Οικονομικό Πανεπιστήμιο Αθηνών
Τμήμα Πληροφορικής

Ευφυή Κινητά Δίκτυα: 3G

Εαρινό Εξάμηνο 2023-24

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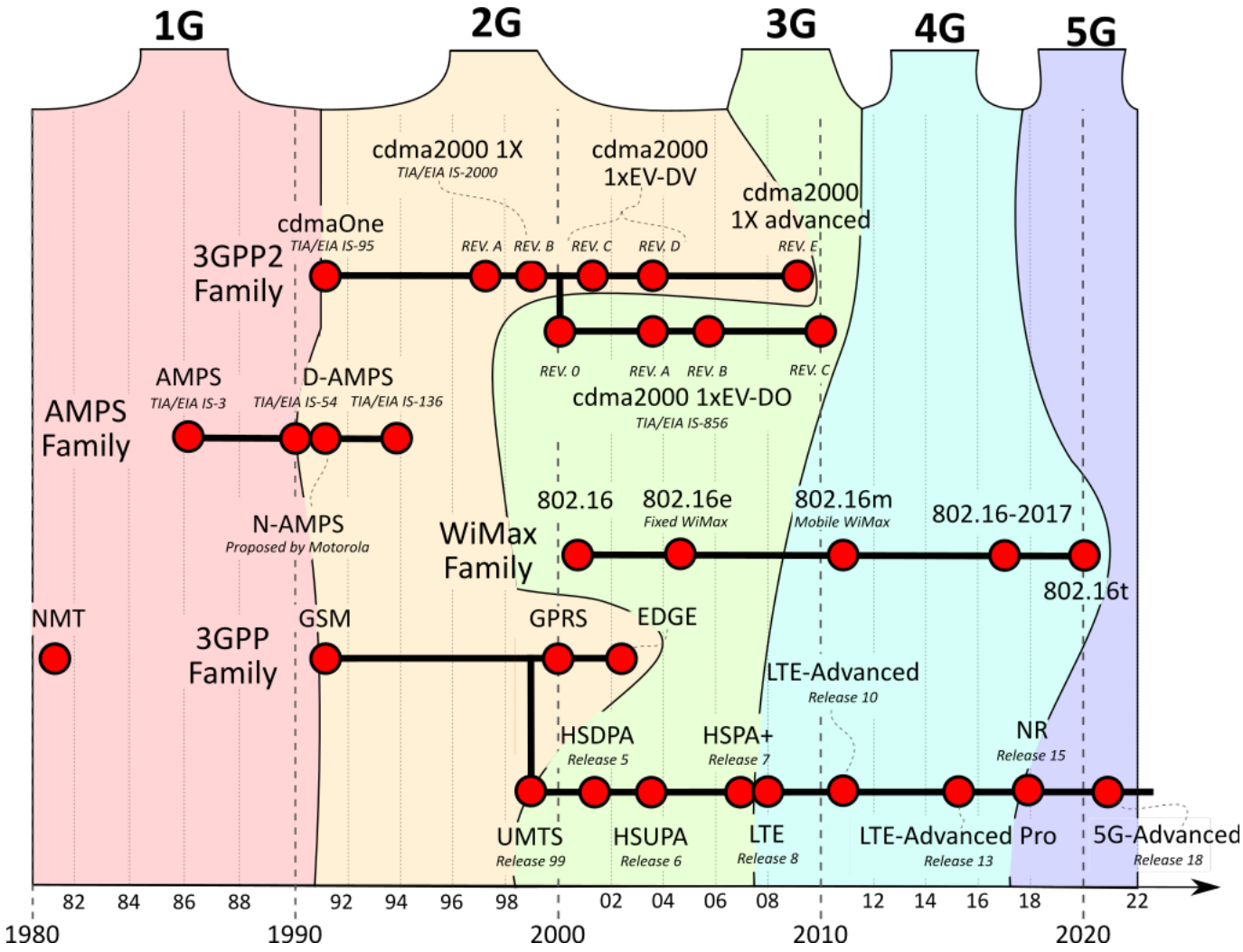
(Βασισμένο σε διαφάνειες του Βασίλειου Σύρη)

Evolution map



https://en.wikipedia.org/wiki/High_Speed_Packet_Access#/media/File:Cellular_network_standards_and_generation_timeline.svg

3rd Gen systems – Obj.

- Support multimedia (eg., video)
- Objectives:
  - Voice quality comparable to telephone network
  - 144 kbps data rate mobile users / 384 kpbs to pedestrains / 2.048 Mbps for office use
  - Symmetrical and asymmetrical data transmission rates.
  - Support for both **packet-switched** and circuit-switched data services.
  - More efficient use of the available spectrum in general.
  - Support for a wide variety of mobile equipment.
  - Flexibility to allow the introduction of new services and technologies.

Standardization

- 3rd Generation Partnership Project (3GPP)
  - collaboration between telecommunication associations: ETSI, ARIB/TTC (Japan), CCSA (China), ATIS (North America), TTA (South Korea)
  - develop 3G mobile system specification within scope of IMT-2000 (ITU)
  - focus on radio, core network, service architecture
    - GSM, UMTS 3G, HSDPA/HSUPA/HSPA,3G LTE
- Different from 3GPP2
  - focus on IS-95 (CDMA2000)

Universal Mobile Telecommunication System (UMTS)

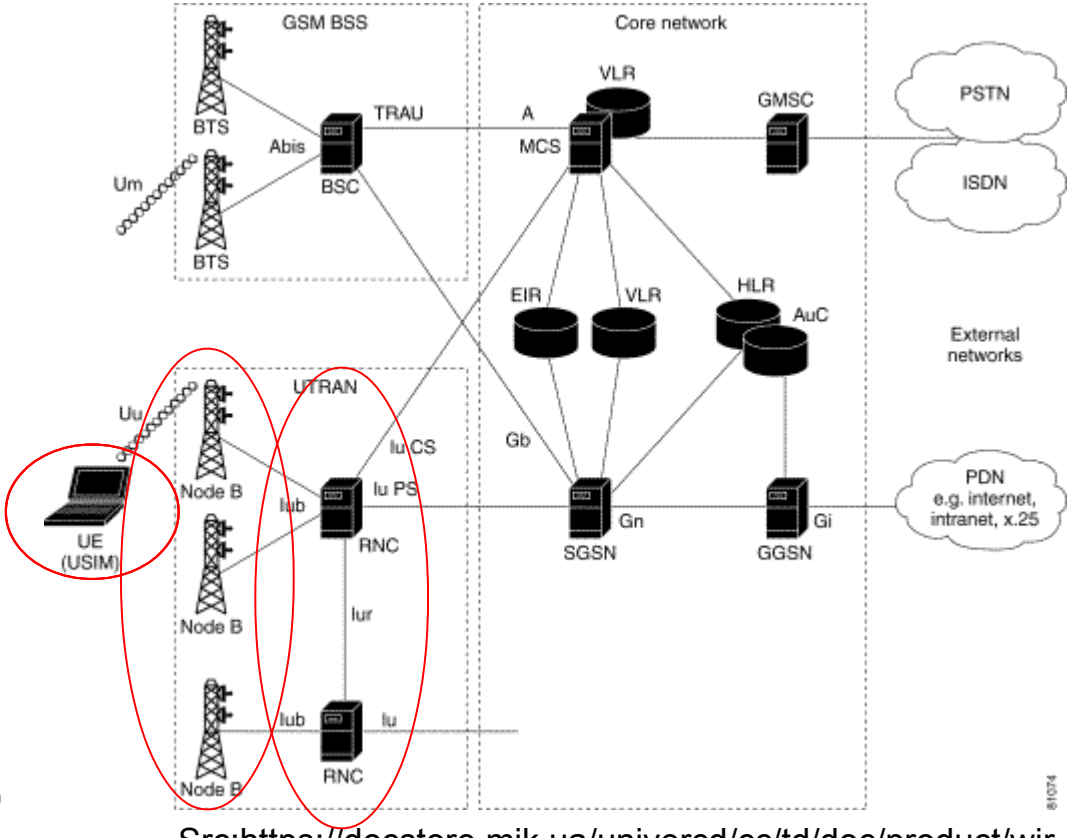
- 3G mobile communications system
  - Extends (2G) GSM/GPRS networks
- delivers low-cost, mobile communications at data rates of up to 2 Mbps.
- preserves the global roaming capability of GSM/GPRS
- designed to deliver multimedia, as well as voice and data, to mobile wireless subscribers.
  - towards an all-IP network
- using Wide-band Code Division Multiple Access (CDMA) technology.
- Handover capability between the UMTS and GSM is supported.
  - GPRS is the convergence point

UMTS: QoS

Traffic Class	Conversational Class	Streaming Class	Interactive Class	Background Class
Fundamental Characteristics	• Preserve time relation of (variation) between information entities of the stream • Conversational pattern (stringent and low delay)	• Preserve time relation of (variation) between information entities of the stream	• Request response pattern • Preserve payload content	• Destination is not expecting the data within a certain time • Preserve payload content
Example of application	voice	streaming video	web browsing	background download of emails

UMTS architecture - Rel. ‘99

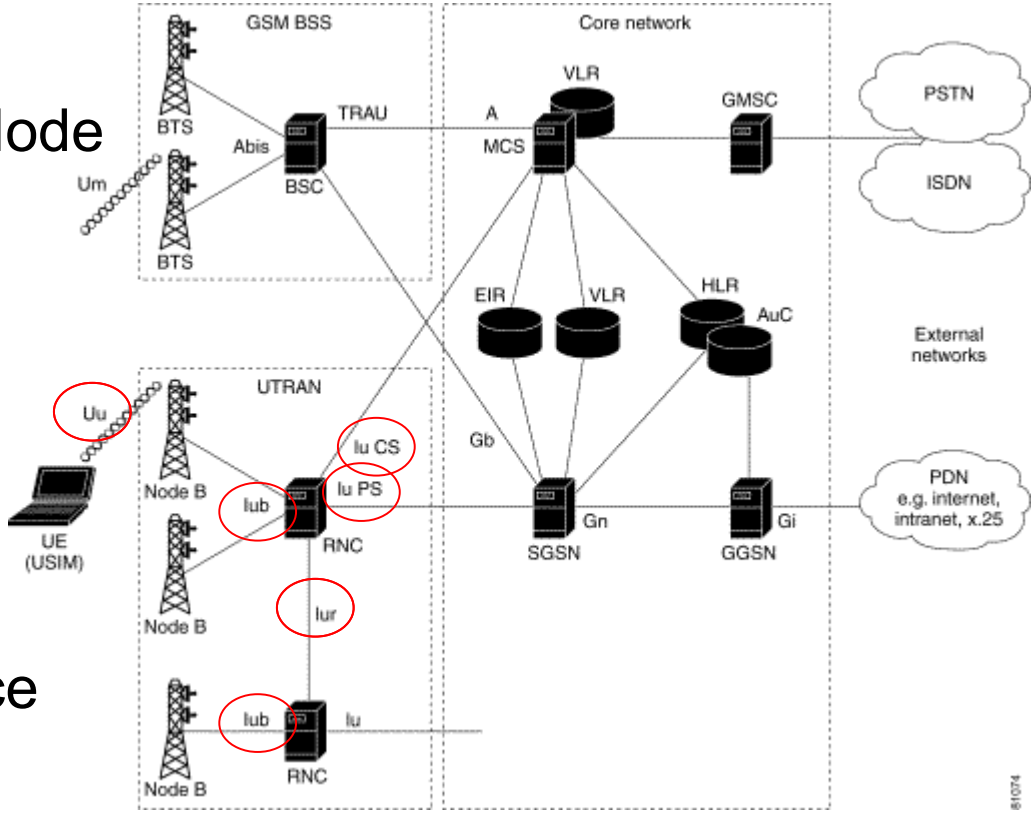
- Based on GPRS top
  - Circuit switched
    - MSC, VLR, MSC
  - Packet switched
    - SGSN, GGSN
  - Both
    - EIR, HLR, AuC
- UMTS-specific
  - User equipment (UE)
  - UMTS terrestrial radio access network (UTRAN)



Src:https://docstore.mik.ua/univercd/cc/td/doc/product/wireless/moblwrls/cmx/mmg_sg/cmxgsm.htm#1057304

UMTS arch. - Rel '99: Interfaces

- UMTS interfaces:
  - Uu: User equipment to Node B
  - Iu: RNC to GSM/GPRS
    - Iu-CS: circuit-switched
    - Iu-PS: packet-switched
  - Iub: RNC to Node B interface
  - Iur: RNC to RNC interface (no equivalent in GSM)
- Iu, Iub, and Iur interfaces are based on Asynchronous Transfer Mode (ATM).



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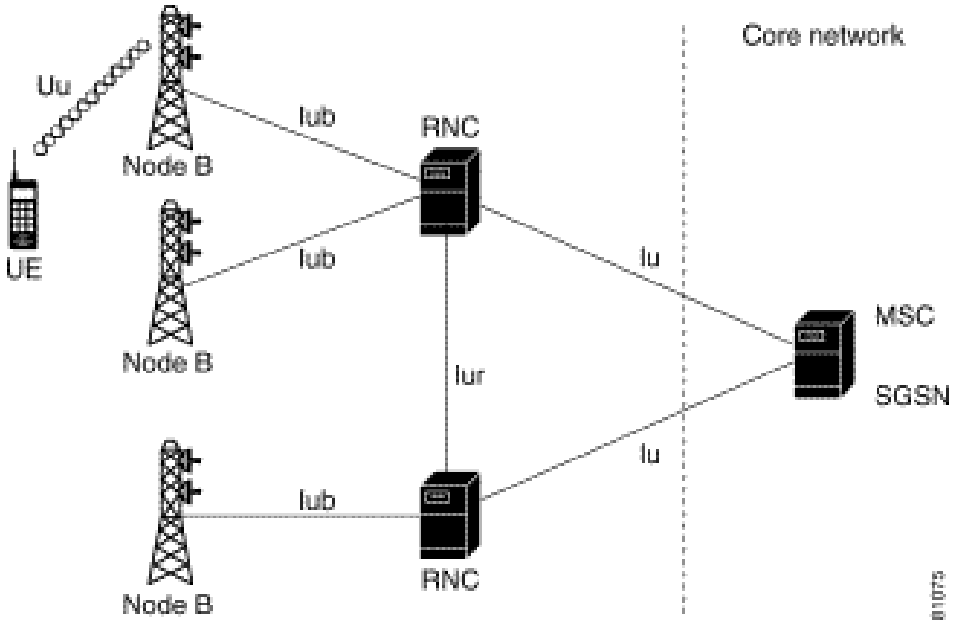
UMTS arch. - Rel '99: UTRAN

- 2 new elements
  - Node B, RNC
  - Similar to BTS and BSC
    - Low upgrade cost!
- Radio Network Controller
  - Controls Node B nodes
- Node B
  - Serve 1 or more cells
  - WCDMA to UEs
  - Error corr., rate adapt., monitors quality and strength of connection, coding, interleaving, modulation



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UMTS User Equipment

- UE = mobile equipment + UMTS subscriber identity module (USIM).
- USIM identifies the subscriber to the core network.
- Similar to the SIM in GSM/GPRS
  - Same physical characteristics
- provides:
  - multiple user profiles on the USIM
  - updates USIM information over the air
  - security functions & user authentication & secure app downloading
  - supports of payment methods
  - Support in 3 and 4G

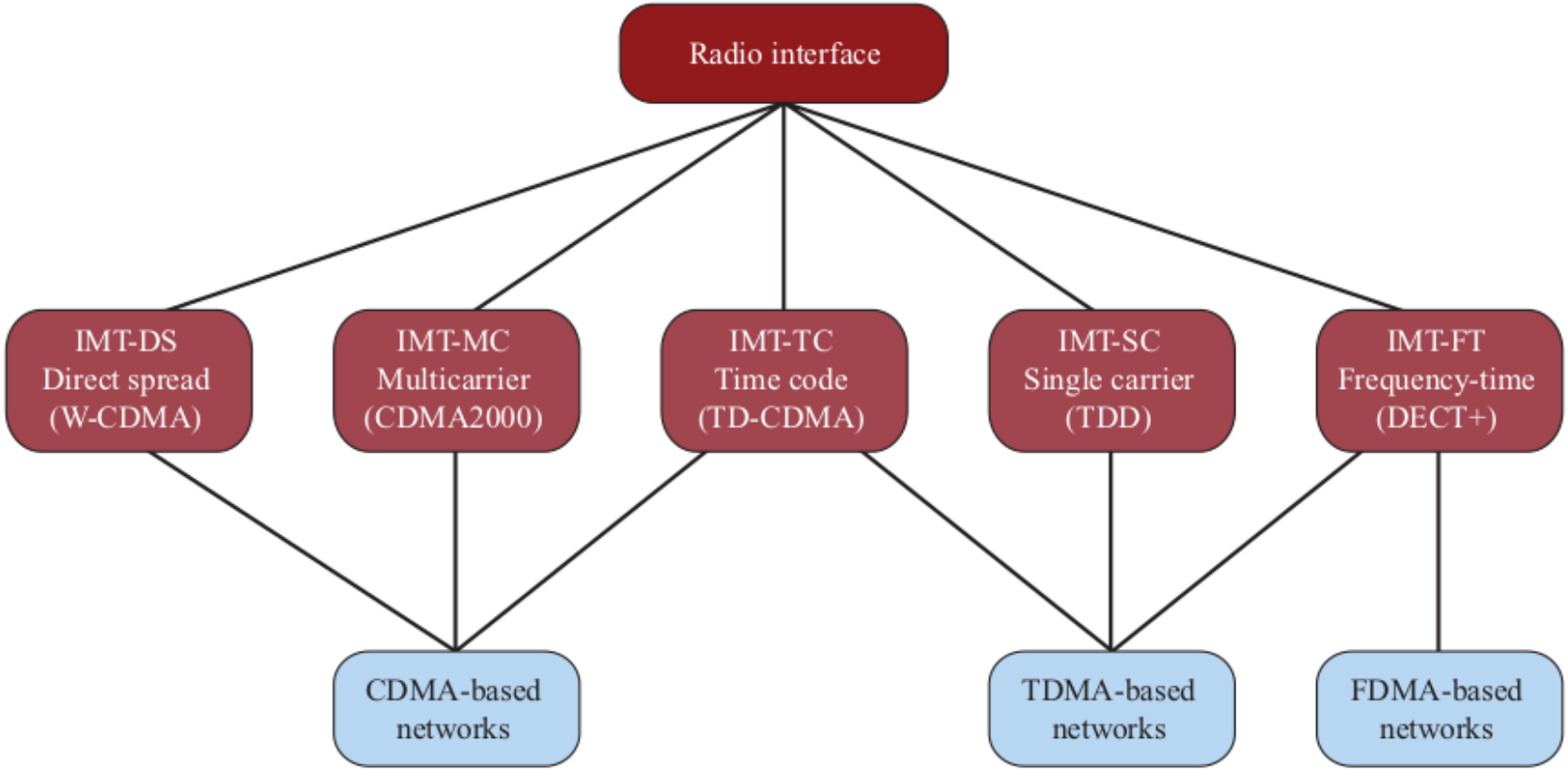
UTRAN: RNC

- RNC (Radio Network Controller) controls multiple base stations
  - comparable to Base Station Controller in GSM
  - layer 2 processing
  - Radio Resource Management
- Key functions
  - outer-loop power control
  - handover
  - admission control
  - code allocation
  - packet scheduling
  - macro diversity across base stations

UTRAN: Node B

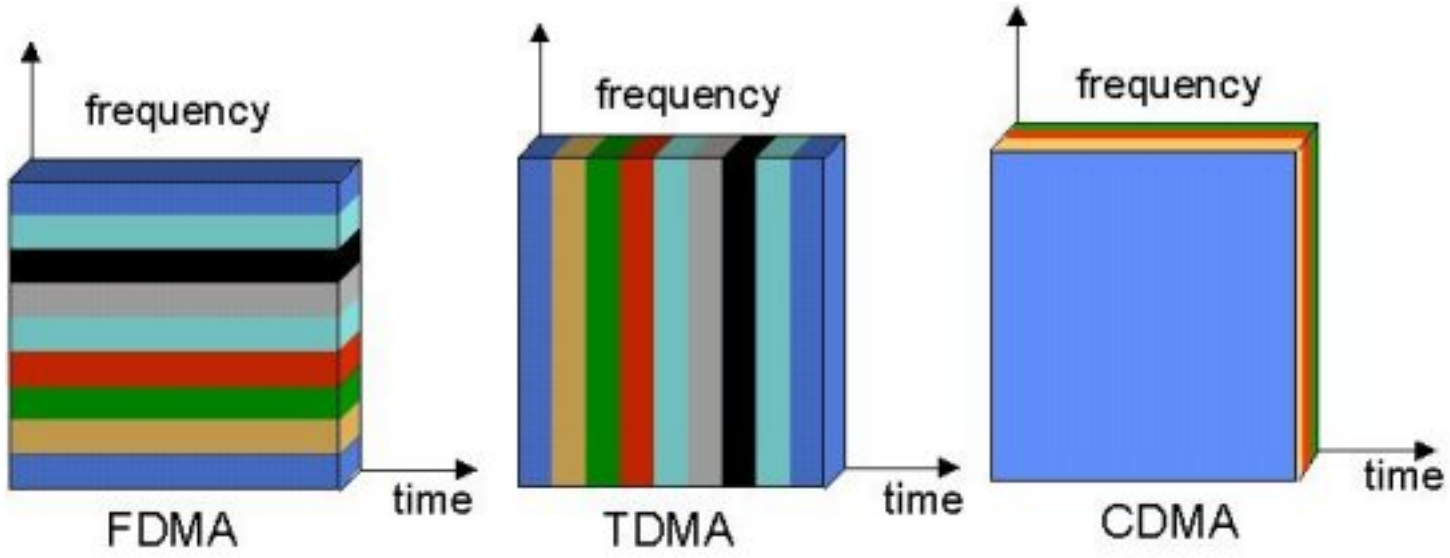
- Node B (commonly called Base Station)
  - comparable to Base Transceiver Station in GSM
  - responsible for air interface layer
- Key Node B functions
  - modulation and spreading
  - RF processing
  - inner loop power control
  - macro diversity

Radio interfaces



- 5 alternatives to assist transition from 1-2G to 3G
- Using **WCDMA** is a salient difference to previous gens

Multi-Access Radio Techniques



Courtesy of Petri Possi, UMTS World

Code Division Multiple Access

- every channel uses the full available spectrum – *no FDM*
  - Uniform distr. of data in channel – like white noise
- Orthogonal channelization codes
  - Bit vectors with zero product → XOR = 0 → no correlation

CDMA example https://www.geeksforgeeks.org/java-cdma-code-division-multiple-access/

Assume 4 stations S1, S2, S3, S4. We'll use 4×4 Walsh Table to assign codes to them.

C1 = [+1 +1 +1 +1], C2 = [+1 -1 +1 -1], C3 = [+1 +1 -1 -1], C4 = [+1 -1 -1 +1]

Let their data bits currently be:

D1 = -1, D2 = -1, D3 = 0 (Silent), D4 = +1

Resultant channel sequence = C1.D1 + C2.D2 + C3.D3 + C4.D4

= [-1 -1 -1 -1] + [-1 +1 -1 +1] + [0 0 0 0] + [+1 -1 -1 +1]

= [-1 -1 -3 +1]

Now suppose station 1 wants to listen to station 2.

Inner Product = [-1 -1 -3 +1] x C2

= -1 + 1 - 3 - 1 = -4

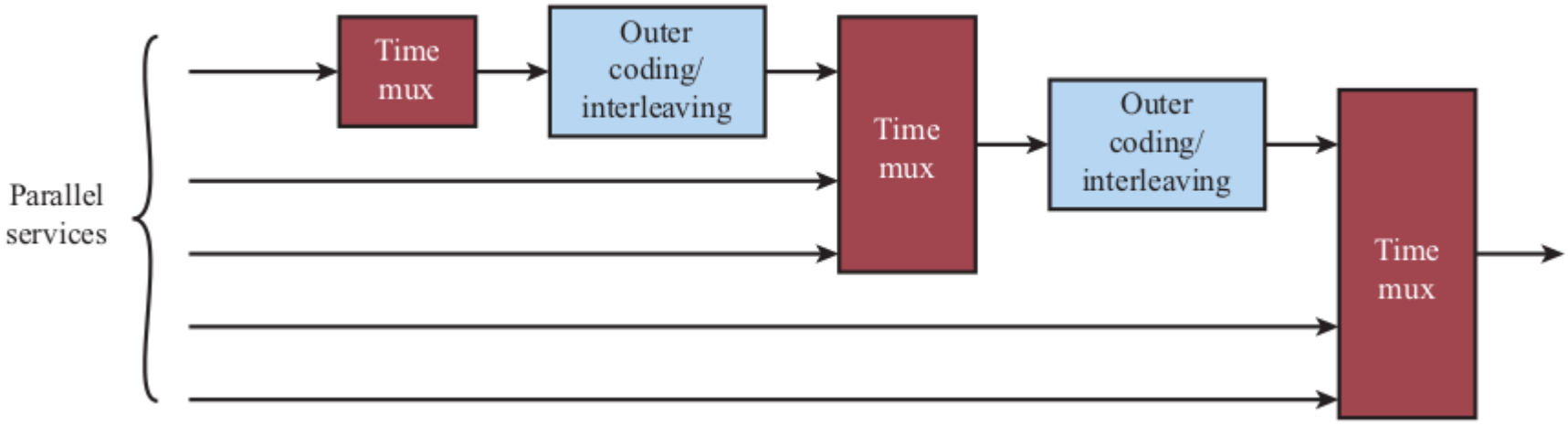
Data bit that was sent = -4/4 = -1.

Wideband CDMA design

- Bandwidth
  - Limit channel usage to 5MHz (1.25MHz for CDMA)
  - Spectrum is limited by competing needs
- Chip rate
  - pulses/s (chips/s) at which the code is transmitted (or received)
  - Want >=3 Mcps
- Multirate
  - multiple fixed-data-rate logical channels to a given user
  - flexible support of multiple simultaneous apps from a user
  - More efficient use of capacity

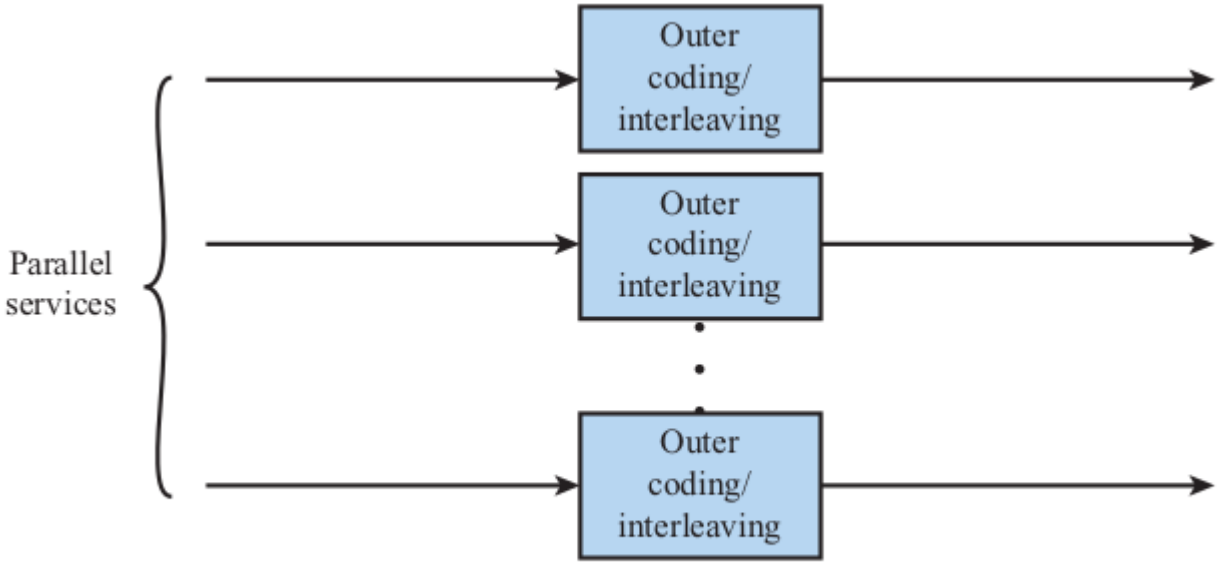
Multirate (w/ time mux)

- TDMA scheme within a single CDMA channel
  - a different number of slots per frame are assigned to achieve different data rates.
  - All the subchannels at a given data rate would be protected by error correction and interleaving



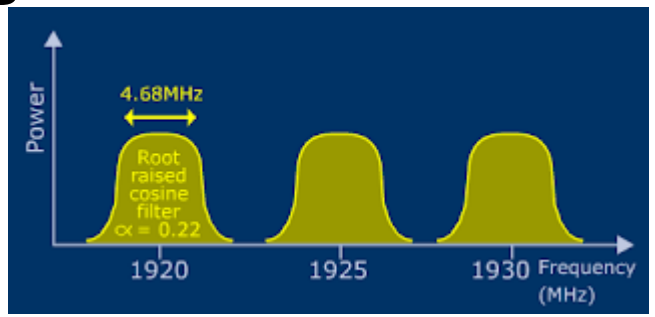
Multirate (w/ code mux)

- TDMA scheme within a single CDMA channel
  - multiple CDMA codes, with separate coding and interleaving
    - map codes to separate CDMA channels



Wideband CDMA and UMTS

- WCDMA is part of IMT-2000, UMTS, 3GPP
- 2048, 384, 144 kbps
  - for speeds 10, 120, 500km/h, respectively
- 1900 to 2025 MHz – 5MHz BW



- Release 5: High-Speed Downlink Packet Access (**HSDPA**)
  - Adaptive modulation and coding, hybrid ARQ and fast scheduling
  - 14.4Mbps
- Release 6: High-Speed Uplink Packet Access (**HSUPA**)
  - 5.76Mbps uplink
- Release 7: High-Speed Packet Access Plus (**HSPA+**)
  - 64 QAM, 2x2 & 4x4 MIMO, multicarrier combination
  - 336 Mbps
- Release 8: pathway to 4G, will discuss later..

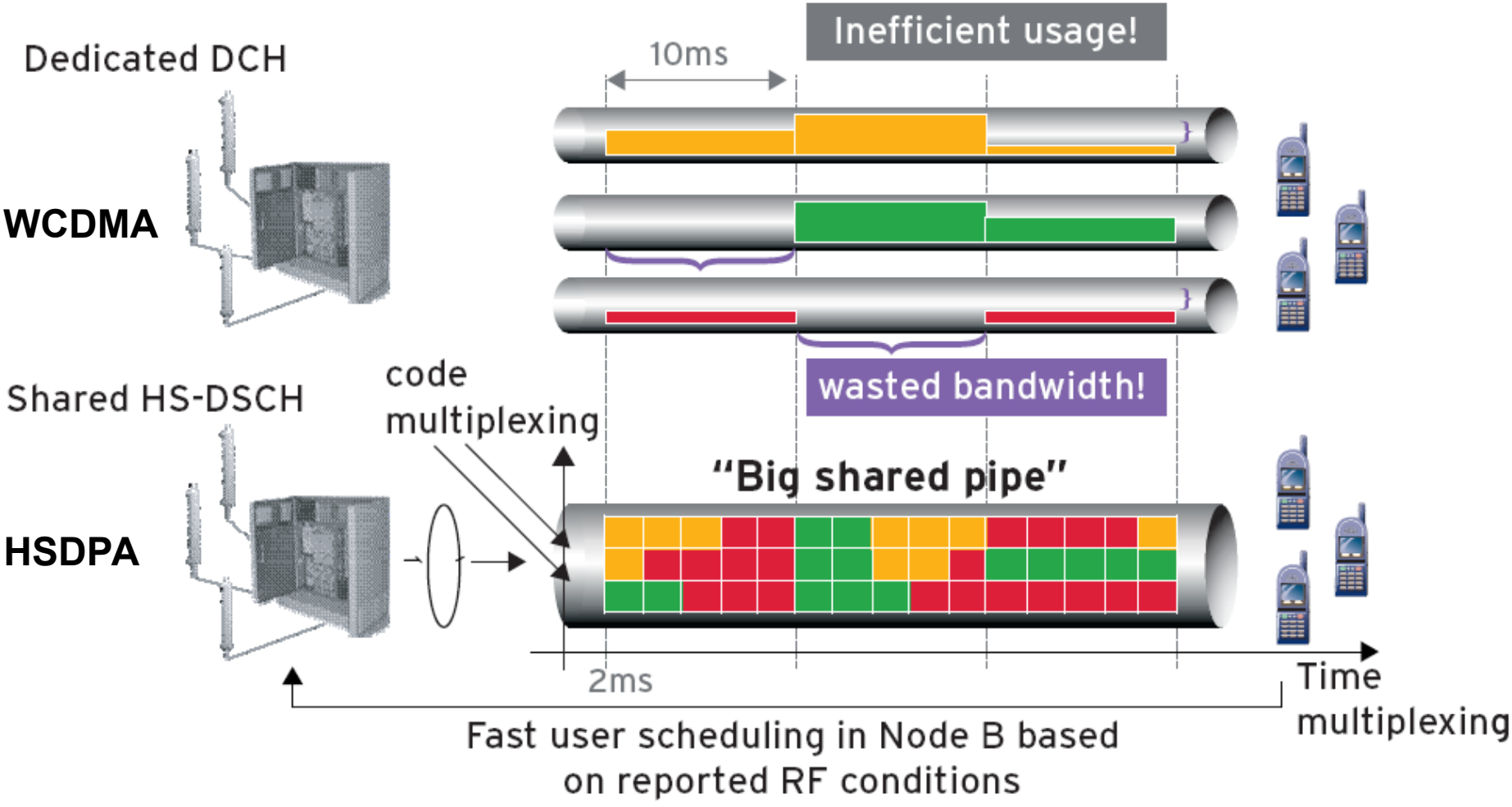
HSDPA

- High speed shared channels (15@5MHz)
  - sharing in both code and time domains
- Fast scheduling
  - shorter TTI (Transmission Time Interval): 2ms
    - from 20-80ms in UMTS Rel 99.
- Adaptive Modulation and Coding (AMC)
  - Higher order modulation: QPSK and 16-QAM
  - Fast link adaptation: different FEC (channel coding)
- Fast hybrid automatic repeat request (ARQ)
  - fast combined with scheduling/link adaptation
  - hybrid: combine repeated data transmissions with prior transmissions to improve successful decoding

Transmission Time Interval (TTI)

- related to encapsulation of data from higher layers into frames for transmission on the radio link layer.
- Equal to time required to transmit one block determines the TTI.
  - data is divided into blocks
    - the bits within a block are encoded and interleaved.
- Block:
  - shortest period over which BER can be estimated
  - shortest period over which BER can be estimated
- Gains of lower TTI:
  - faster response to link conditions
  - Faster schedule transmissions over links with better conditions.
    - system prefers links with best conditions → increased system capacity.

HSDPA vs. WCDMA



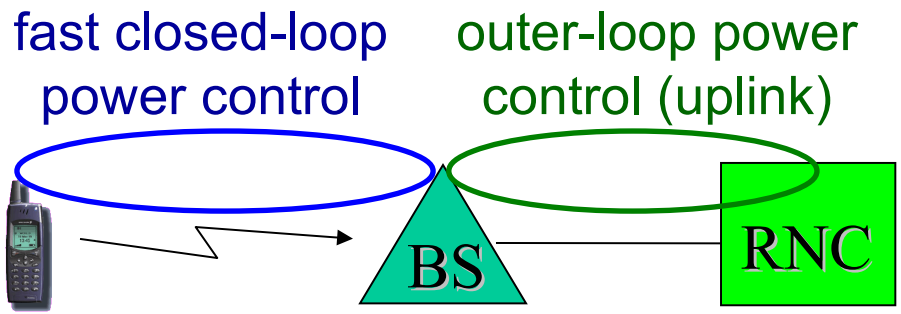
HSUPA

- Enhanced dedicated physical channel
- Fast scheduling with short TTI (2ms)
- Fast hybrid ARQ

HSPA and HSPA+

- HSPA (Rel. 6)
  - DL: 14.4 Mbps, UL: 5.76 Mbps
- HSPA+ goals
  - exploit full potential of CDMA before moving to OFDMA (3G LTE)
  - operation of packet-only mode for voice and data
- HSPA+: many versions
  - Rel.7 HSPA+ (DL 64 QAM, UL 16 QAM): DL: 21Mbps, UL: 11.5Mbps
  - Rel.7 HSPA+ (2X2 MIMO, DL 16 QAM, UL 16 QAM): DL: 28Mbps, UL: 11.5Mbps
  - Rel. 8 HSPA+ (2X2 MIMO, DL 64 QAM, UL 16 QAM): DL: 42.2Mbps, UL: 11.5Mbps

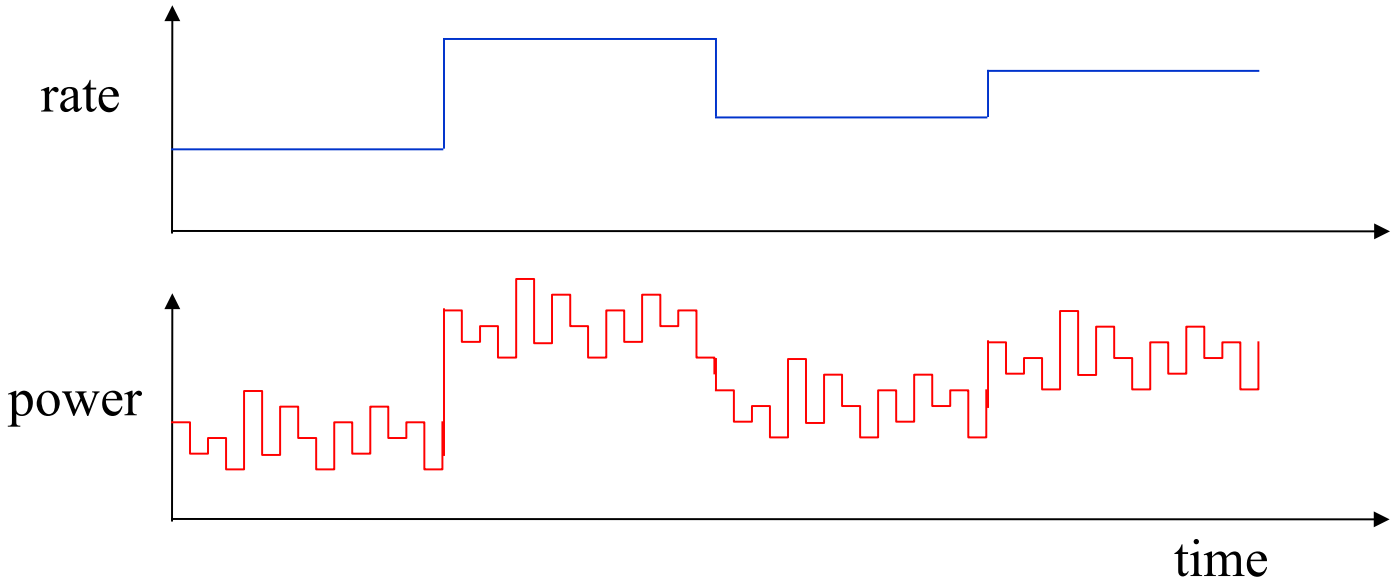
Power control in WCDMA



- Fast closed-loop power control: between MS and BS
  - Adjusts transmission power to achieve target signal quality (Signal-to-Interference Ratio, SIR)
  - Both uplink & downlink, frequency: 1500 Hz
- Uplink outer-loop power control: between BS and RNC
  - Adjusts target SIR to achieve given frame error rate (data: 10-20%, voice: 1%), frequency < 100 Hz
- Increase power when interference increases
- Diverge when signal qualities are infeasible

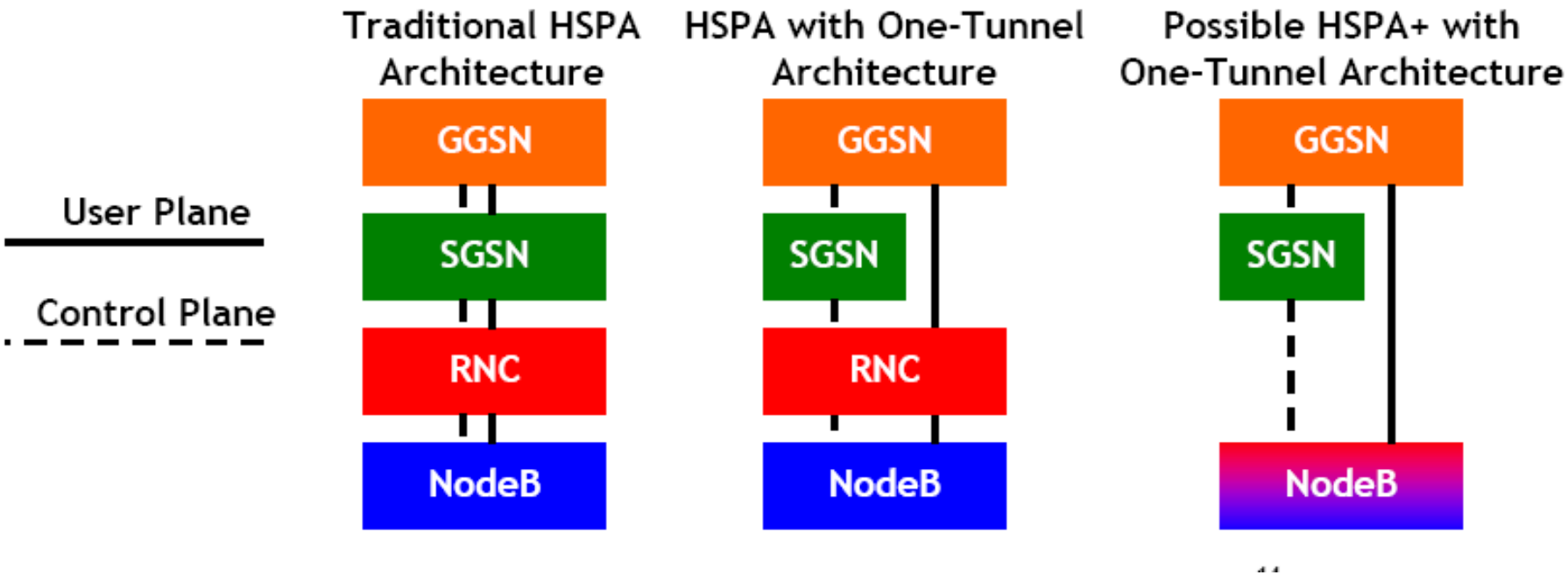
Power and rate control

- WCDMA: rates fixed within single frame (10ms)
- Fast closed-loop power control (Mobile-BS) operates at 1500 Hz (0.67ms)



- Outer loop power control (BS-RNC) adjusts target E_b/N_0 to achieve specific frame or block error rate

Towards a simpler architecture



CDMA2000 and EV-DO

- phase 1: CDMA2000 1xRTT
  - Goal: near-broadband speeds for wireless Internet access
  - Uses 1x (1 times) the 1.2288 Mcps spreading rate of a standard 1.25 MHz IS-95 CDMA channel
  - not consistent with 3G objectives → considered a "2.5G" technology
- Phase 2: Evolution-Data Only format and data/voice format, **1xEV-DO** and **1xEV-DV**, respectively
  - EV-DV never made it..
  - EV-DO R0: 153 kbps uplink, 1.25MHz BW (when WCDMA required 5MHz!!)

EV-DO more

- 1xEV-DO RevA
  - 3.1 and 1.8 Mbps down and uplink, resp.
  - QoS for VoIP
- 1xEV-DO RevB
  - Multicarrier → from 1.25MHz to 5MHz BW
  - 14.7 and 5.4 Mbps down and uplink, resp.
- EV-DO is designed for **data only**
  - Towards IP packets and Internet access

CDMA2000 1xEV-DO

- **IP-based** 1xEV-DO
  - User ↔ BS
  - BS ↔ Coffice
  - Coffice ↔ Internet
- IP lowers connections costs
  - Forwarding options:
    - Frame relay, ATM, DSL
- "Data only" approach Vs. VoIP QoS
  - Low Delay Vs. high BW utilization