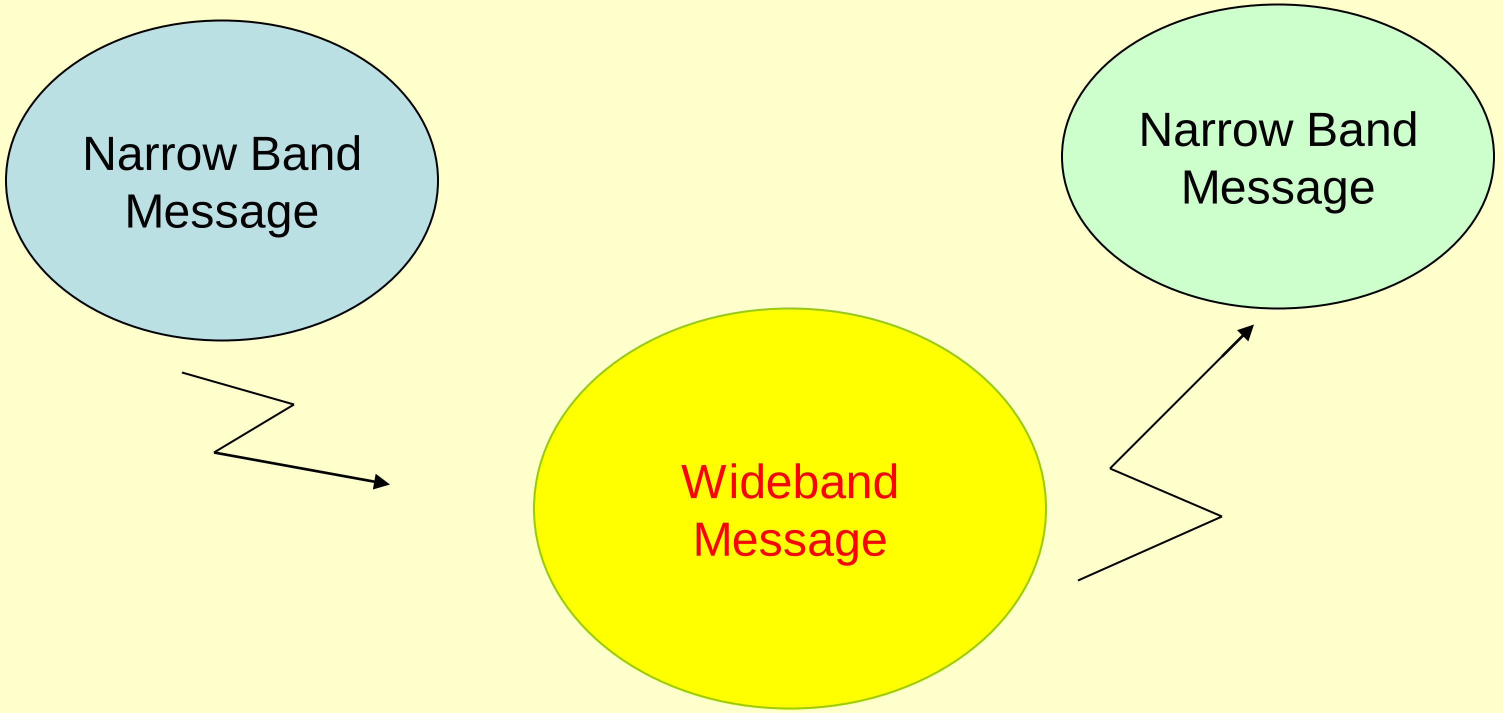
Overview

- **Why consider Spread Spectrum ?**
- **What is Spread Spectrum & CDMA ?**
- **Frequency Hopping Spread Spectrum**
  - **Impact of channel**
  - **Current systems**
- **Direct Sequence Spread Spectrum**
  - **Spreading Codes**
  - **Analytical Performance Model**
  - **Rake Processing**
  - **Near Far Effect (Power Control)**
  - **Handover**

Why Consider Spread Spectrum ?

- Spread Spectrum has been adopted as the air interface standard for ۳rd Generation Mobile Systems (IMT۲۰۰۰):
  - Europe (ETSI): UMTS (W- CDMA)
  - Japan (ARIB): Wideband CDMA
  - USA (TIA TR۴۵. ۵) CDMA ۲۰۰۰
- ۲nd Generation standard deployed in US and Korea
  - IS۹۵ (Qualcomm CDMA)

What is spread spectrum?



Frequency Hopping Spread Spectrum

- Classification of Spread Spectrum Systems
- Frequency Hopping (FH)
- Narrow band message signal is modulated with a carrier frequency which is rapidly shifted . The hop frequency is indicated by a spreading function.
- This spreading function is also available at the receiver and enables it to retune to the correct channel for each ‘hop’.

Hop rates in an FH system

- Fast frequency hopping
- – Data symbol spread over several hop frequencies
- –Symbol diversity
- – Very resistant to jamming and interference, often used in military systems
- Slow frequency hopping
- – Several data symbols on each hop frequency
- –Codeword diversity with interleaving

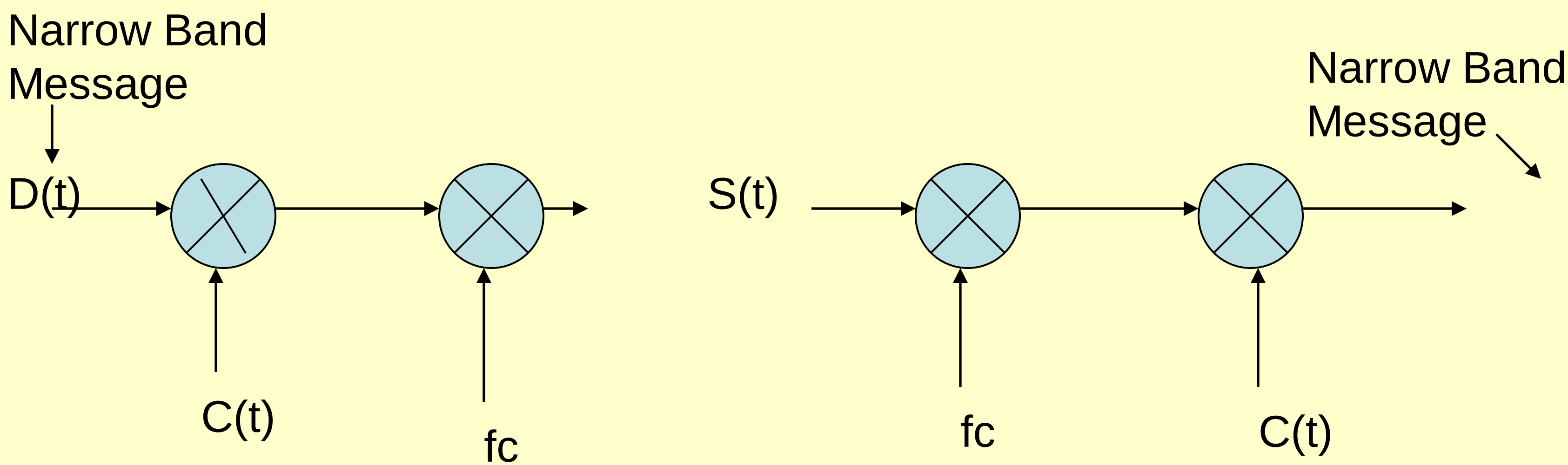
– Less complex

Direct Sequence Spread Spectrum

Classification of Spread Spectrum Systems

- Direct Sequence (DS)
  - Secondary modulation in the form of pseudo-noise is applied to an already modulated narrowband message, thereby spreading the spectrum.
  - At the receiver, the incoming waveform is multiplied by an identical synchronized spreading waveform in order to recover the message.

Direct sequence spread spectrum

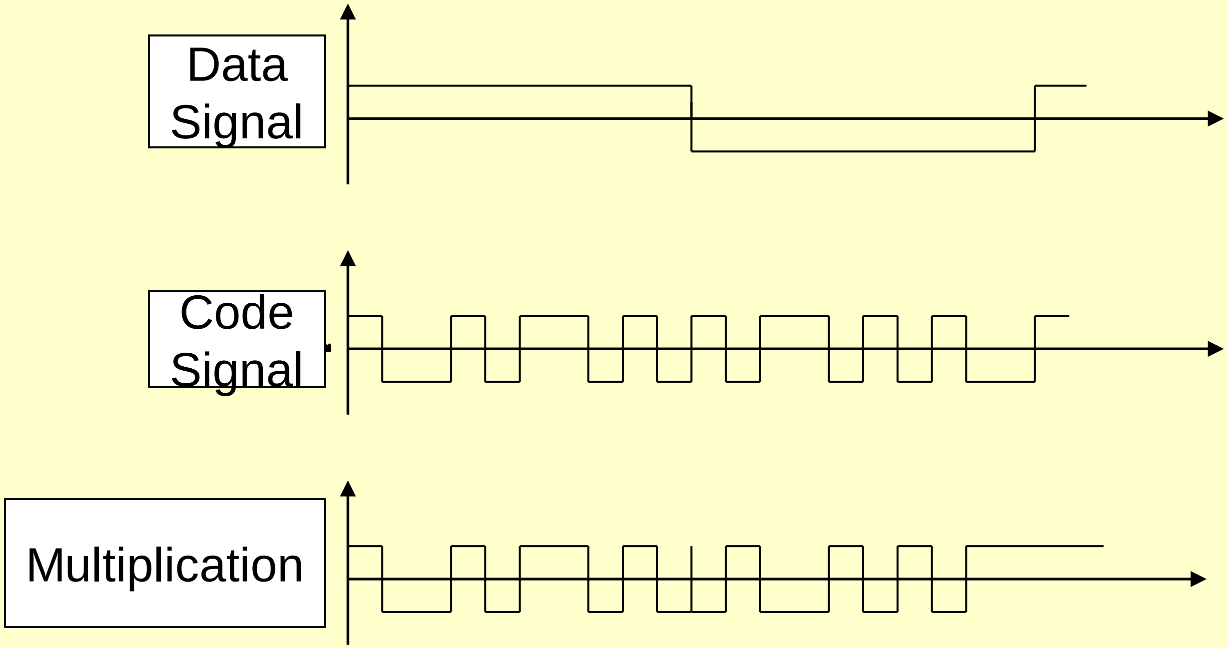


Wide Band Pseudo Random Noise

Up conversion To fixed carrier frequency

Down conversion

Wide Band Pseudo Random Noise


Data Signal
Code Signal
Multiplication

Spreading codes

- Maximal length sequences

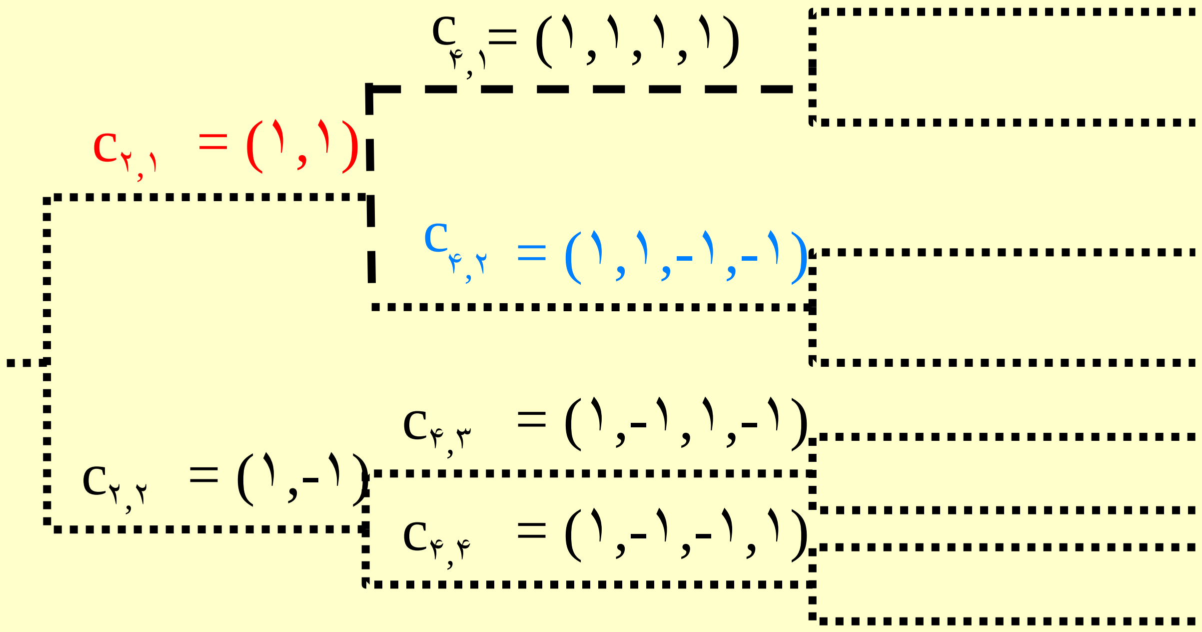
  – good auto- and cross- correlation

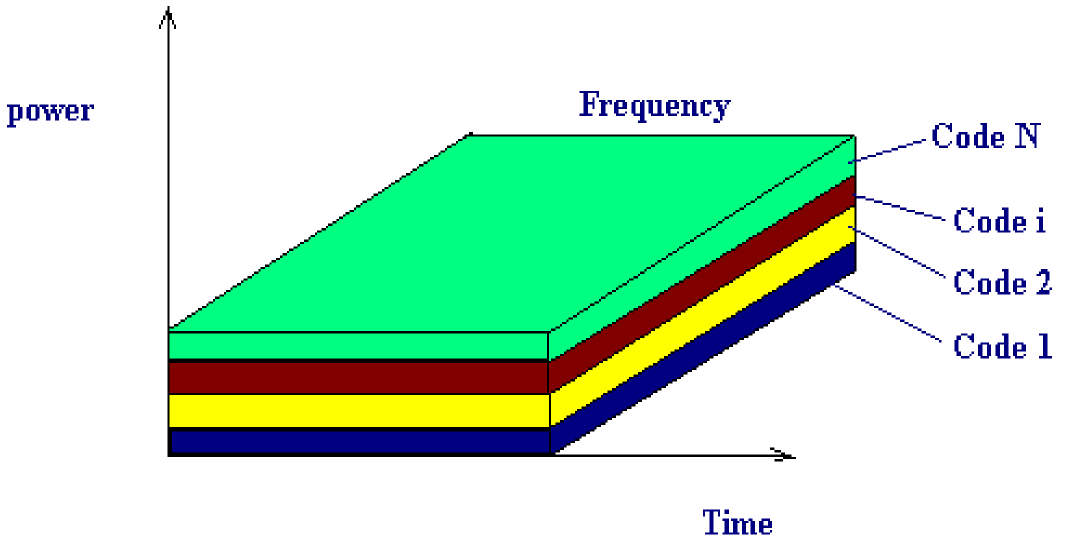
  Gold codes and Kasami sequences are derived from M- sequences with similar
- correlation properties, and a larger code set.

Orthogonal spreading Codes

- Walsh and Hadamard sequences
  - zero correlation between codes when aligned
  - cross- correlation non- zero when time shifted
  - fixed spreading factor (codes of different length are not orthogonal)
- Orthogonal Variable Spreading Factor (OVSF) codes
  - permit orthogonal codes for different rate services
- Both types of code lose orthogonality when shifted due to channel dispersion
  - e. g. ۴۰% loss of orthogonality in a large macrocell

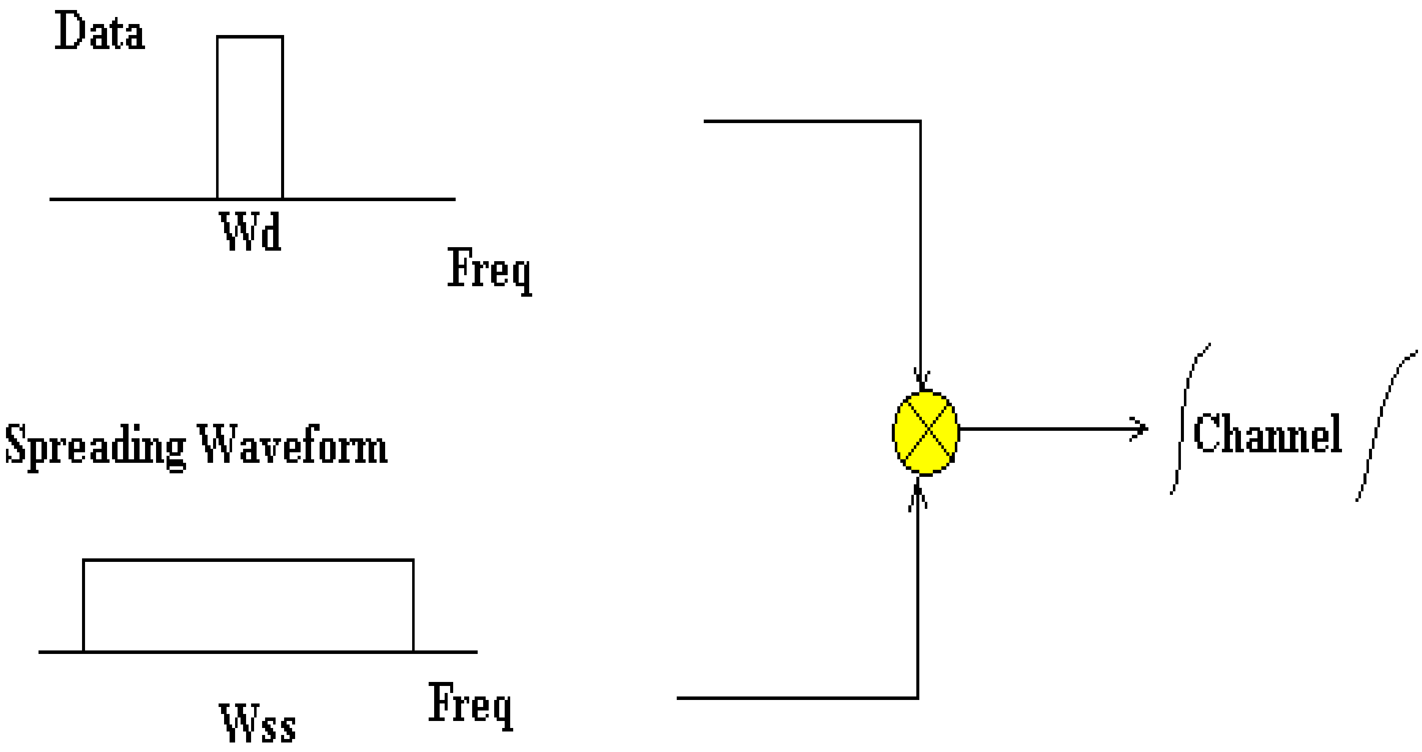
Orthogonal Variable Spreading Factor



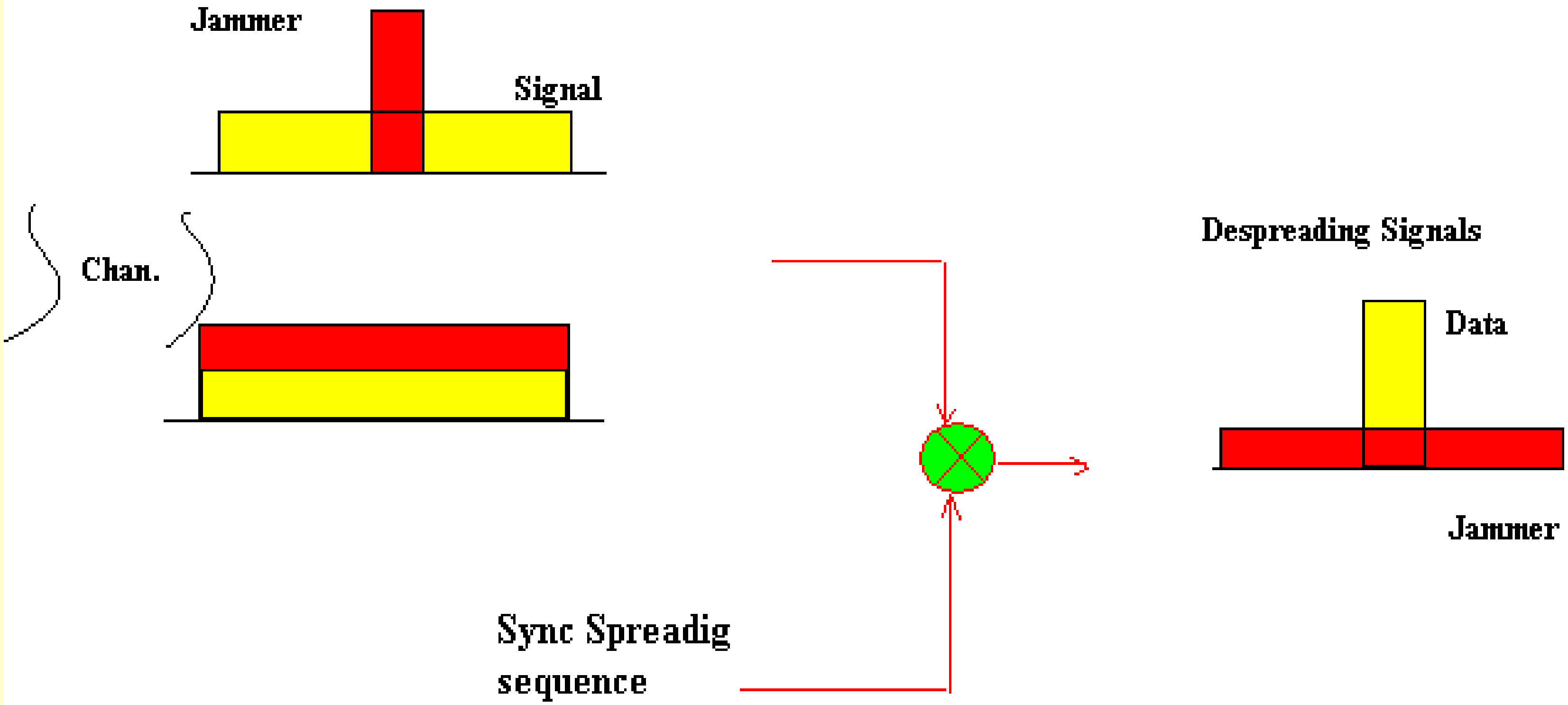


Code Division Multiple Acess CDMA

Processing Gain in Direct Sequence

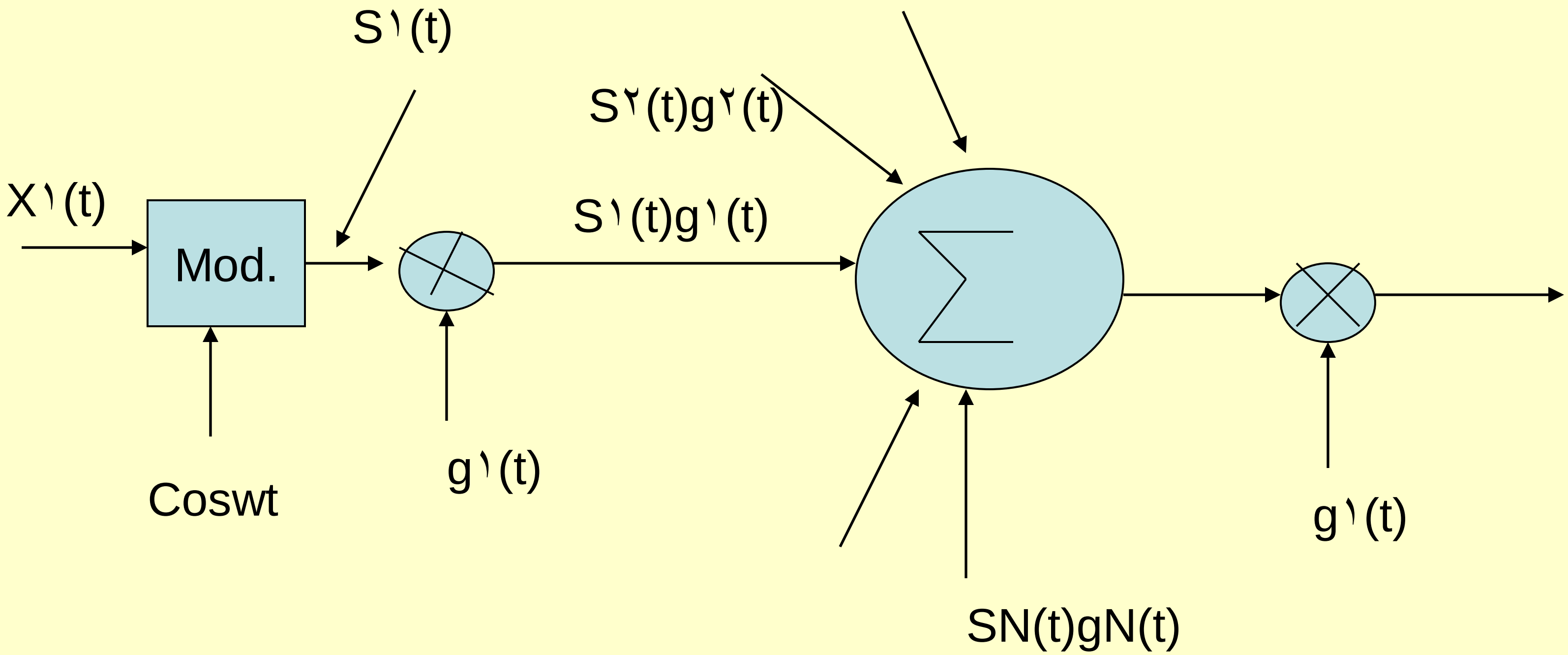


$$\text{Processing Gain, PG} = \frac{W_{ss}}{W_d} = \frac{R_c}{R_d} = \frac{T_d}{T_c}$$



$$\frac{E_b}{N_0} = \frac{S\,T_d}{J/R_c} = \frac{R_c}{R_d}\;\frac{S}{J}$$ PG S/J

DS-SS Application for CDMA



Theoretical CDMA capacity

- DS- CDMA capacity is inversely proportional to the energy per bit per noise power density which is tolerated
- A standard DS- CDMA system is interference limited by

  - intra- cell interference

  - Therefore increase capacity by:

  - voice activity detection

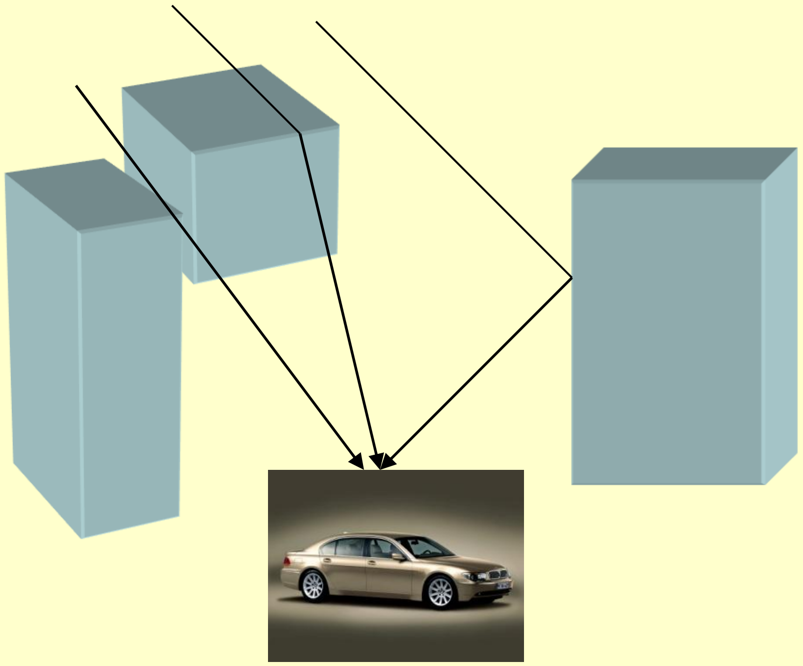
  - antenna sectorisation

  - adaptive antennas

  - interference cancellation

The Multipath Environment

- The received signal is made up of a sum of attenuated, phase-shifted and time delayed versions of the transmitted signal.
- Propagation modes include diffraction, transmission and reflection.

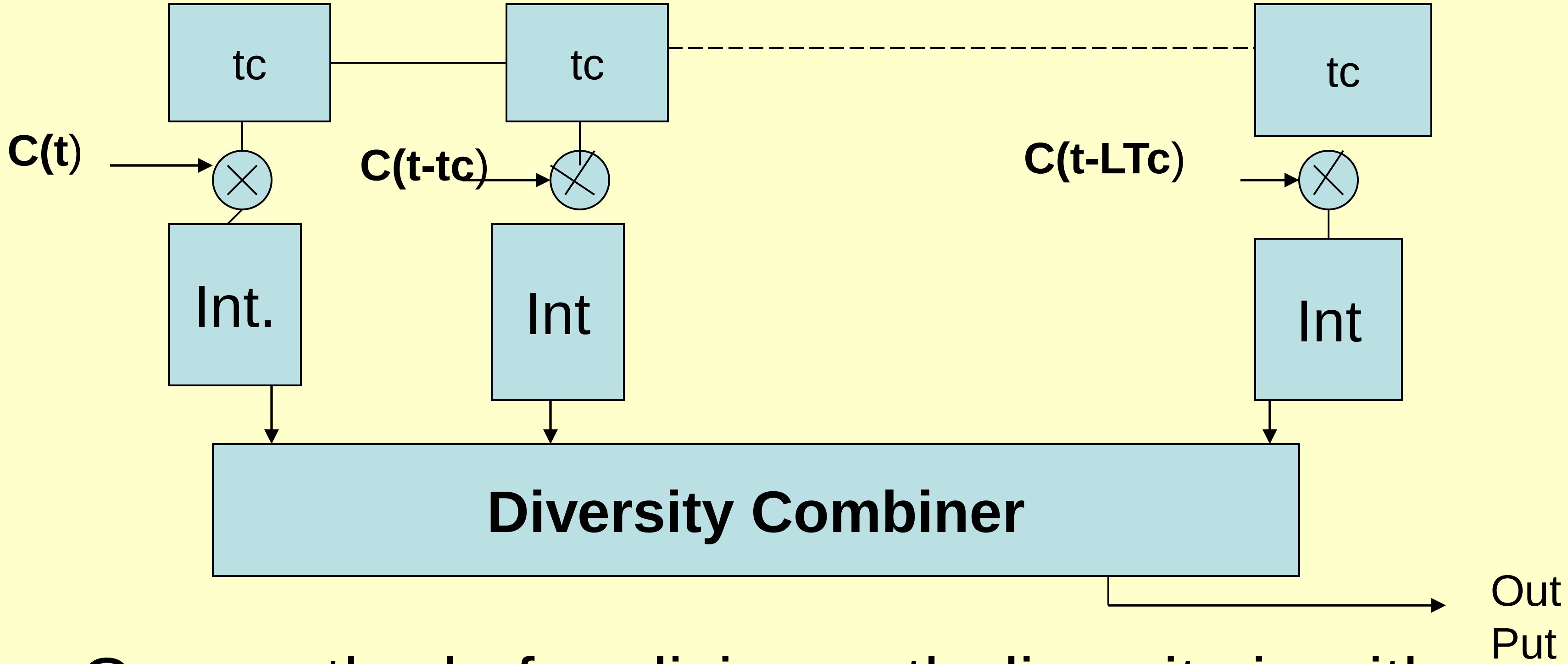


Path diversity in the multipath Path diversity

- Path diversity can be exploited by separating out the multipath components, co- phasing and summing them.

- Number of paths resolved (Lm) depends on the total multipath delay (Tm) and the chip period (Tc) Lm< Tm/Tc +١

RAKE Receiver



- One method of realising path diversity is with a RAKE and a bank of correlators

Diversity and diversity combinig

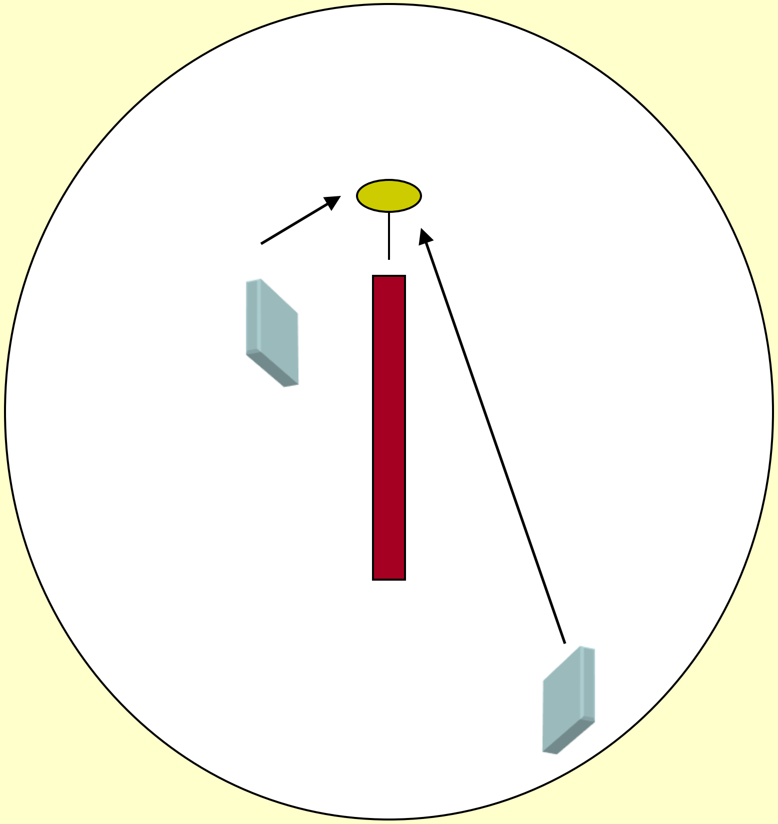
- **Diversity: providing multiple versions of the transmitted signal. Commonly:**
  - **multiple antennas**
  - **multiple paths**
- **Diversity combining**
  - **selection: best branch is chosen**
  - **equal gain: equal combining: all branch summed**
  - **maximal ratio: branches summed and weighted depending on their quality**

The near-far effect in CDMA

- Everyone on same
- frequency at the same
- time.

- A MS close to the BS will "drown out" other MSs unless it reduces it's power.

- Power control is required.



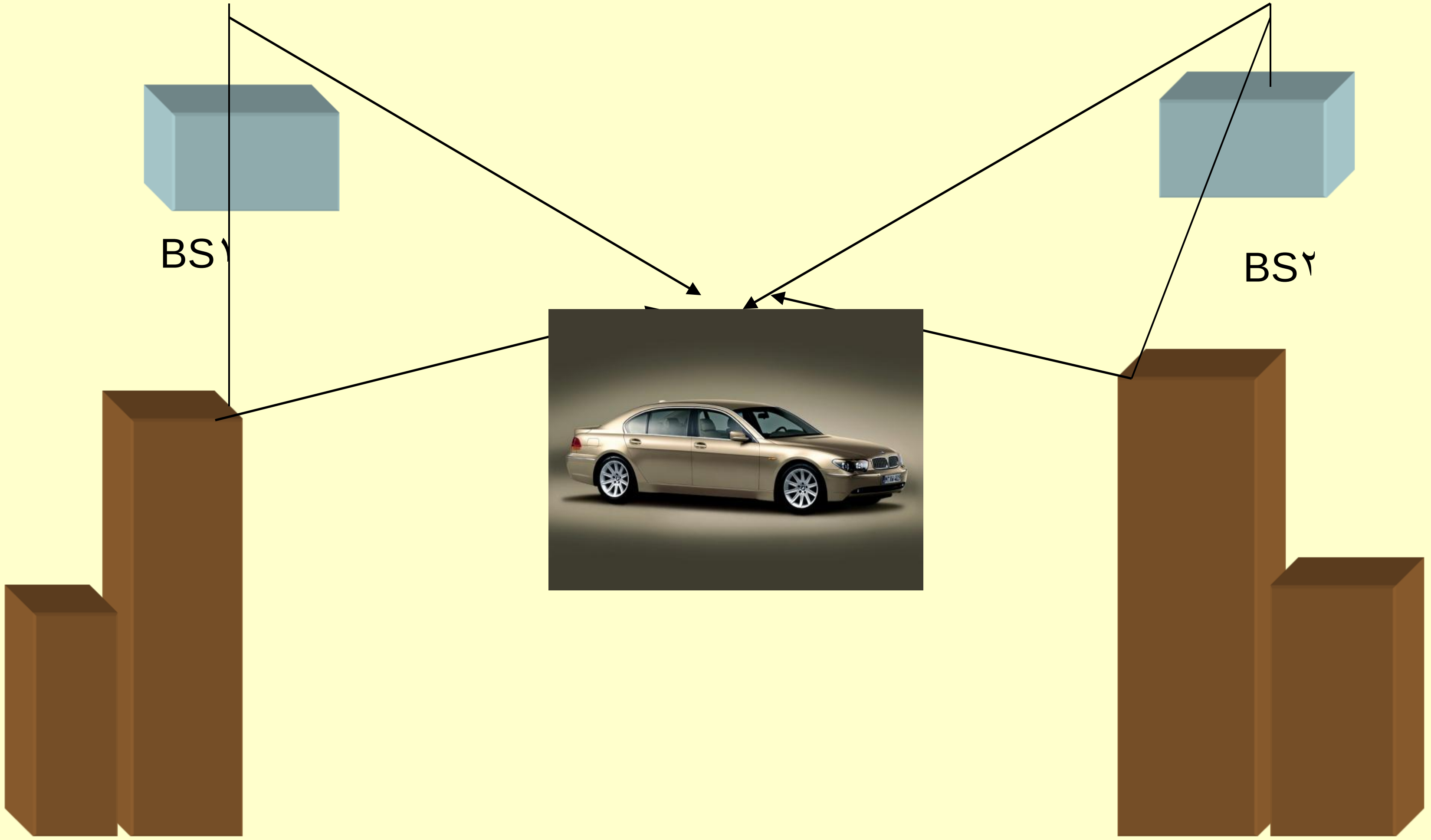
CDMA Power Control

- Power control required on uplink, desired on
- downlink.
- Open loop control can be used to remove shadowing (as the channel is reciprocal).
- Closed loop control is required to remove the
- fast fading
  – BS receives MS signal and calculates the SIR
  – BS sends MS a transmit power control (TPC)
- signal to increase or decrease its power
- TPC issues include rate and step size

Uplink closed loop power control algorithms

- Sigma- delta scheme used
- Command rate must be sufficient to track channel changes
- Trade- off in step size between tracking and accuracy

Handover and Mobility

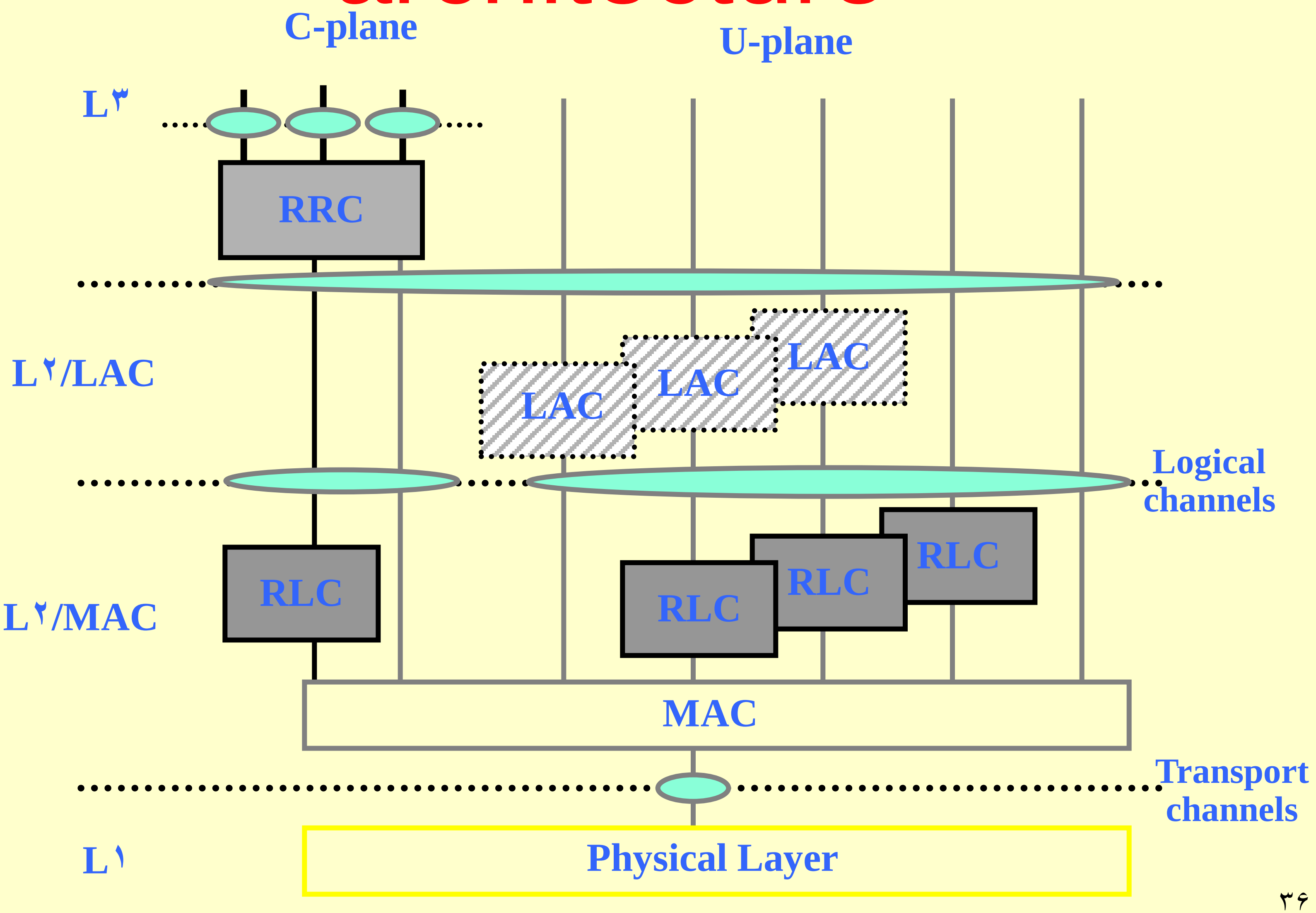


W-CDMA in UMTS

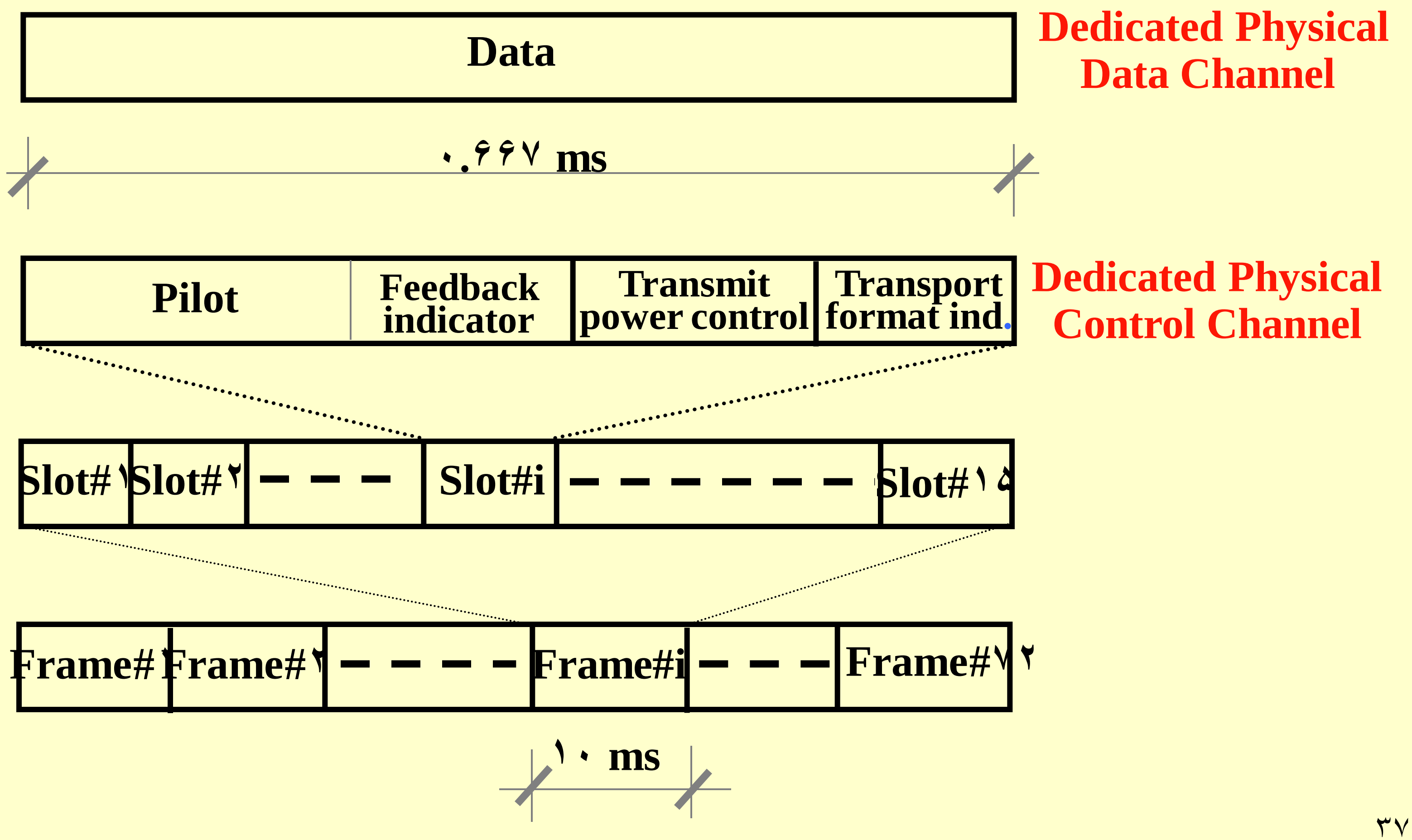
- W- CDMA is used in FDD mode in UMTS
- On the downlink it is possible to use orthogonal reading codes to reduce interference. A scrambling code is used to separate the cells
- On the uplink, low cross correlation codes are used to separate the mobiles. A single mobile can use multi-code transmission: each service is mapped onto several bearers, each of which is spread by an orthogonal code.

WCDMA Air Interface

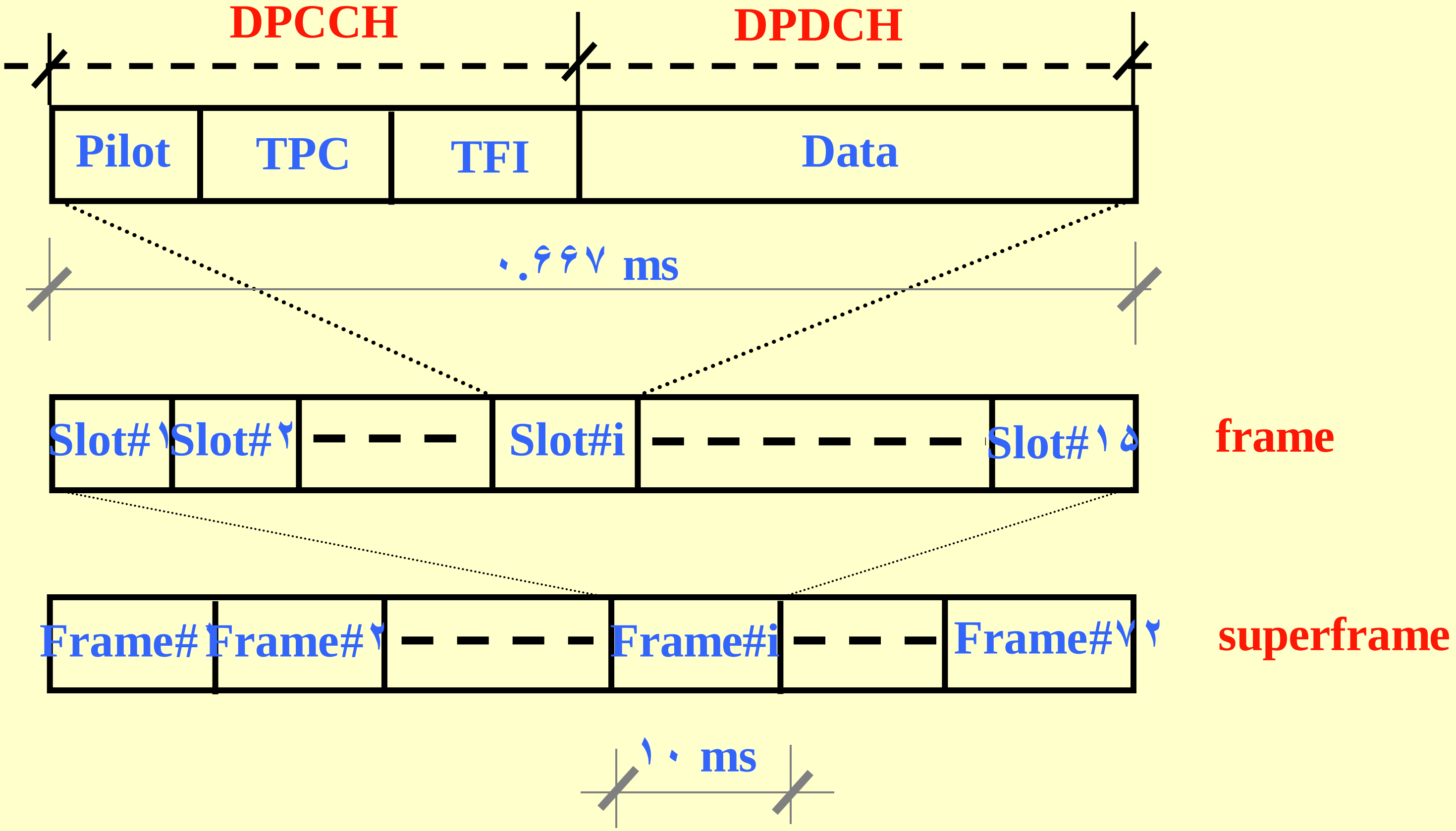
Radio Interface - protocol architecture



Layer ١ - up link physical channels (W-CDMA example)



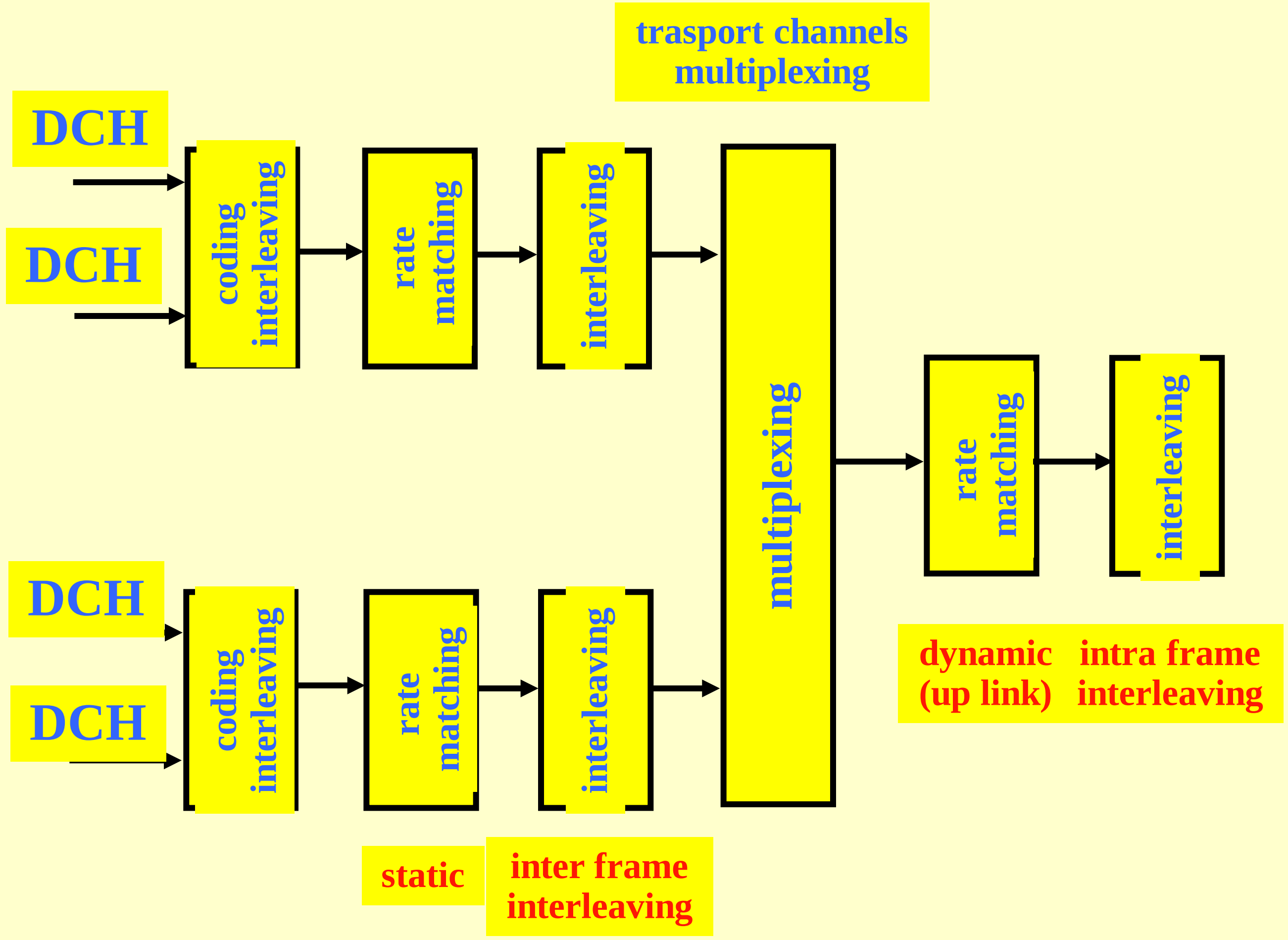
Layer ١ - down link physical channels (W-CDMA example)



Transport channels (example)

- **Dedicated Channel (DCH):** **fast change of bit rate (١٠ms)**
  fast power control
  inherent MS addressing
- **Random Access Channel (RACH) - up link:** **collision**
  open loop power control
  explicit MS addressing
- **Broadcast Control Channel (BCH) - down link**
- **Forward Access Channel (FACH) - down link:** **slow power control**
  explicit MS addressing
- **Paging Channel (PCH) - down link:** **use of sleep modes**

Multiplexing transport channels onto physical channels

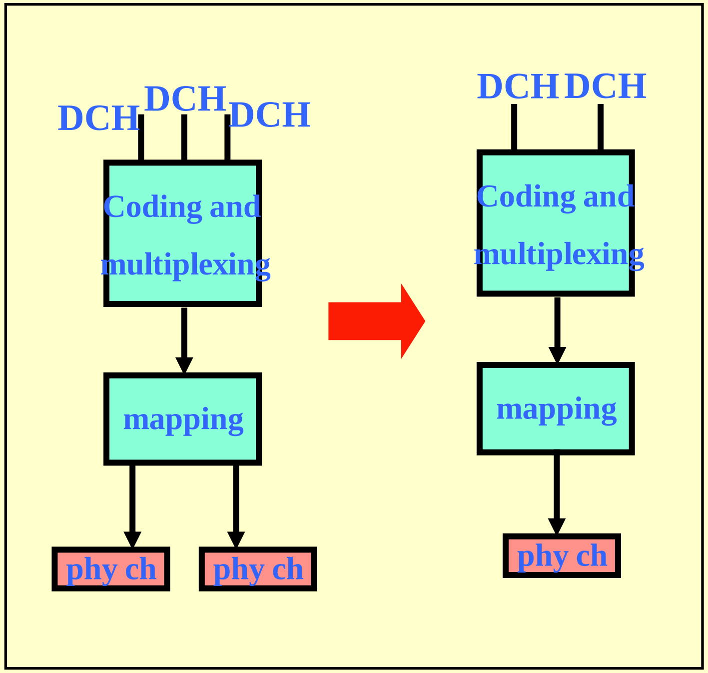


MAC Services and Functions

- set-up, release of logical channels
- data transfer service on logical channels
- allocation/re-allocation of radio resources
- measurement report

Functions

- Selection of the transport format
- Handling of priority within one user/between users
- Scheduling of control messages (broadcast, paging, notification)
- Multiplexing/de-multiplexing of higher layers PDUs on/from common or dedicated transport channels
- Contention control on the random access channel



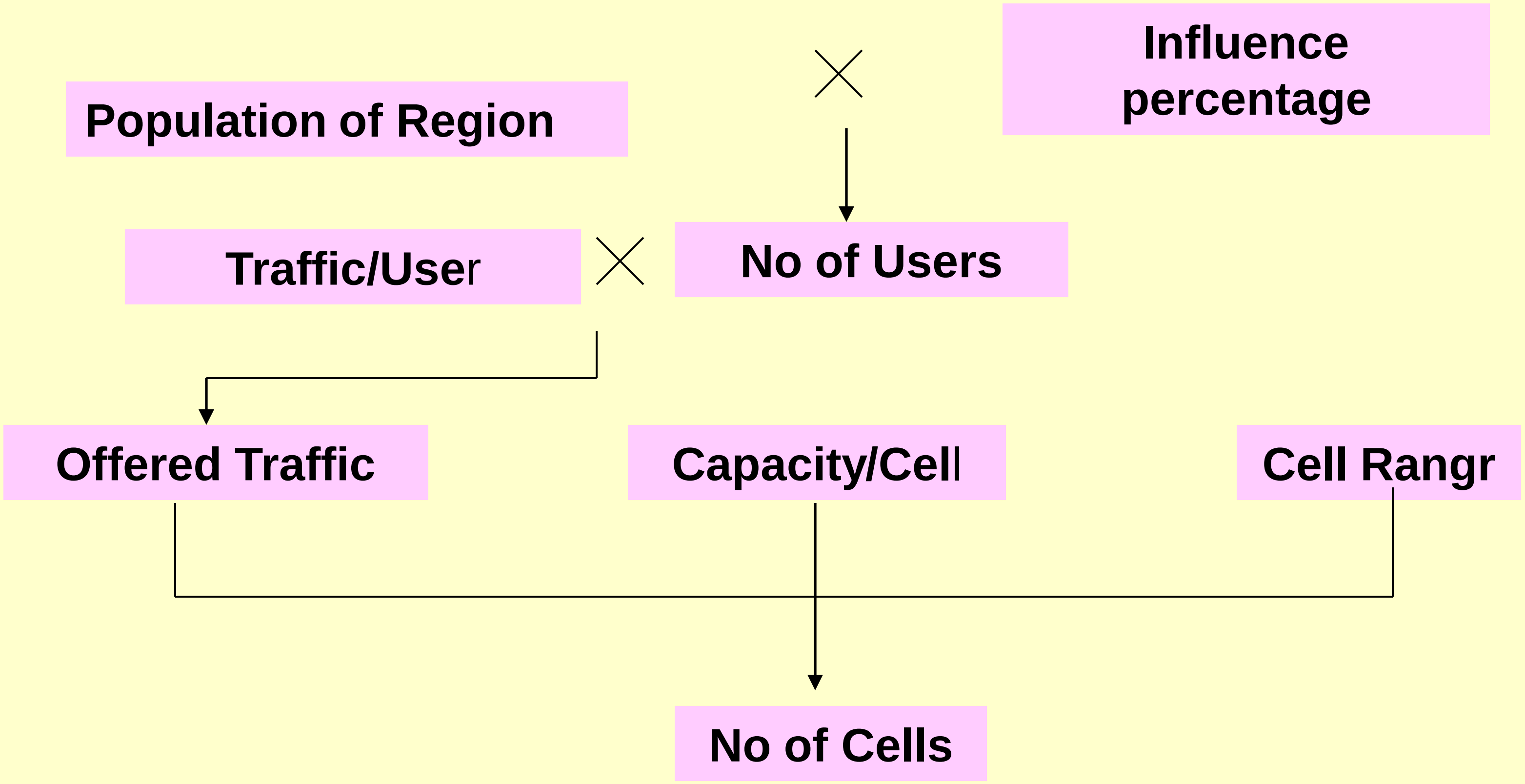
Radio Network planning And Dimensioning Procedures

- Preparation
- Estimation No. of Cells
- Detailed Planning

Preparation

- ١-Targets of Capacity and Coverage
- ٢-Strategy of Network Planning

Estimation No. of Cells



Estimation Capacity of Cell

- Principle Factors :

۱. Data Rate
۲. Traffic characteristics (variation Rates,..)
۳. Requirements (delays, BER)
۴. Disconnect Probability
۵. Sectorized Effect
۶. Load Effect

Cell Range

Link Budget

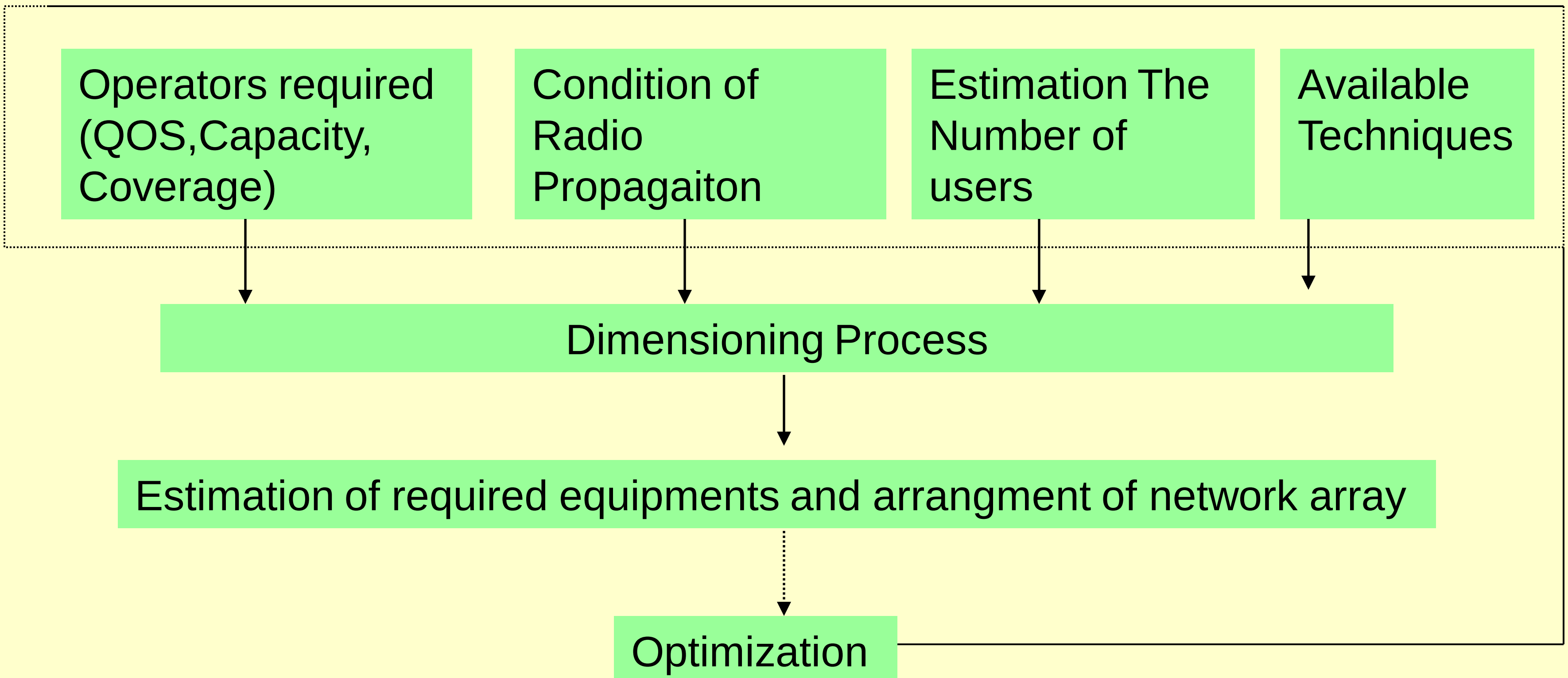
A Chip Rate	۳.۸۴	Mchip/s
B Information Rate	۱۲.۲	Kbit/s
C Processing Gain (۱۰log(A/B))	۲۴.۹۸	dB

D Mobile transmit power	۲۱.۰	dBm
E Mobile antenna gain	۲.۰	dBi
F Body Loss	۳.۰	dB
G Mobile EIRP (D+E-F)	۲۰.۰	dBm

H Base Station antenna Gain	۱۴.۰	dBi
I Thermal noise density	-۱۷۴.۰	dBm/Hz
J Base Station Noise density	-۱۰۸.۲	dBm
K Base Station Noise Figure	۵.۰	dB
L Target Eb/N۰	۵.۵	dB
M Base Station Sensivity	-۱۲۲.۶۸	dBm

N Cable Loss	۳.۰	dB
O Lognormal shadowing margin	۹.۰	dB
P Noise Rise (intracell)	۳.۰	dB
Q Noise Rise (intercell)	۲.۰	dB
R Soft handoff gain	۴.۰	dB
Maximum path loss=G+H-M-N-O-P-Q+R=	۱۴۳.۶۸	dB

UMTS Dimensioning



UMTS RAN Dimensioning Process

Node B Dimensioning

↓

RNC Dimensioning

↓

Interface Dimensioning

↓

Offering prepare topology for RAN

- Required Data for each phase of Network development

١. Radio coverage (regions, subregions, region classifications)

٢. Traffic (Frequency spectrum, customers Density in each region, customers profile)

٣. QOS (coverage probability, Blocking prob. , service level in each region)

Node B Dimensioning

- Up Link

۱. Considering a radius for cell r۱
۲. Estimation average traffic inside cell
۳. Estimation no. of channels for peak traffic service
۴. Considering a Statistical method for calculating accumulated noise

Up Link

۵. Calculating Maximum path loss then cell range r۲

۶. Continuing till r۱ = r۲

۷. Cell bar test

Down Link

۱. Considering a cell range r۱
۲. From input traffic, estimate average cell traffic
۳. Estimation no. of channels for peak traffic service
۴. Calculation of One user required power for each service
۵. Calculating transmit accumulated power in Node B

Down Link

- Calculating Cell range r۲
- Continue till r۱=r۲

RNC Dimensioning Process Steps

١. Knowing No. of Node Bs then By Considering Management Limitations ,Estimate minimum RNC, RNC١

٢. By considering input average traffic and traffic limitations , Estimate minimum RNC that needs for traffic handling , RNC٢

٣. Average traffic for each RNC is known, then peak traffic for each RNC must be calculated

٤. Max(RNC١,RNC٢)=No. of RNC

RNC Dimensioning Process

Efficient factors for RNC Dimensioning Process are:

١. Traffic Limitations

٢. Management Limitations

٣. Communications Limitations