

UMTS
Universal Mobile Telecommunication System

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Bibliografia

- ◆ Harri Holma, Antti Toskala, “WCDMA for UMTS, Radio Access For Third Generation Mobile Communications”, 2000, John Wiley & Sons, Ltd.
- ◆ Flavio Muratore, “UMTS, Mobile Communications for the Future”, 2000, John Wiley & Sons Ltd.

Estrutura da Apresentação

1. Gerações de Redes de Comunicação Móvel
2. Sistema de Acesso Radio UMTS
3. Rede de Acesso UMTS
4. Rede Central UMTS

1. Gerações de Redes de Comunicação Móvel

3 Gerações de Redes de Comunicação Móvel

- ◆ 1ª Geração
 - Sistemas analógicos
 - NMP, AMPS, TACS

- ◆ 2ª Geração
 - GSM, PDC, cdmaOne (IS-95), US-TDMA (IS-136)
 - GPRS

- ◆ 3ª Geração
 - WCDMA (UMTS) → Europa, Ásia (Japão, Coreia)
 - cdma2000 (cdma com multiportadoras)
 - EDGE (evolução do GSM e US-TDMA)

2G → 3G: As Causas da Mudança

- ◆ Redes móveis
 - Crescimento exponencial nos últimos 10 anos (Europa → penetração de 80%)
 - Previsão: 2005 → tráfego de dados > tráfego de voz

- ◆ Dados → novos serviços → acesso Internet → multimédia
 - Débitos variados, elevados, assimétricos
 - Ponto-a-ponto, ponto-a-multiponto, difusão
 - Garantia de qualidade de transporte da rede

- ◆ 3G → UMTS, na Europa → pensado para novos serviços
 - Voz e dados de baixo débito → continuam em sistemas de 2ª geração

Os Serviços 3G

Serviços	Débito (kbit/s)	Fiabilidade	Tempo Real
Mensagens (email, etc)	1-10	Alta	Não
Voz	4-20	Baixa (BER<10e-3)	Sim
Web	10-100	Alta (BER < 1e-9)	Depende do material
Video-conferência	100-1000	Média	Sim
Video-vigilância	50-300	Média	Não
Áudio de alta qualidade	100-300	Média	Sim
Acesso a bases de dados	>30	Muito alta	Não

Requisitos dos Sistemas 3G

- » Débitos variáveis e elevados (até 2Mbit/s)
- » Serviços assimétricos
- » Multiplexagem de serviços
- » QoS variável e garantido
- » Coexistência e handover com sistemas 2G

Expectativas dos Actores

◆ Utilizadores

- Acesso a Internet/Intranets
- Novos serviços, multimédia
- Terminais simples, preços entendíveis

◆ Operadores de rede e fornecedores de serviços

- Acesso rádio que minimize custos de instalação da rede
- Interfaces normalizadas → interoperação de equipamentos de fabricantes diferentes
- Sistemas efectivos de criação de novos serviços
- Fornecimento de serviços a clientes de outros operadores

◆ Fabricantes

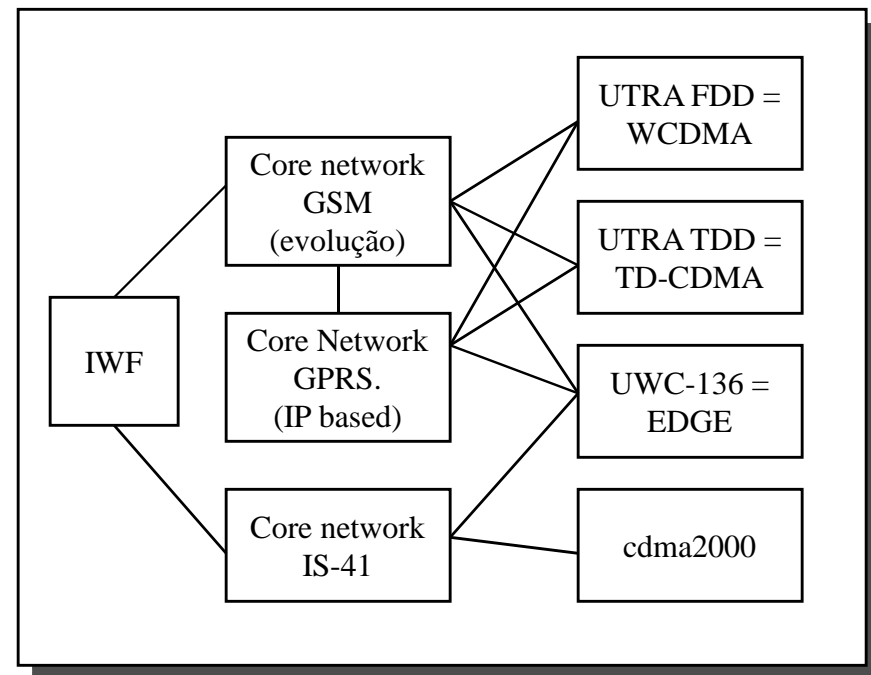
- Telecomunicações, colocados no GSM → oportunidade de negócio na continuidade
- Dados (IP) → Solução inovadora, diferenças significativas com o GSM

◆ Institutos de normalização

- Mercado competitivo → multi-operador, multi-fabricante

Evolution 2G → 3G

- ◆ 2G core networks are reused
 - GSM, GPRS, IS-41
- ◆ New radio technologies
 - UTRA, EDGE, cdma2000



Comparação GSM/UMTS

	WCDMA	GSM
Carrier spacing	5 MHz	200 kHz
Frequency reuse factor	1	1–18
Power control frequency	1500 Hz	2 Hz or lower
Quality control	Radio resource management algorithms	Network planning (frequency planning)
Frequency diversity	5 MHz bandwidth gives multipath diversity with Rake receiver	Frequency hopping
Packet data	Load-based packet scheduling	Time slot based scheduling with GPRS
Downlink transmit diversity	Supported for improving downlink capacity	Not supported by the standard, but can be applied

Evolução do UMTS

- ◆ 3GPP (organismo normalização) → lança *releases* anuais
 - <http://www.3gpp.org>
- ◆ Release-99
 - Primeira versão das especificações. Serviços básicos. Débitos até 2 Mbit/s
 - Transporte baseado em ATM
- ◆ Release 4, fim 2001
 - Correções
 - TDD, funções de localização de posição na rede
- ◆ Release 5
 - Transporte baseado em IP
 - Integração de subredes de circuitos e pacotes
 - Débitos maiores
- ◆ Release 6
 - Consumo de potência no terminal
 - Gestão dos recursos rádio

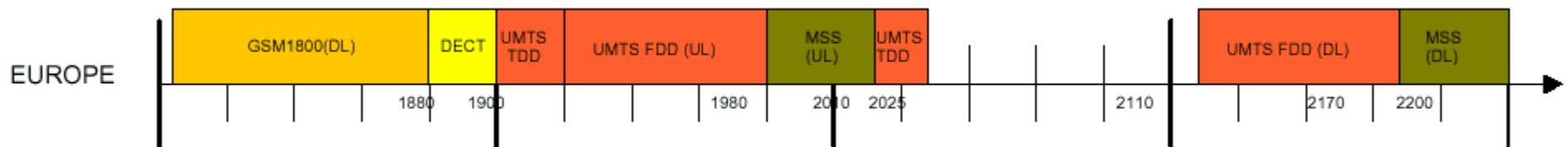
2. Sistema de Acesso Radio UMTS

Métodos de Acesso ao Rádio

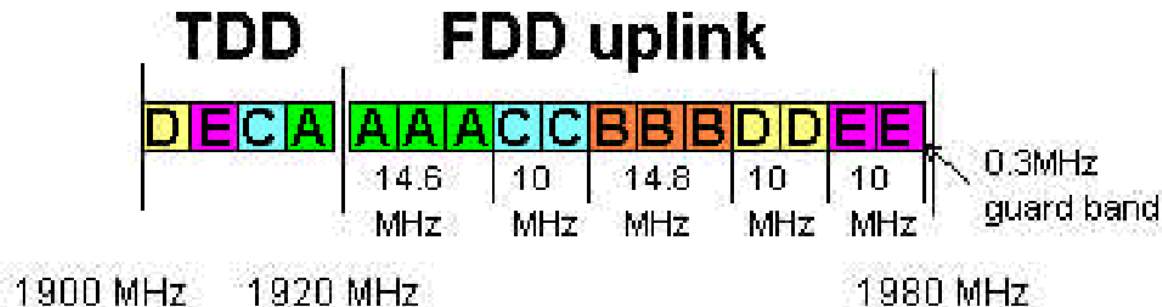
- ◆ **Nível físico UMTS**
- ◆ **Métodos de acesso ao radio**
 - W-CDMA → 2 bandas emparelhadas → Frequency Division Duplexing (FDD)
 - TD-CDMA → bandas não emparelhadas → Time Division Duplexing (TDD)
- ◆ **FDD**
 - Uplink → banda inferior → 5 MHz
 - Downlink → banda superior → 5 MHz
 - Transmissão simultânea
 - Adequado para serviços simétricos (mesmo débito nos dois sentidos)
- ◆ **TDD**
 - Mesma banda usada para uplink e downlink → 5 MHz
 - Separação no tempo
 - Adequado para serviços assimétricos

Radio Spectrum for UMTS in Europe

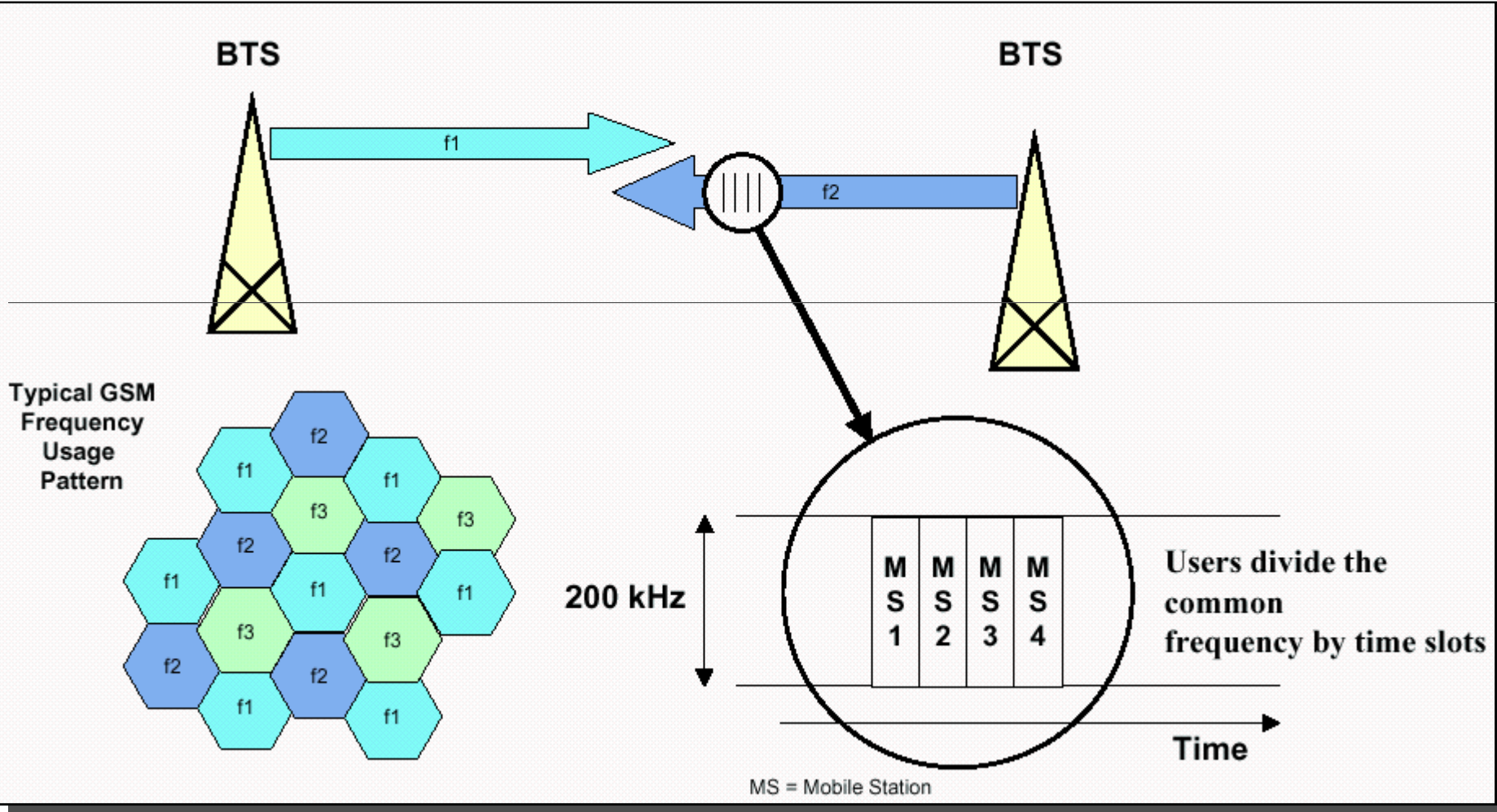
- ◆ New services → + radio resources → new spectrum required
- ◆ Bands reserved for 3G networks, in Europe
 - FDD, uplink (60MHz) → 1920 – 1980 MHz
 - FDD, donwlink (60MHz) → 2110 - 2170MHz
 - TDD (35 MHz) → 1900-1920 + 2010-2025 MHz



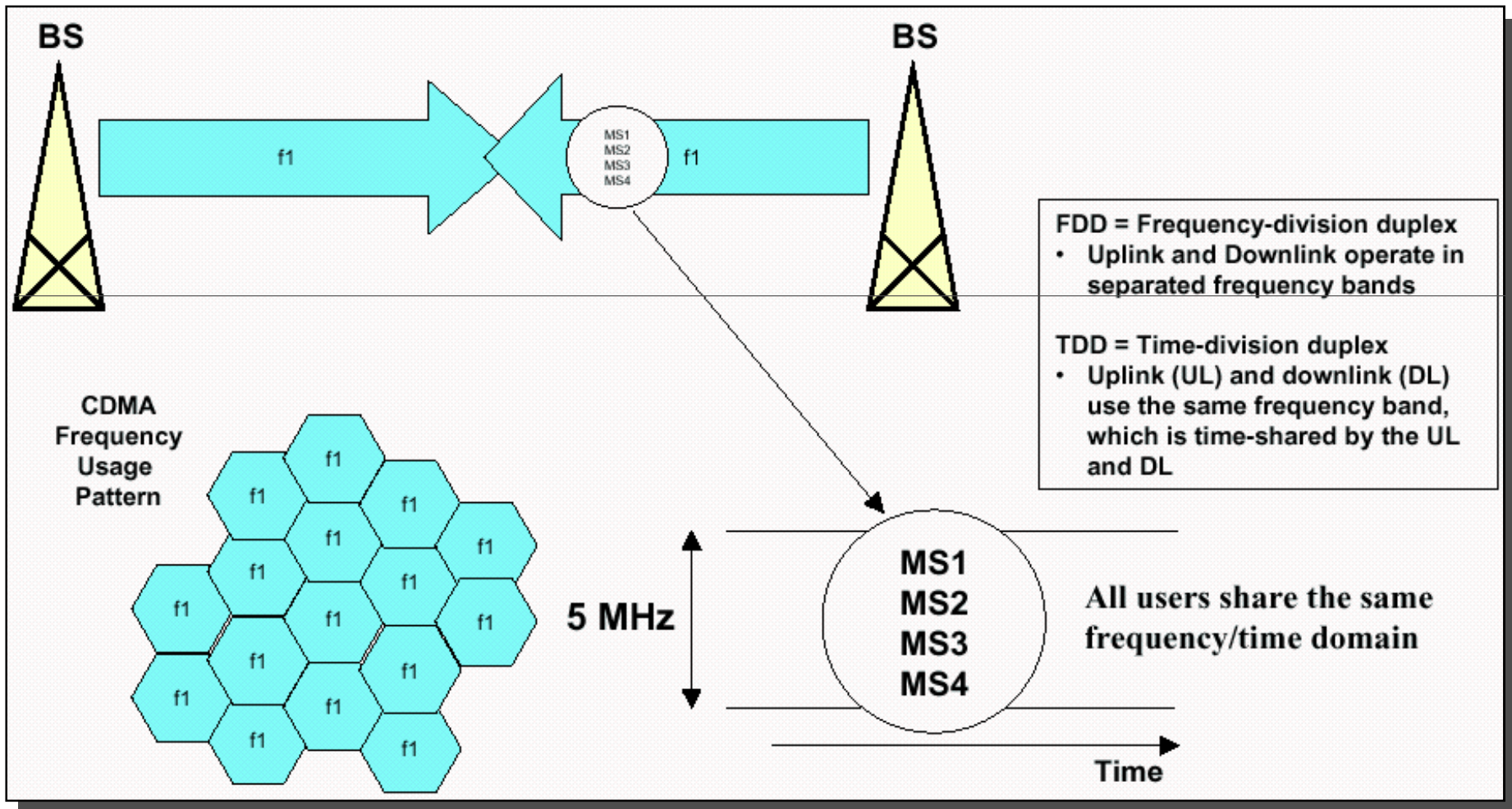
- ◆ Distribution by 5 operators



GSM → TDMA



UMTS → CDMA

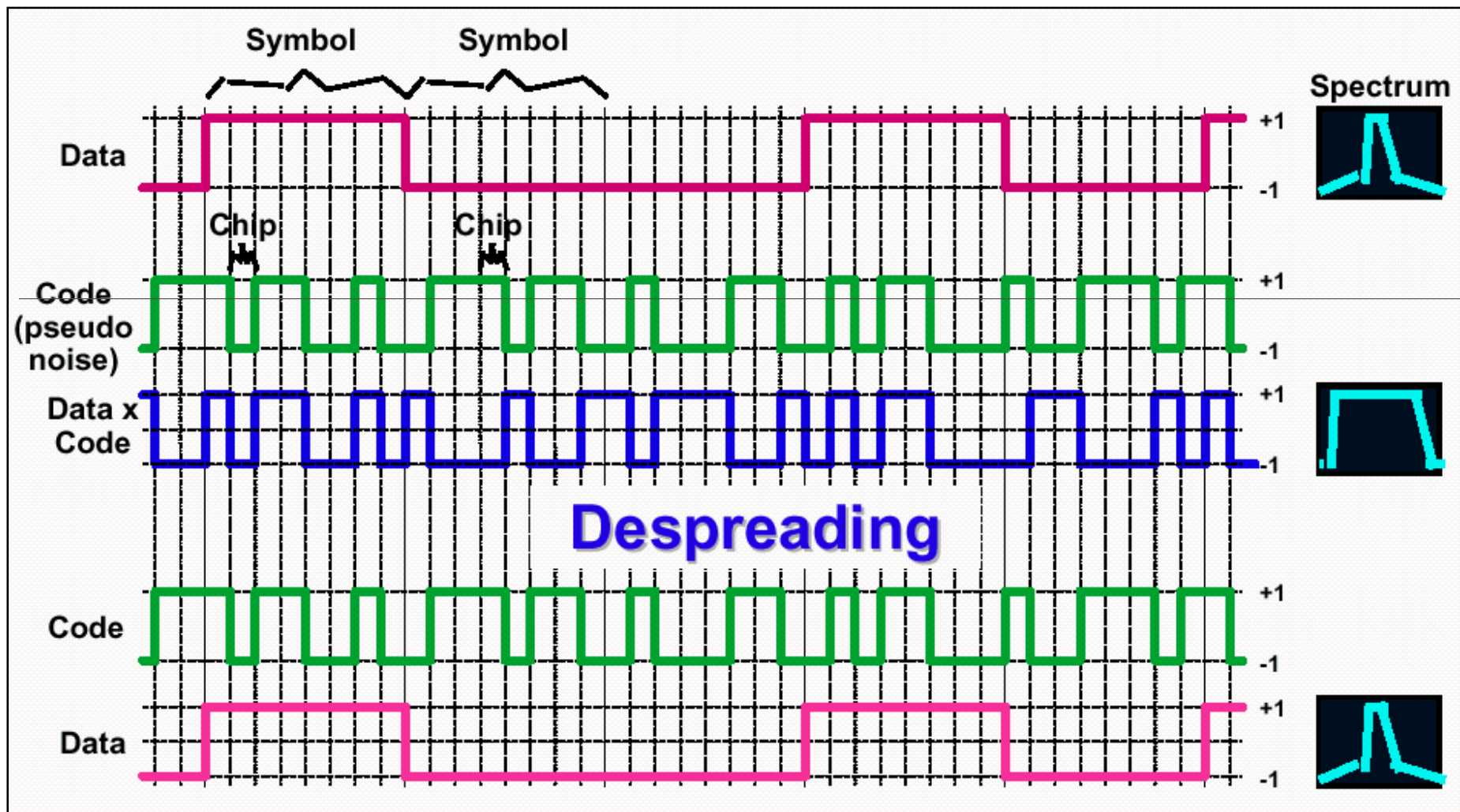


CDMA – Code Division Multiple Access

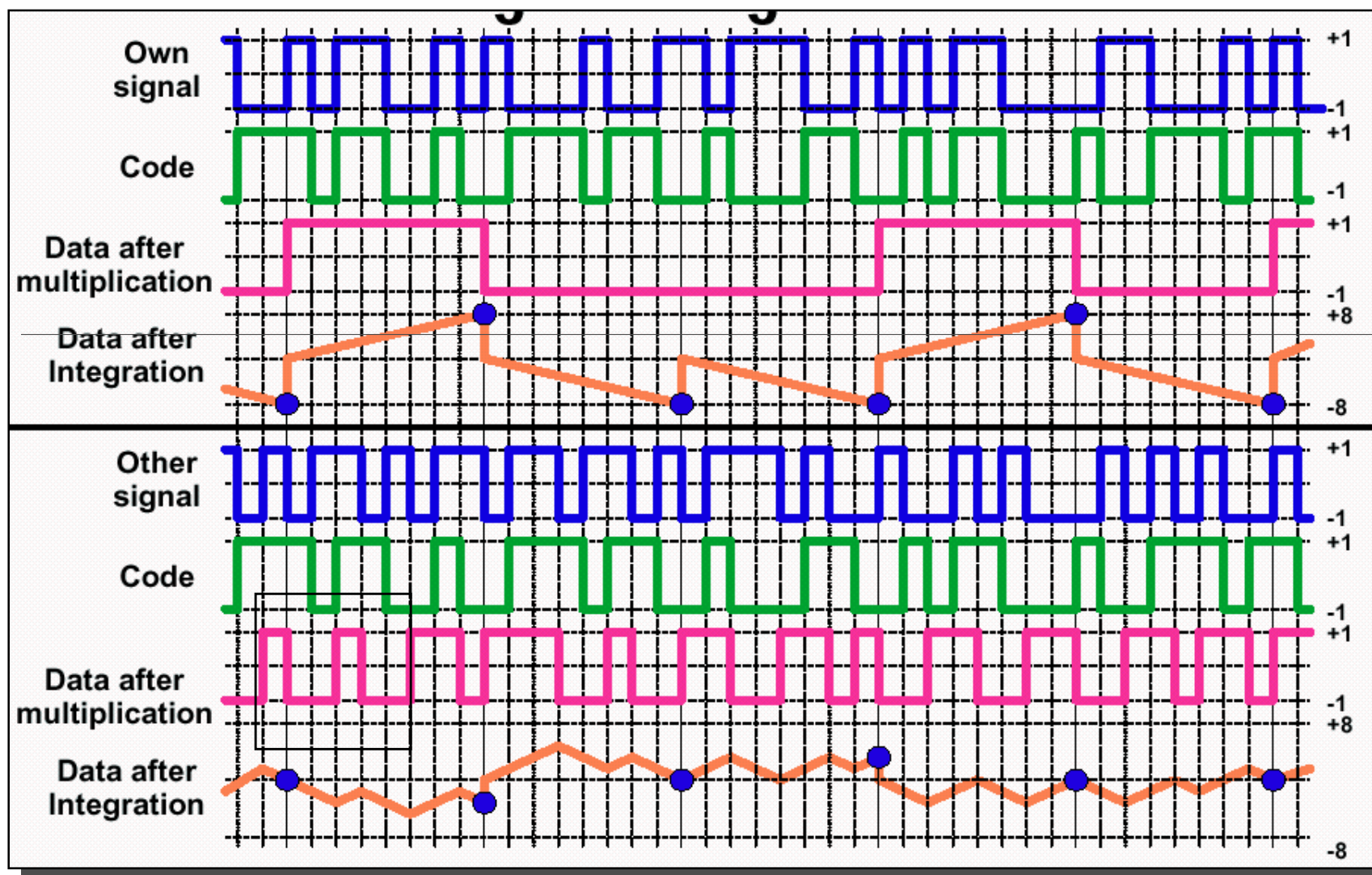
Analogy

- ◆ One code is used for each transmission
- ◆ Analogy with languages

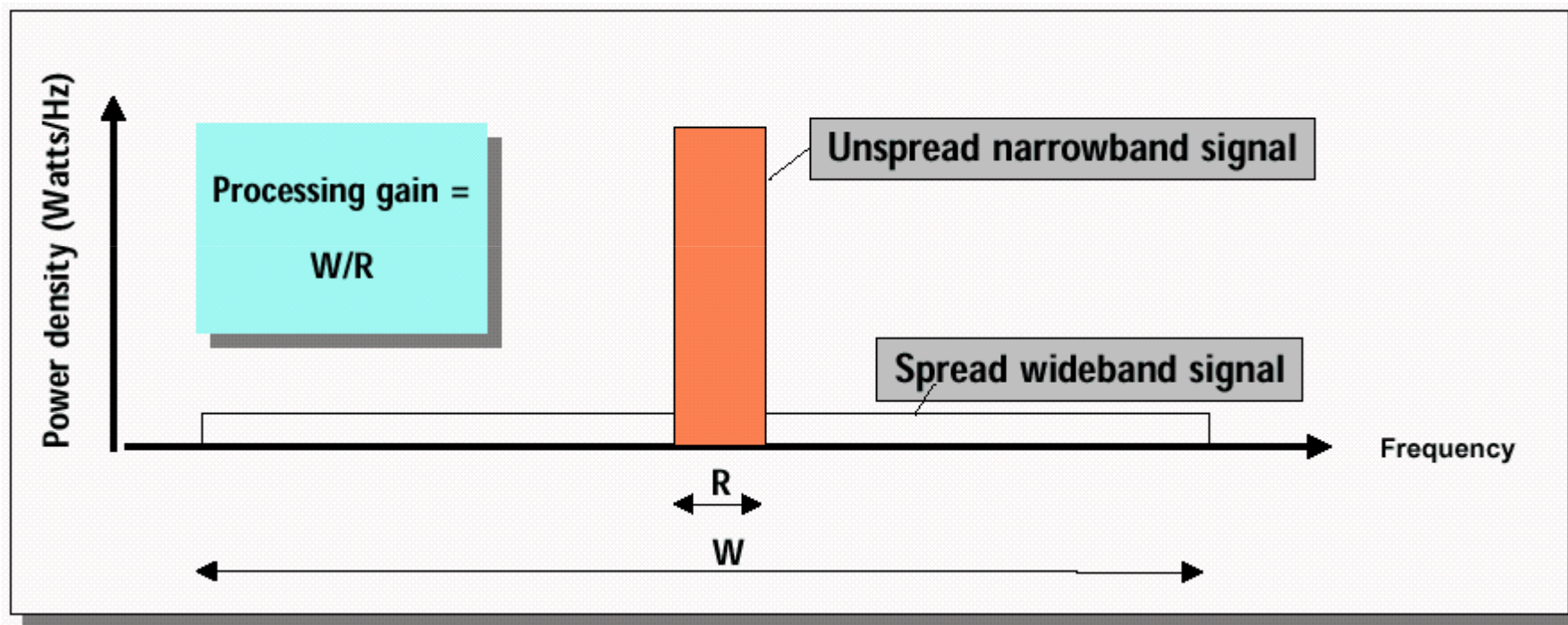
Spreading, Despreading



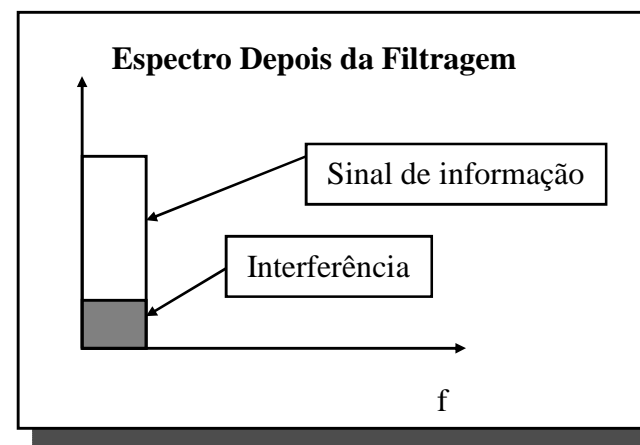
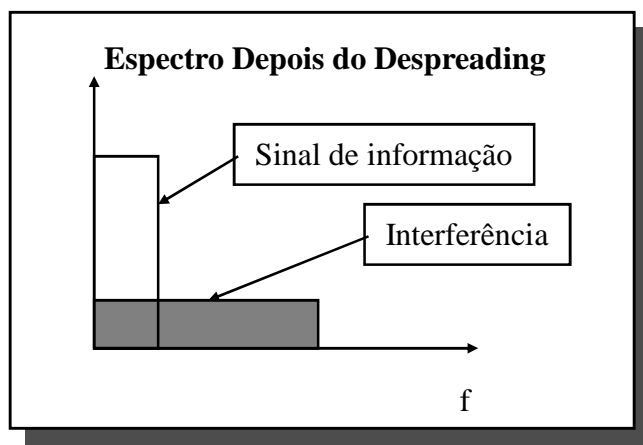
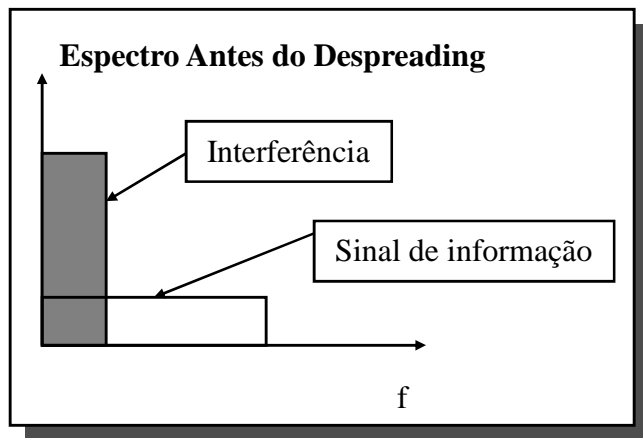
Own vs Other Signals Despreading



Ganho de Processamento (W/R)



CDMA - Rejeição de Interferência



Capacidade do Uplink

- » Controlo de potência perfeito
- » Todos os sinais recebidos com a mesma potência

$$\frac{C}{I} = \frac{C}{C(N-1)} = \frac{1}{N-1}$$

$$\frac{E_b}{I_0} = \frac{C/R}{I/W} = \frac{W}{R} \frac{C}{I} = \frac{W}{R} \frac{1}{N-1}$$

N – número de utilizadores

C - potência recebida utilizador (W)

I – interferência dos outros utilizadores (W)

E_b – energia por bit de informação (J/bit)

I₀ – densidade espectral da interferência (J/Hz)

W – débito de chips (chip/s)

R – débito de bits de informação (bit/s)

- » Número de utilizadores servidos numa célula
 - Proporcional ao ganho de processamento
 - Inversamente proporcional à relação “sinal-ruído”

$$N \cong \frac{W}{R} \frac{1}{\frac{E_b}{I_0}}$$

- + Terminal deve transmitir com o menor potência possível
- + Potências baixas → BER elevados

UTRAN - Interface Radio

	UTRA/FDD	UTRA/TDD
Técnica de Acesso	W-CDMA	TD-CDMA
Chip Rate	3.84 Mchip/s	3.84 Mchip/s
Banda	4.4-5MHz	4.4-5MHz
Duração de Trama	10 ms	10 ms
Slots por Trama	15	15
Modulação	Downlink → QPSK Uplink → Dual BPSK	QPSK

Canais de Transporte

◆ Canais de transporte

- Serviços oferecidos pelo nível físico
- Definição → tipo de informação transportada

◆ Canais dedicados ← Informação associada a 1 terminal

- DCH, Dedicated Channel. Uplink, downlink

◆ Canais comuns ← Informação associada a n terminais

- BCH, Broadcast Channel. Downlink Difusão numa célula
- FACH, Forward Access Channel. Downlink. Terminal localizado. Sinaliz, pacotes
- PCH, Paging Channel. Downlink. Terminal n/ localizado. Sinalização, pacotes
- DSCH, Downlink Shared Channel. Downlink. Pacotes
- RACH, Random Access Channel. Uplink. Aleatório. Sinalização, pacotes
- CPCH, Common Packet Channel. Uplink. Contenção. Pacotes

Mapeamento de Canais

Canais de Transporte \leftrightarrow Canais Físicos

Canais de Transporte

BCH

FACH

PCH

RACH

DCH

DSCH

CPCH

Canais Físicos

Primary Common Control Physical Channel (PCCPCH)

Secondary Common Control Physical Channel (SCCPCH)

Physical Random Access Channel (PRACH)

Dedicated Physical Data Channel (DPDCH)

Dedicated Physical Control Channel (DPCCH)

Physical Downlink Shared Channel (PDSCH)

Physical Common Packet Channel (PCPCH)

Synchronization Channel (SCH)

Common Pilot Channel (CPICH)

Acquisition Indication Channel (AICH)

Paging Indication Channel (PICH)

CPCH Status Indication Channel (CSICH)

Collis. Detection / Channel Assign Indicator Channel (CD/CA-ICH)

Canal Dedicado

◆ Transporte

- » DCH (Dedicated Channel)

◆ Físico

- » DPDCH (Dedicated Physical Data Channel)

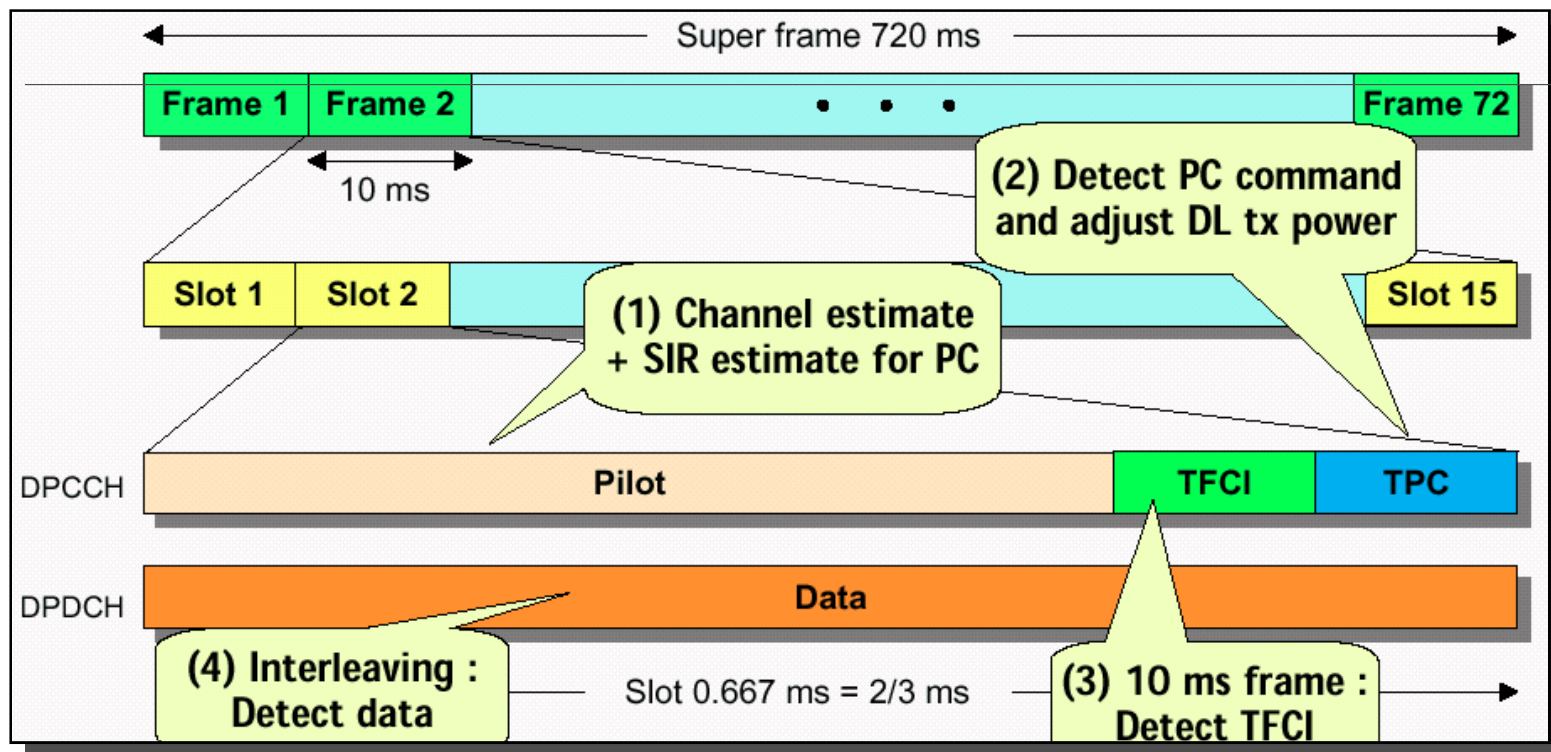
- Dados de utilizador
- Sinalização de níveis superiores
- Cada canal DPDCH tem um canal DPCCH associado
- Débito do canal indicado em DPCCH

- » DPCCH (Dedicated Physical Control Channel)

- Débito constante
- Informação para estimação do SIR (no controlo de potência rápido)
- Informação de controlo de potência
- Informação formato da informação de transporte

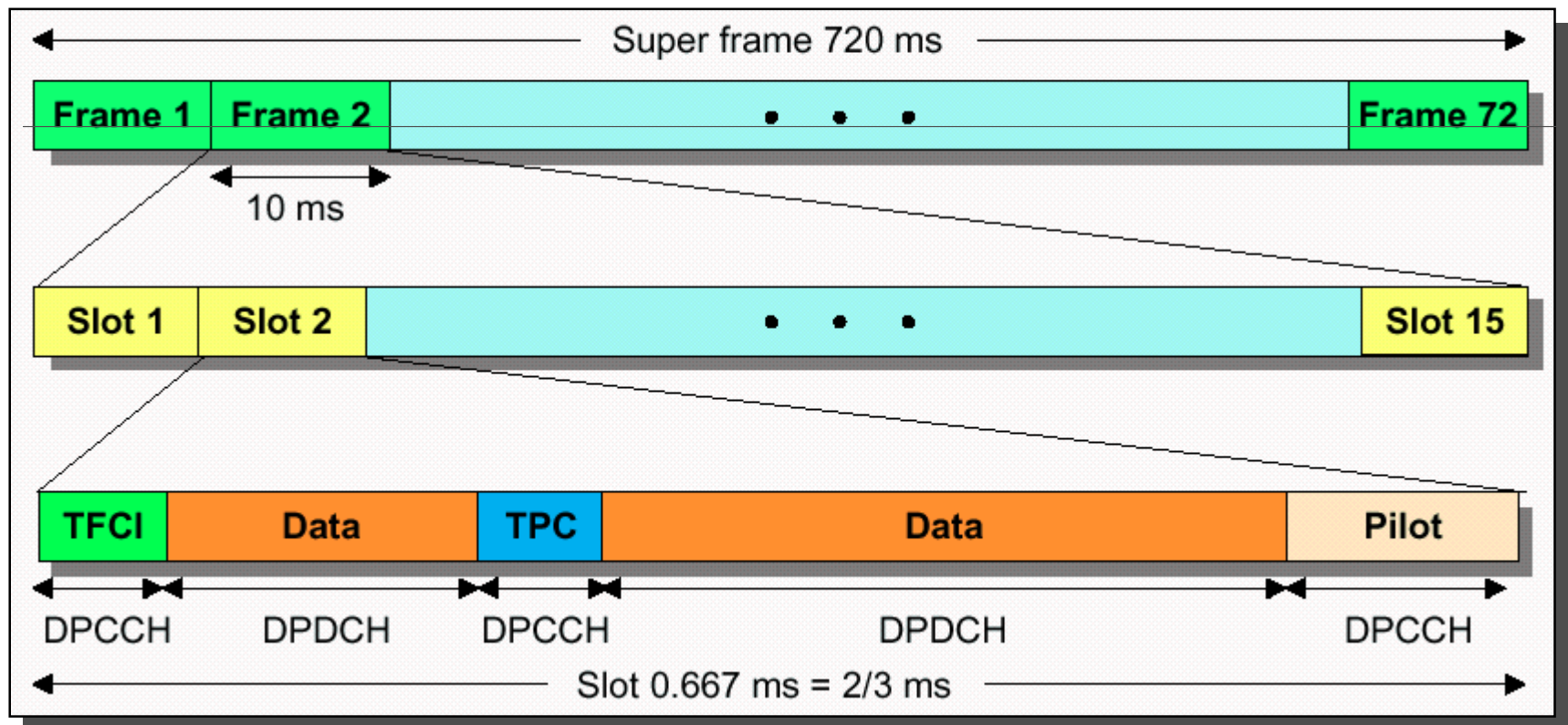
Dedicated Channel- Uplink

- » DPCCH e DPDCH sent as In-phase/Quadrature components
 - Pilot symbols → used to estimate channel response and interference (C/I)
 - TFCI, Transport Format Combination Indicator → code, frame bitrate
 - TCP, Transmit Power Control → controls the power to be transmitted in downlink



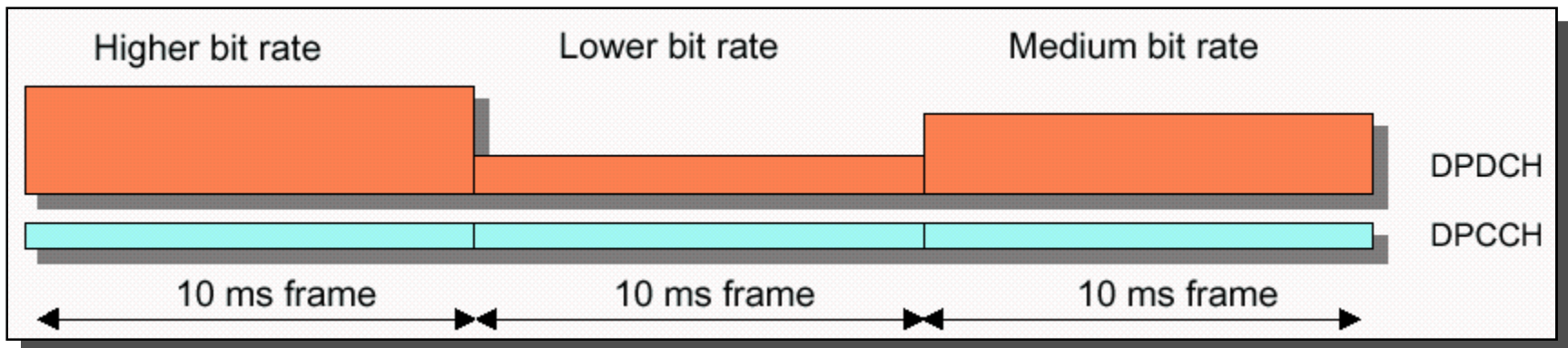
Dedicated Channel - Downlink

- » QPSK Modulation
- » DPCCH and DPDCH are multiplexed in time
- » Non-continuous data transmission



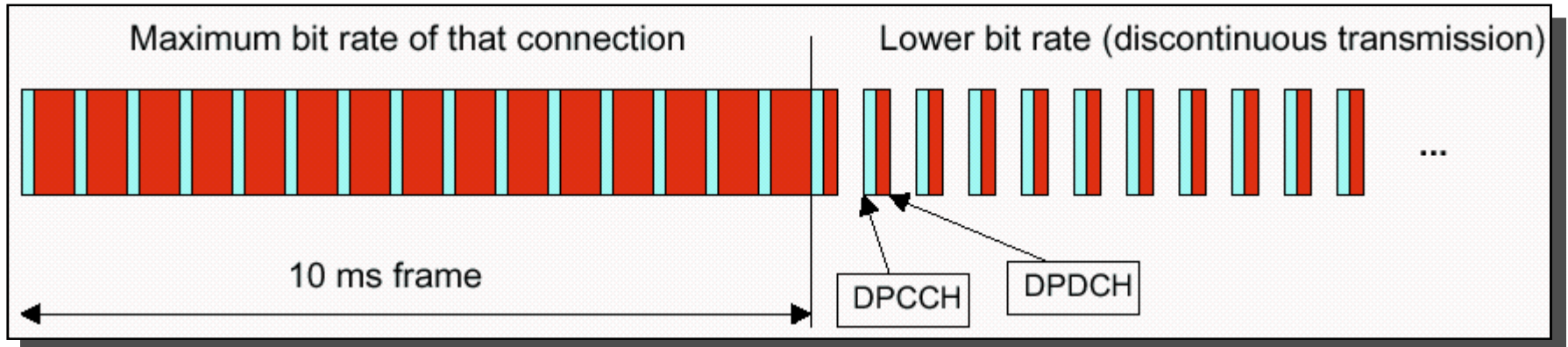
Dedicated Channel– Variable Bitrate in Uplink

- » DPDCH bitrate may vary from frame to frame (changing the code)
- » High bitrates → high transmission powers → high interference
- » Continuous transmission, independently of the bitrate



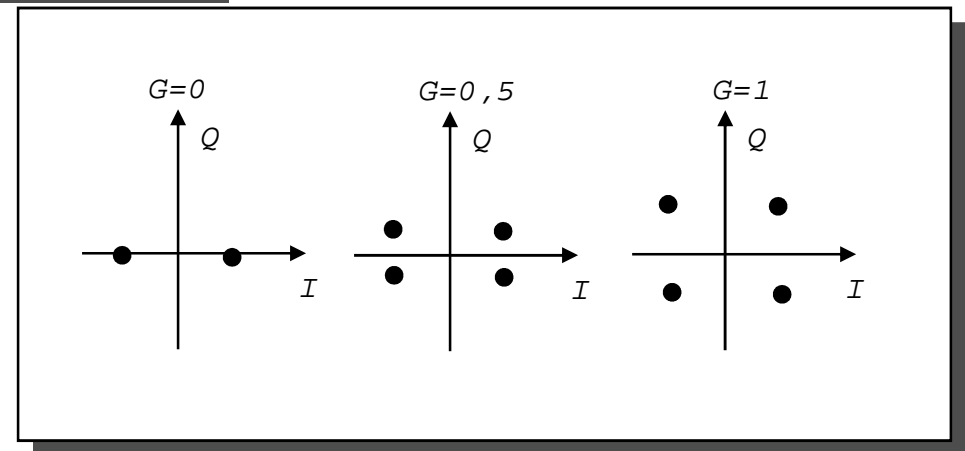
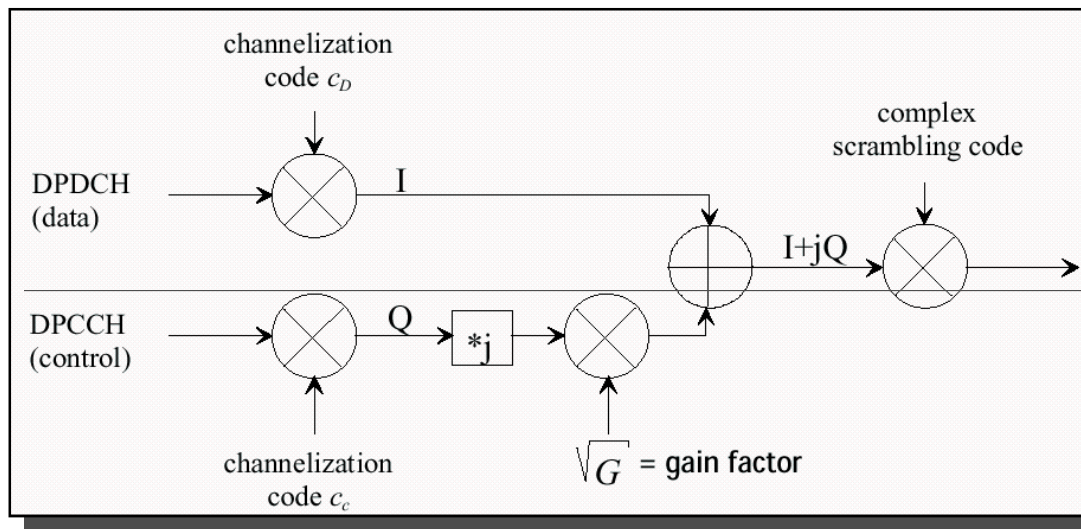
Dedicated Channel – Variable Bitrate in Downlink

- » DPDCH bitrate may vary from frame to frame
- » Transmission at the maximum bitrate
- » Low bitrates achieved using non-continuous transmission



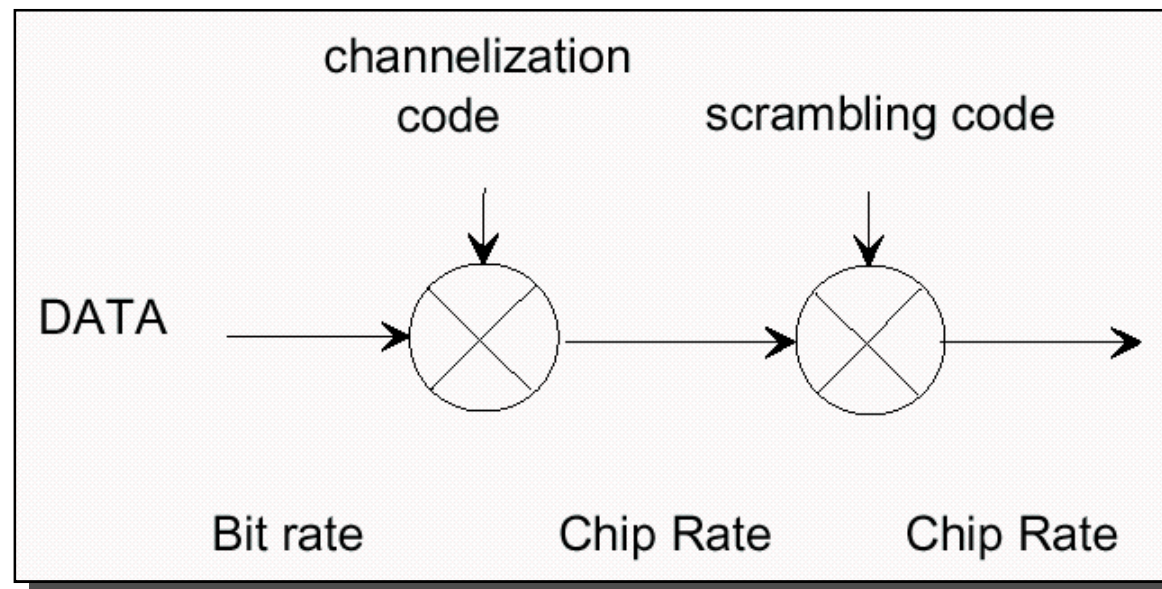
Dedicated Channel – Multiplexing I-Q components in Uplink

» Dual Channel BPSK



Spreading e Scrambling

- ◆ Código de Spreading (curto)
 - ◆ Controlo sobre o débito
 - ◆ Código pequeno (poucos chips) → débito elevado de bits de informação
- ◆ Código Scrambling (longo)
 - ◆ Separação de utilizadores e células
 - ◆ Não afecta débitos



Spreading & Scrambling

	Short code = Channelisation code	Long code = Scrambling code
Usage	Uplink: Separation of physical data (DPDCH) and control channels (DPCCH) from same terminal Downlink: Separation of downlink connections to different users within one cell	Uplink: Separation of mobile Downlink: Separation of sectors (cells)
Length	4–256 chips (1.0–66.7 μ s) Downlink also 512 chips Different bit rates by changing the length of the code	Uplink: (1) 10 ms = 38400 chips or (2) 66.7 μ s = 256 chips Option (2) can be used with advanced base station receivers Downlink: 10 ms = 38400 chips
Number of codes	Number of codes under one scrambling code = spreading factor	Uplink: 16.8 million Downlink: 512
Code family	Orthogonal Variable Spreading Factor	Long 10 ms code: Gold code Short code: Extended S(2) code family
Spreading	Yes, increases transmission bandwidth	No, does not affect transmission bandwidth

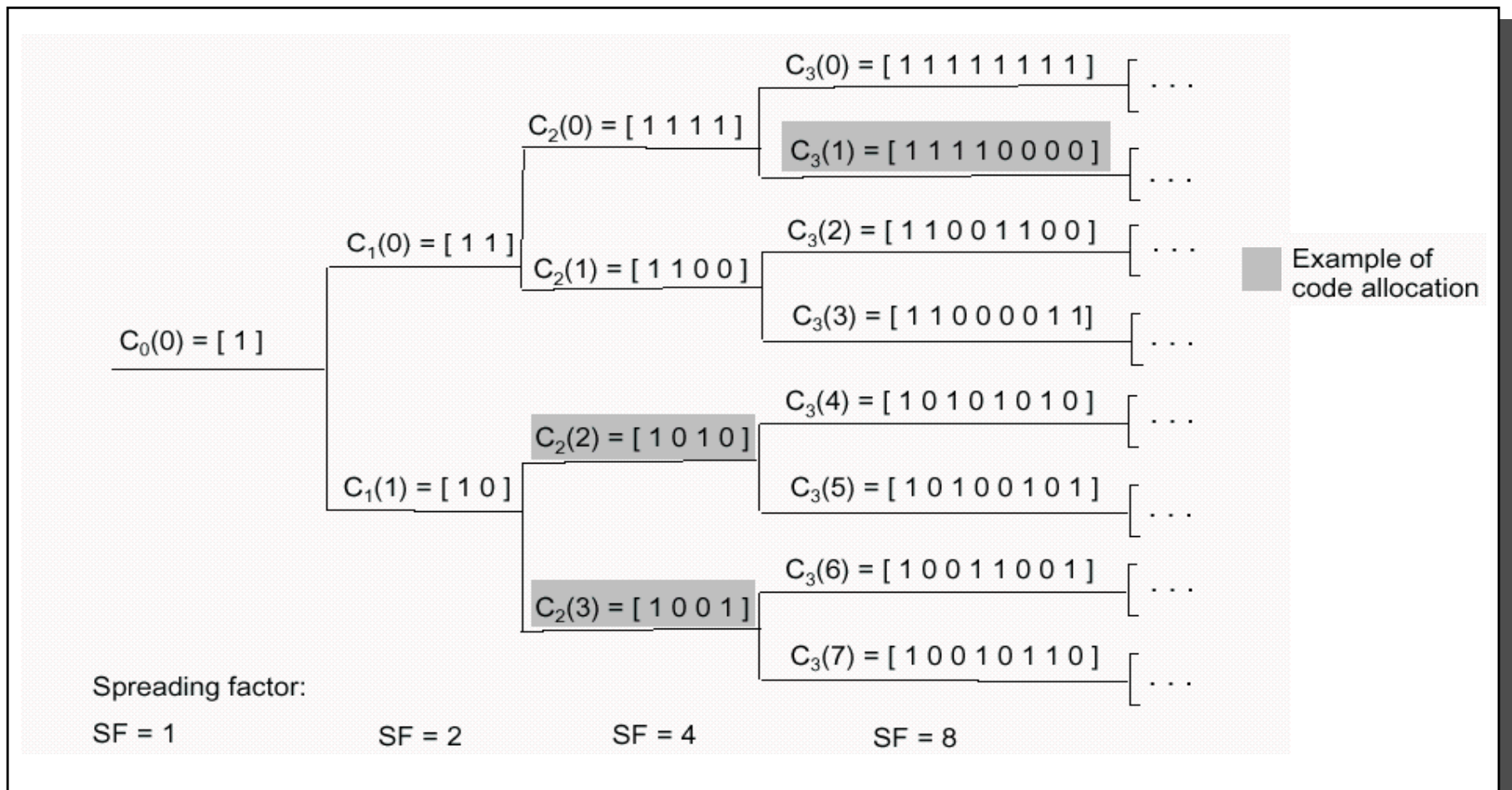
Downlink codes must be managed

Downlink codes are orthogonal

Simple code planning in downlink

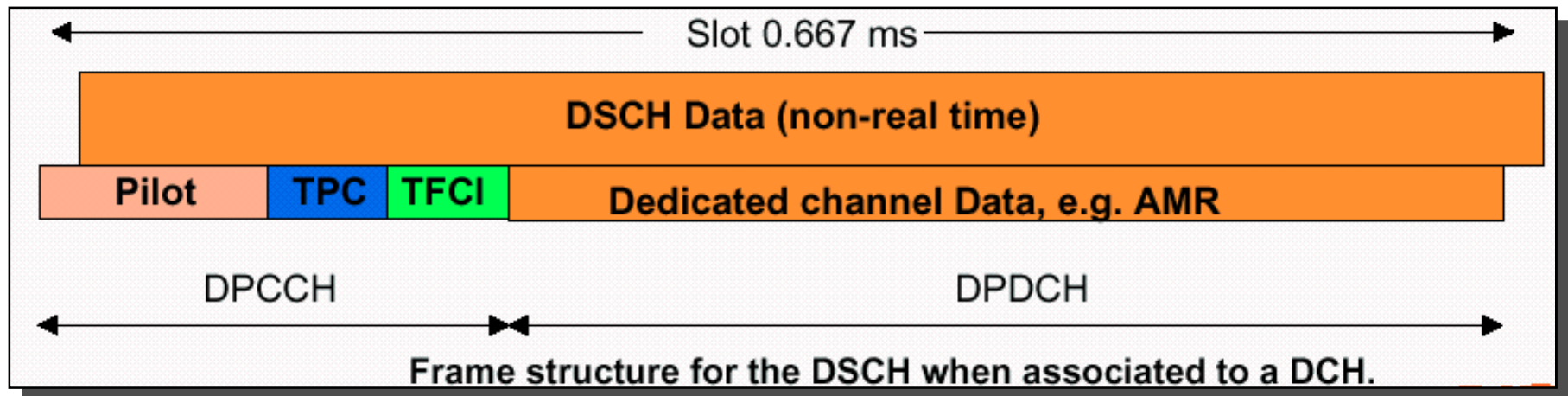
Spreading Codes

» Hierarchical selection of codes → orthogonality



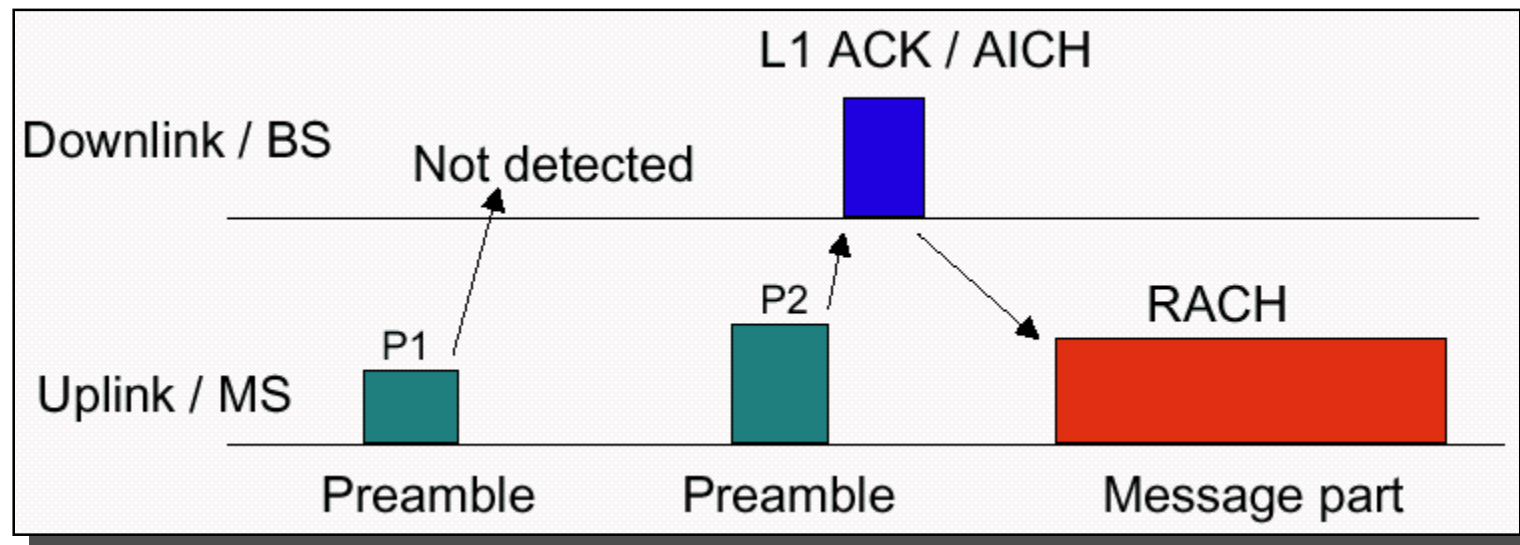
Canal Partilhado no Downlink

- » **DSCH / PDSCH**, (Physical) Downlink Shared Channel
- » Partilhado por um grupo de terminais
- » Sempre associado a canal dedicado (DPCCH+DPDCH)
- » Dados para um terminal → informação em TFCI de DPCCH
- » Não sincronizado com canal dedicado



Canal Partilhado no Uplink

- » RACH/PRACH, (Physical) Random Access Channel
- » Preâmbulo
 - Terminal envia assinatura de 1 ms (canal RACH)
 - Aumenta potência em cada tentativa não sucedida
- » L1 Ack → estação confirma recepção e potência (canal FACH)
- » Terminal envia mensagem (canal RACH)



Serviço de Pacotes

◆ Pacotes pequenos e infrequentes

- PCH, paging ← localização terminal desconhecida, downlink
- FACH, forward, ← localização terminal conhecida, downlink
- RACH, acesso por contenção, uplink

◆ Pacotes infrequentes, débitos elevados

- DSCH, partilhado, downlink
- CPCH, comum, acesso por contenção, uplink (usa FACH como retorno)
- Canais comuns → têm controlo de potência frequente

◆ Pacotes com canal dedicado

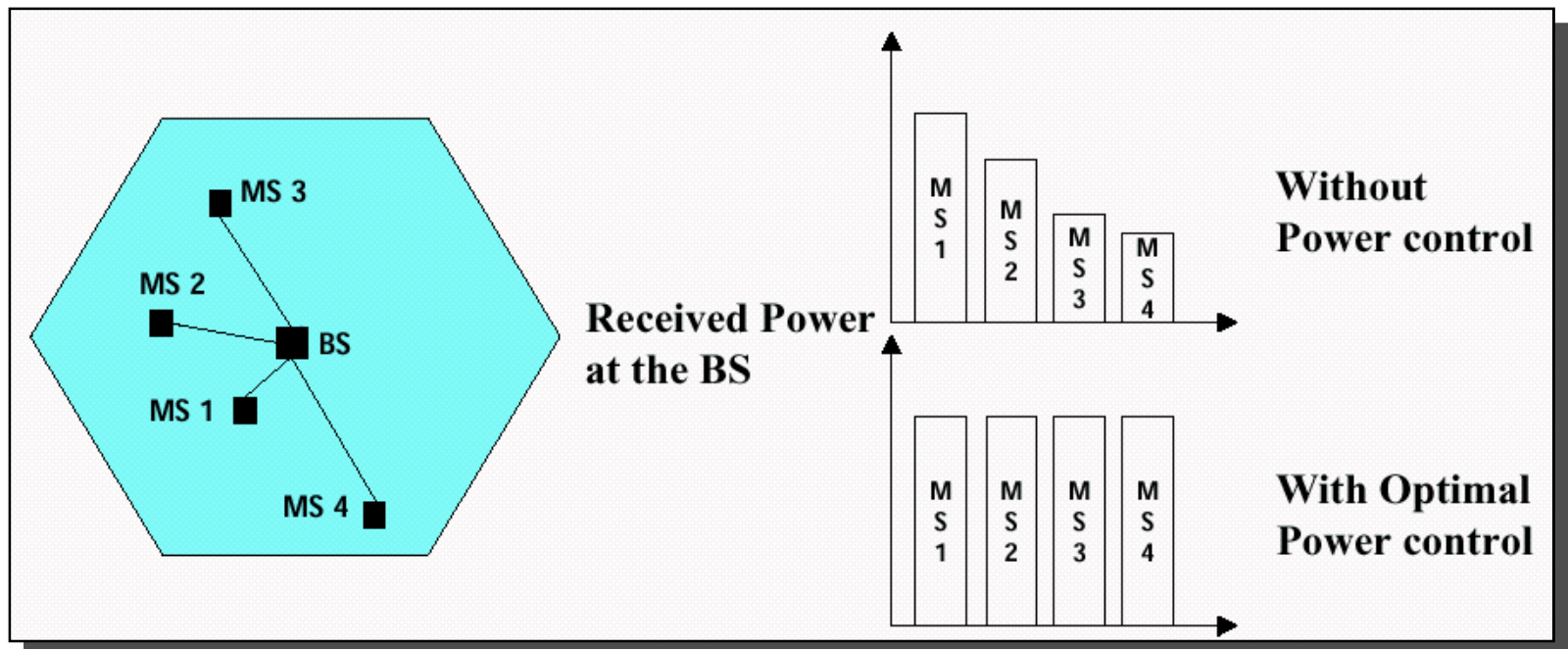
- DCH, downlink, uplink

O Receptor

- ◆ Modelização do canal
- ◆ Receptor Rake

Power Control

- » To enable the signals from Mobile Stations to be received with equal power at the Base Station → to minimize interference (C/I)
- » Terminal transmits and receives using the lowest power



Power Control – Adaptation Mechanisms

◆ Open loop control

- Used in the uplink, during call establishment
- Power Tx in RACH is determined based on the power Rx in a common channel
 - Powers Tx by BaseStations are known → terminal measures Rx power → terminal calculates (down)link attenuation → terminal assumes same attenuation in Uplink
- Problem → duplex in frequency → different attenuations for both directions

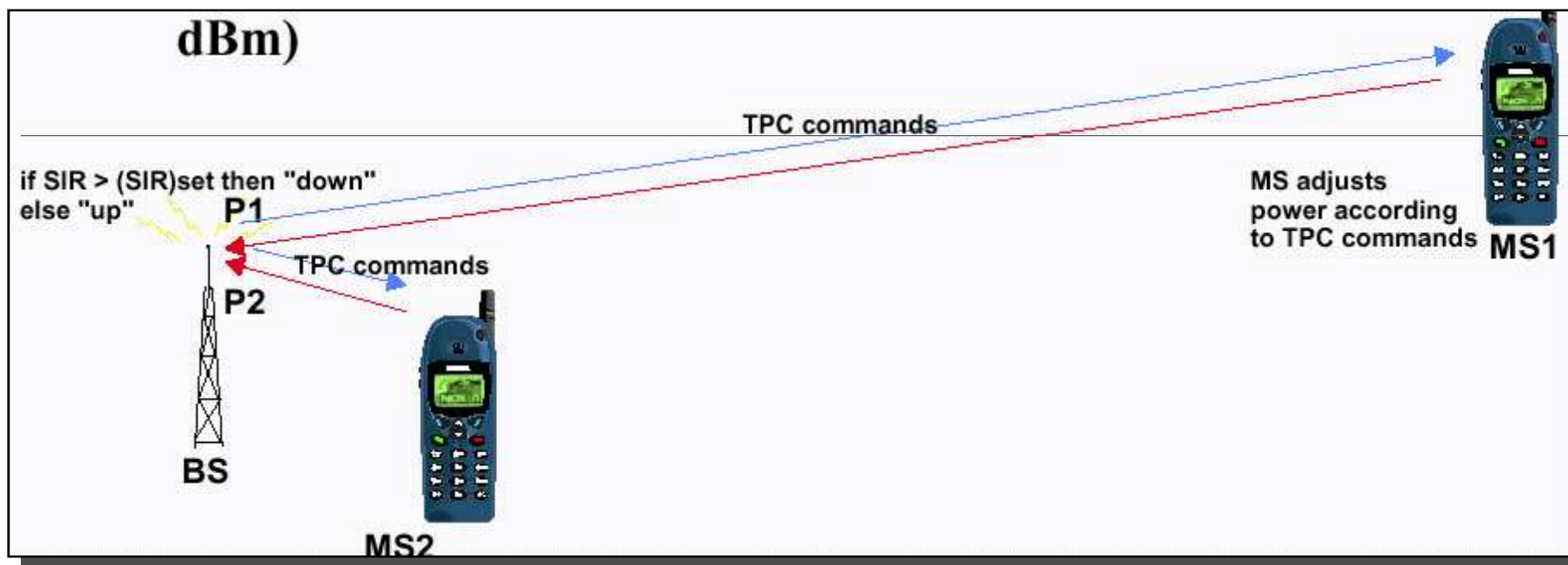
◆ Closed loop control

- Frequent commands sent by Terminal/BS to increase/decrease Tx power
- One command by timeslot (1500 command/s)
- SIR objective (set) → SIR measurement → request to increase/decrease Tx power
- Delta of 1 dB; range 70 db
- Command sent in control channel (DPCCH)

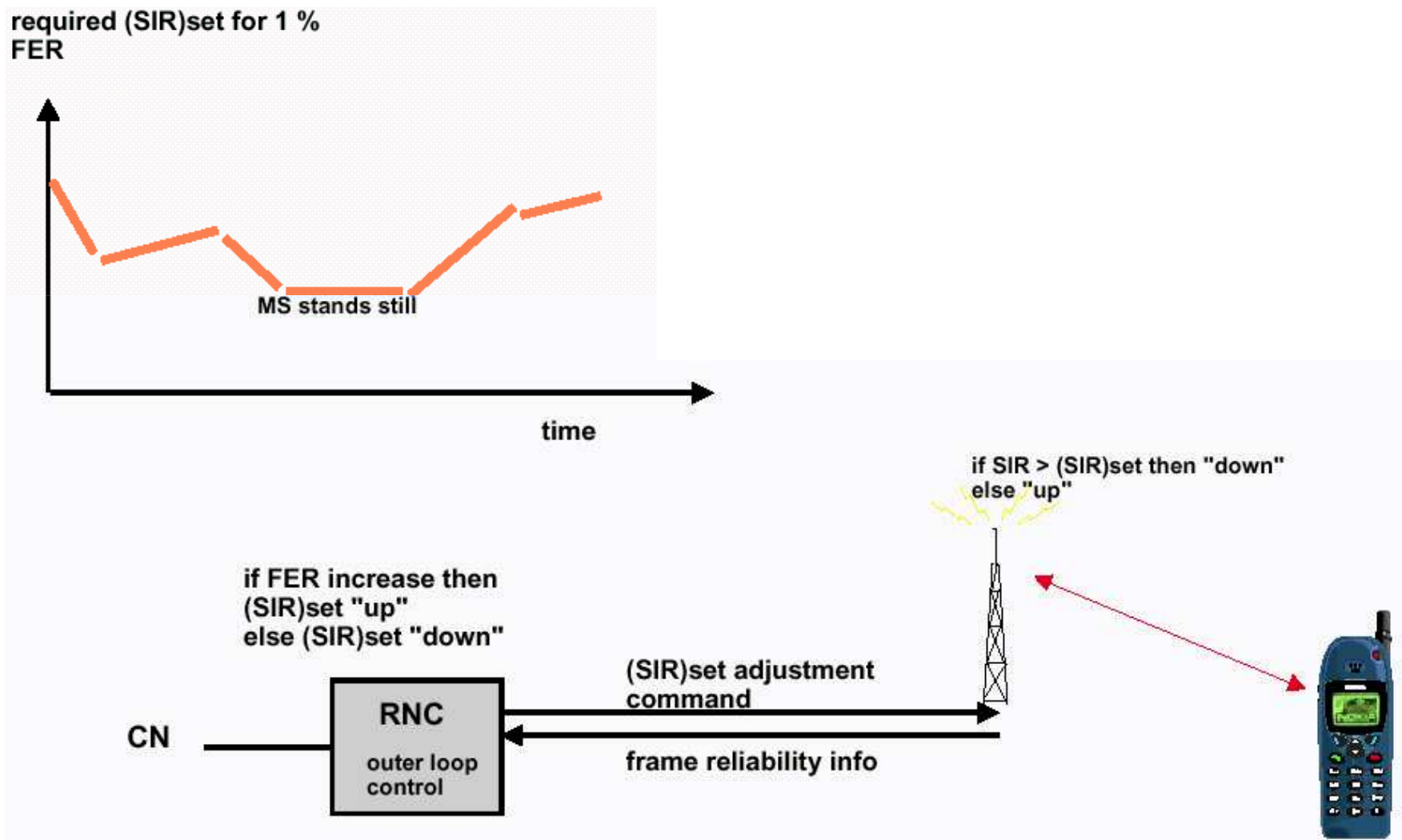
◆ External control

- Calculates SIR (C/I) objective
- Using the connection BER (Bit Error Ratio) or FER (Frame Error Ratio)

Power Control – Close Loop



Power Control – External Control



3. UMTS Access Network

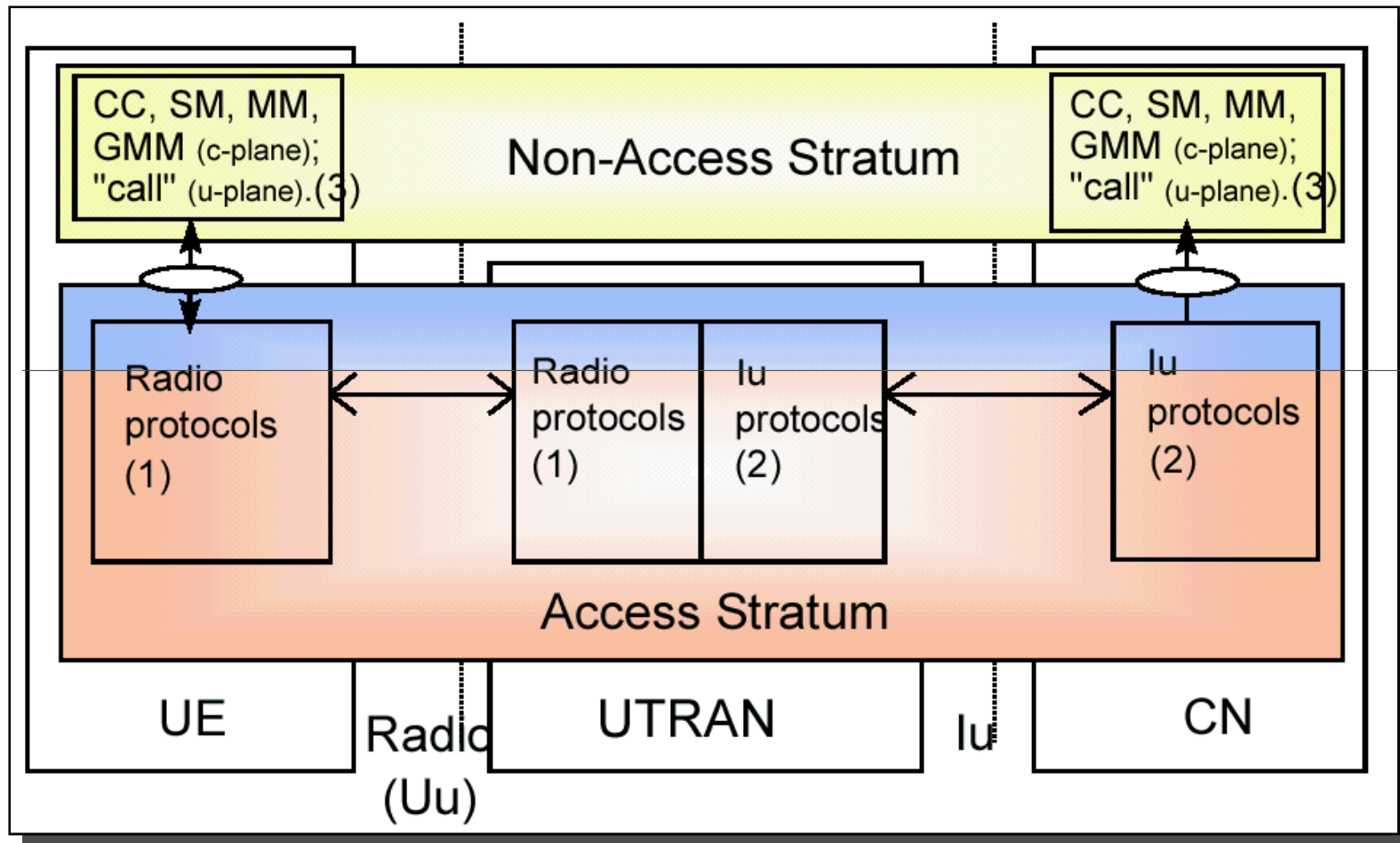
UMTS - Arquitectura Funcional Genérica

- ◆ Organização física rede UMTS → rede acesso rádio + rede central
 - » Redes independentes
 - » Sistema móvel universal usado com múltiplas tecnologias de acesso rádio

- ◆ Organização lógica rede UMTS → 2 níveis
 - » Acesso, dependente da tecnologia de rádio
 - Protocolos rádio, rede fixa de acesso
 - Gestão da mobilidade dentro de uma rede de acesso

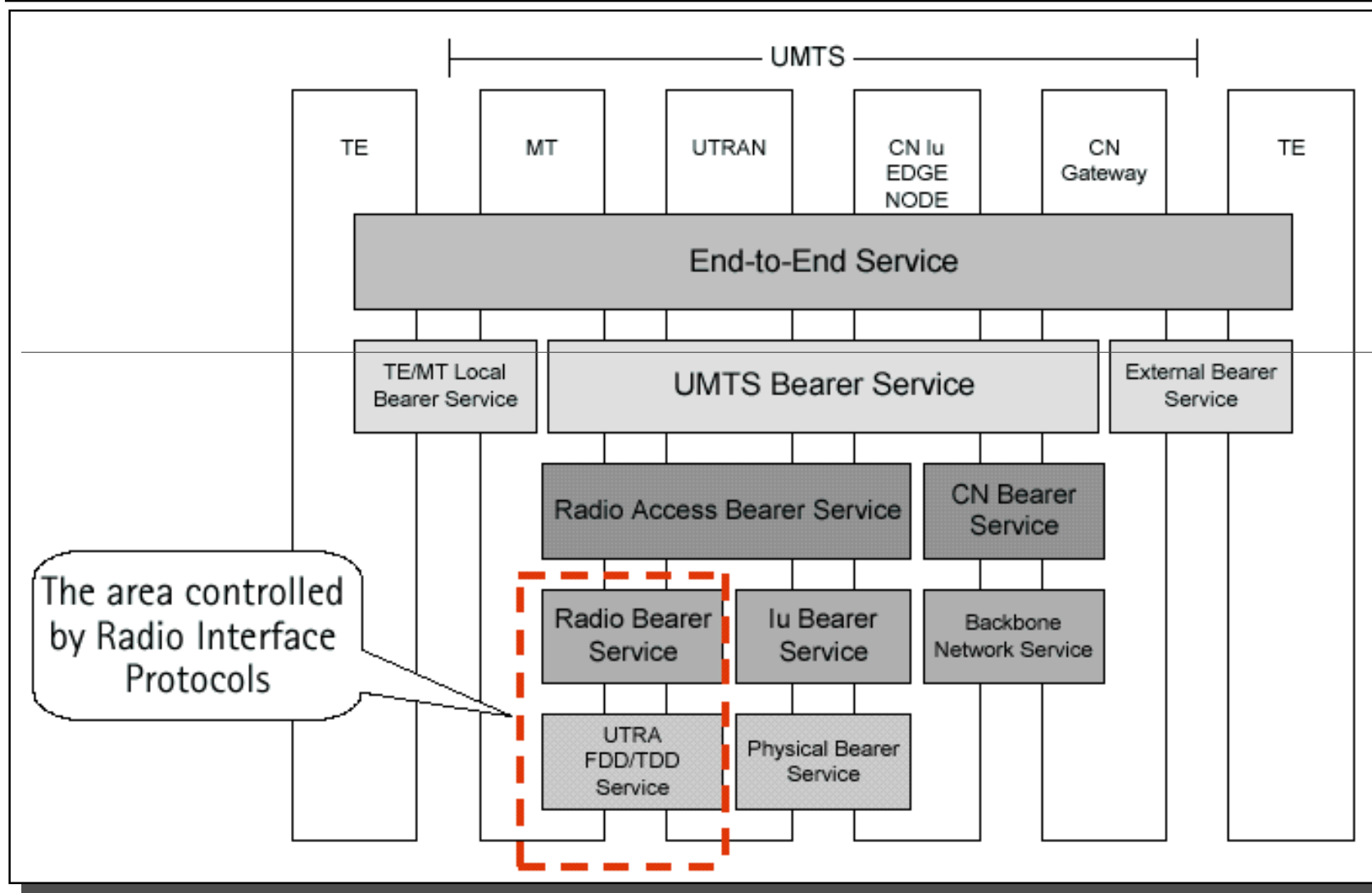
 - » Não-acesso, independente da tecnologia rádio
 - Controlo de chamada e sessão
 - Controlo da mobilidade entre redes de acesso diferentes

UMTS - Arquitectura Funcional Genérica

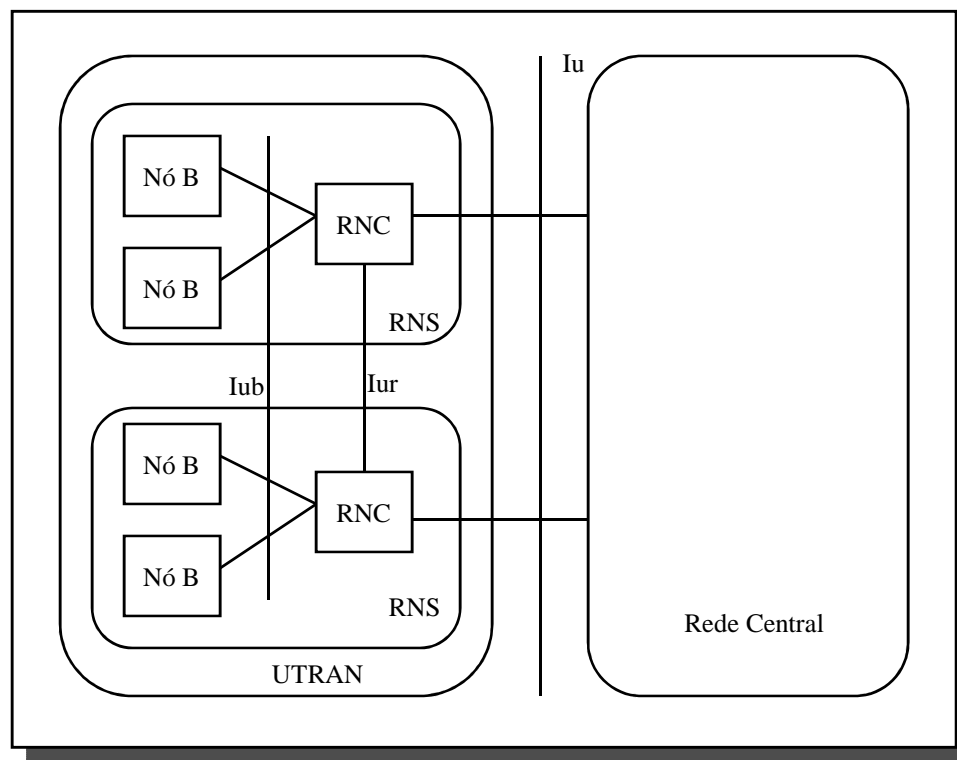


UTRAN - UMTS Terrestrial Radio Access Network

Serviços Básicos UMTS

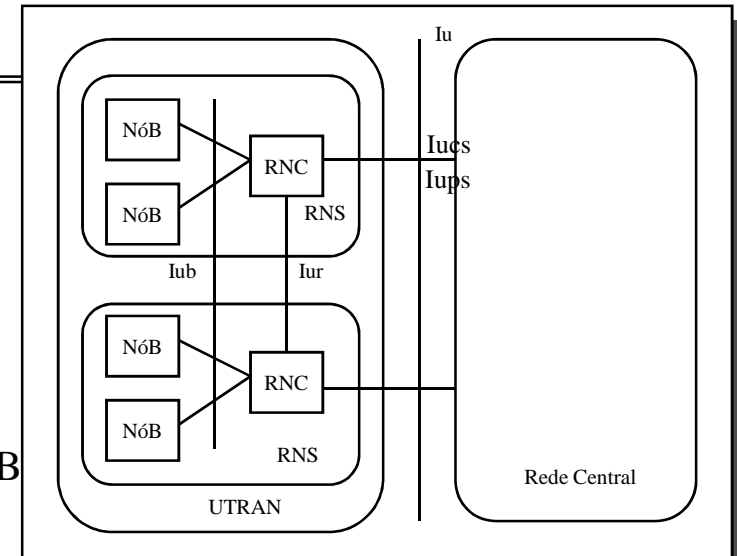


Arquitectura da UTRAN

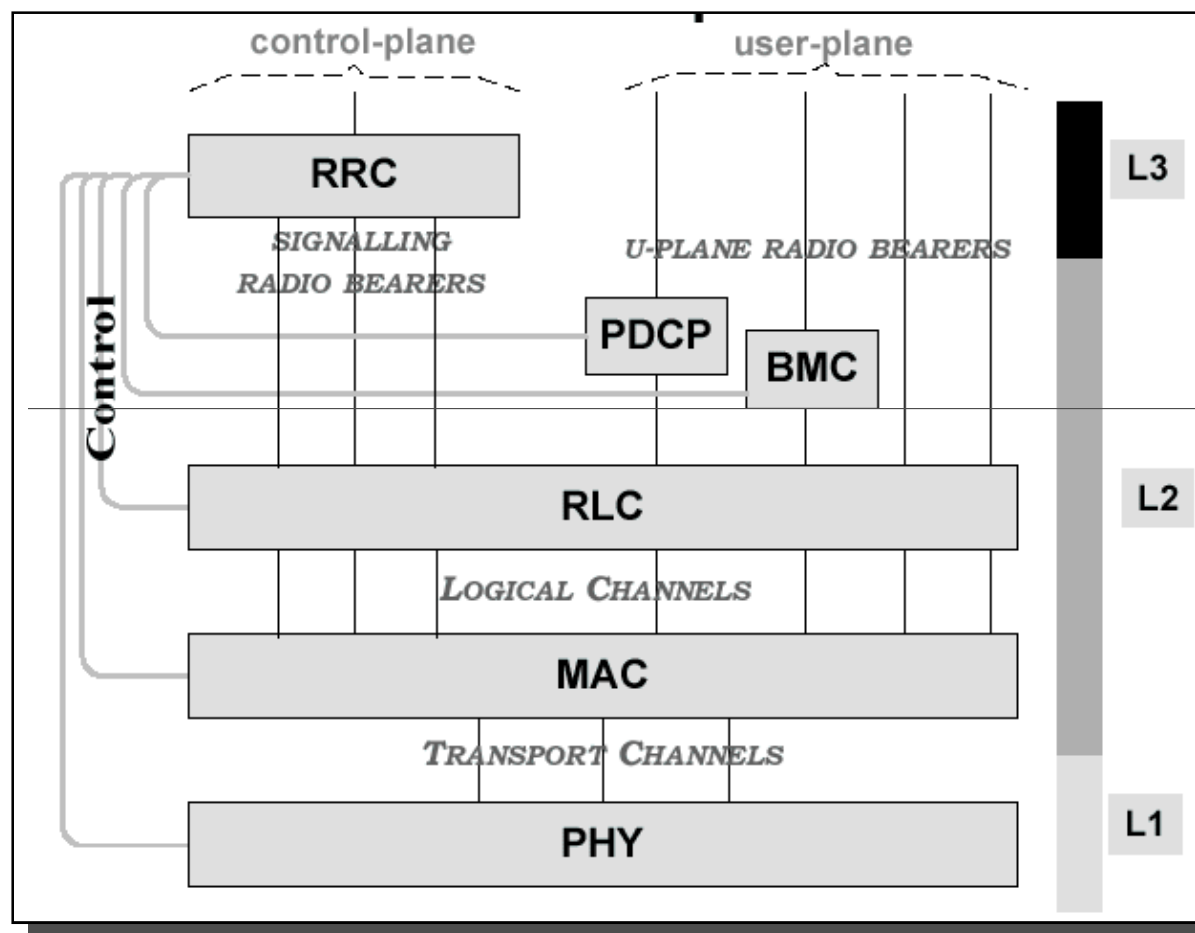


UTRAN Architecture

- » UTRAN → set of RNS (Radio Network Subsystem)
- » RNS
 - Interconnects to core networks → Iu interface
 - ◆ Circuits (Iucs), Packets (Iups)
 - Consists of
 - ◆ 1 RNC (Radio Network Controller)+n NodeB
- » RNC
 - Protocols in charge of radio management
 - Decides about handover and macro-diversity between Nodes B
- » Node B
 - Controls a set of cells
 - Responsible for handover decisions and macro-diversity between cells
 - Operates in FDD, TDD or in both modes
- » ATM transport
 - AAL2 → signaling (Iub, Iur, Iucs), user data (Iucs)
 - AAL5 → signaling (Iups), user data (Iups)

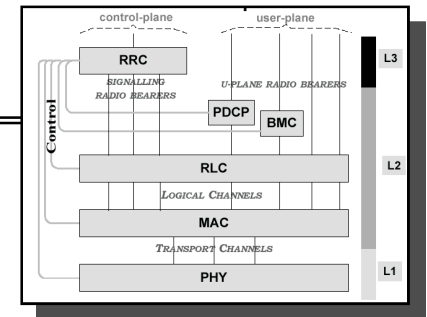


Protocols in the Radio Interface



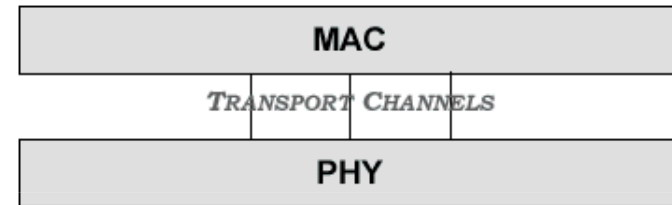
» Protocols between terminals and UTRAN (RNC or Node B)

Interface de Radio – Physical Layer



◆ Functions

- » WCDMA, frame formats, modulations

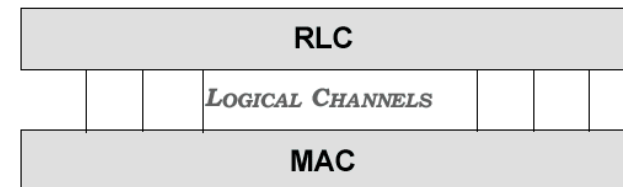
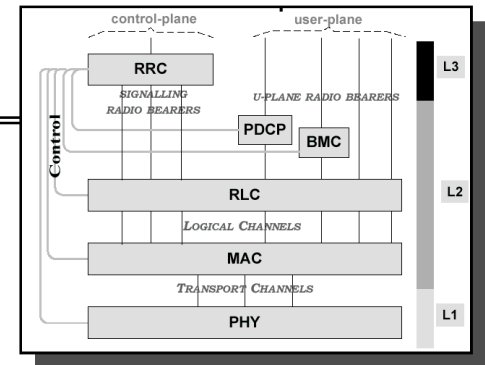


◆ Services → Transport channels

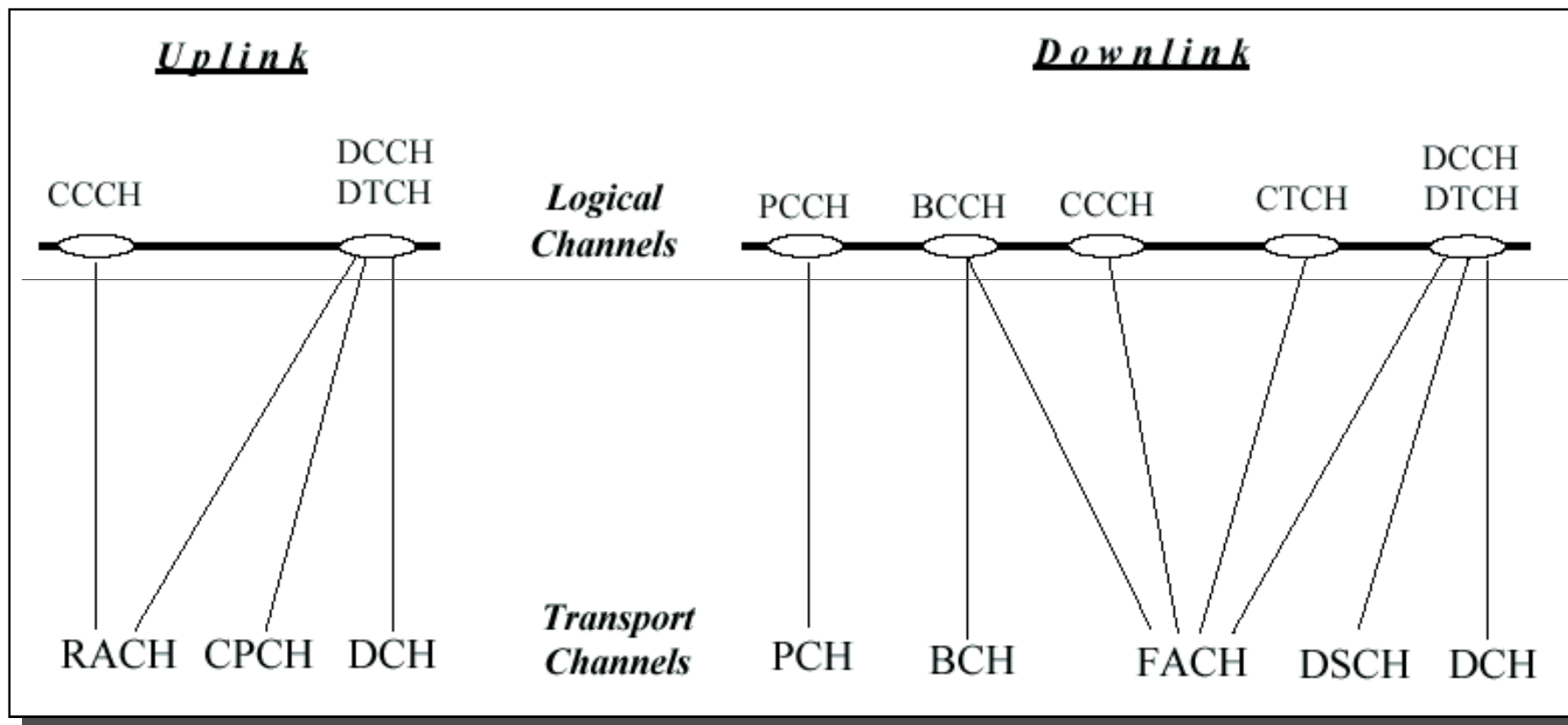
- » Dedicate channels ← Information associated to 1 terminal
 - DCH, Dedicated Channel. Uplink, downlink
- » Common channels ← Used by multiple terminals
 - BCH, Broadcast Channel. Downlink Broadcast in a cell
 - FACH, Forward Access Channel. Downlink. Terminal localized. Signaling, packets
 - PCH, Paging Channel. Downlink. Terminal non-localized. Signaling, packets
 - DSCH, Downlink Shared Channel. Downlink. Packets
 - RACH, Random Access Channel. Uplink. Random. Signaling, packets
 - CPCH, Common Packet Channel. Uplink. Contention. Packets

Radio Interface –MAC Layer

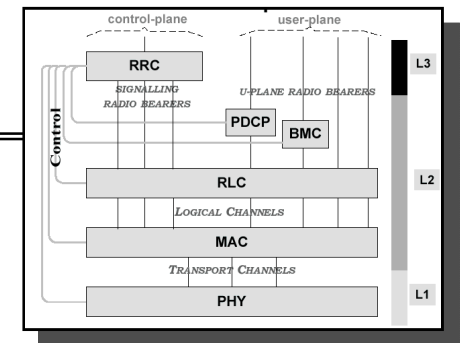
- ◆ MAC, Medium Access Control
- ◆ Funções
 - Multiple access to shared channels
 - Optimized for packet transmission
- ◆ Serviços → Logical channels
 - » Control channels
 - BCCH, Broadcast Control Channel. Downlink
 - PCCH, Paging Control Channel. Downlink
 - DCCH, Dedicated Control Channel. Uplink, Downlink.
 - CCCH, Common Control Channel. Uplink, Downlink
 - » Traffic channels
 - DTCH, Dedicated Traffic Channel. Uplink, Downlink
 - CTCH, Common Traffic Channel. Downlink



Canais Lógicos \leftrightarrow Canais de Transporte



Radio Interface –RLC Layer



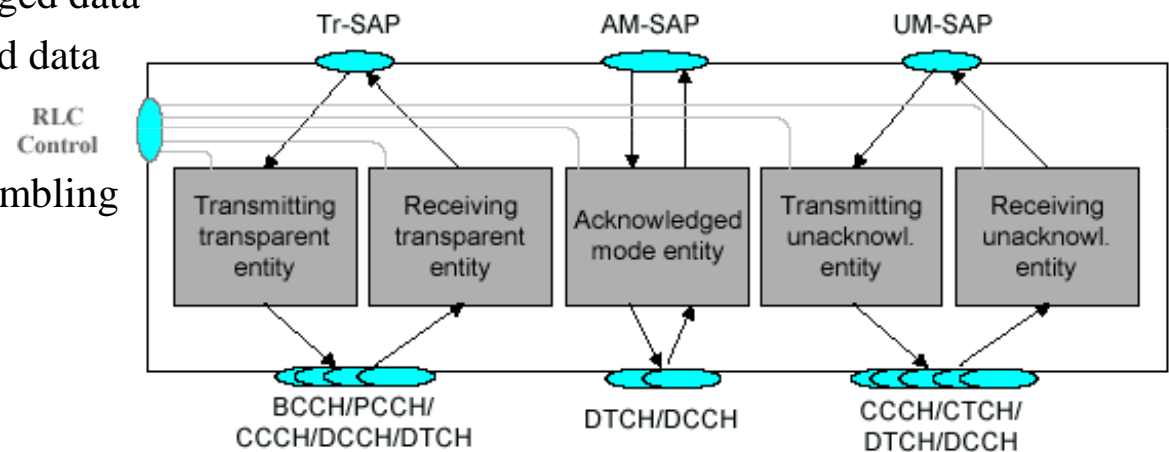
» RLC, Radio Link Control

» Services

- Tr-SAP: Transparent data
- UM-SAP: Unacknowledged data
- AM-SAP: Acknowledged data

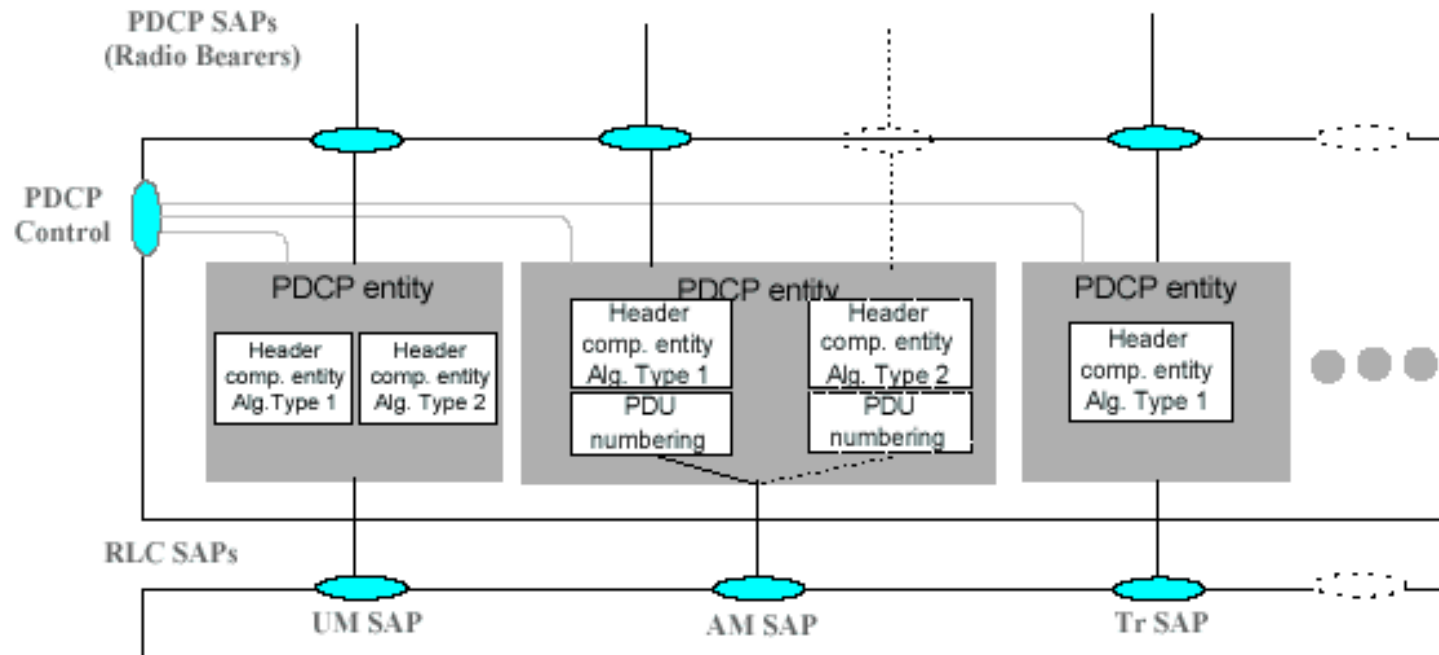
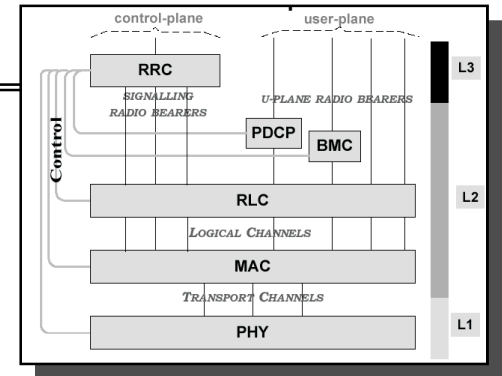
» Function

- Segmentation and reassembling
- Concatenation
- Padding
- Ordered delivery
- Flow control
- Encryption
- ARQ (error detection, error retransmission)
- User data transference
- Verification of sequence number (in the Unacknowledged data mode)

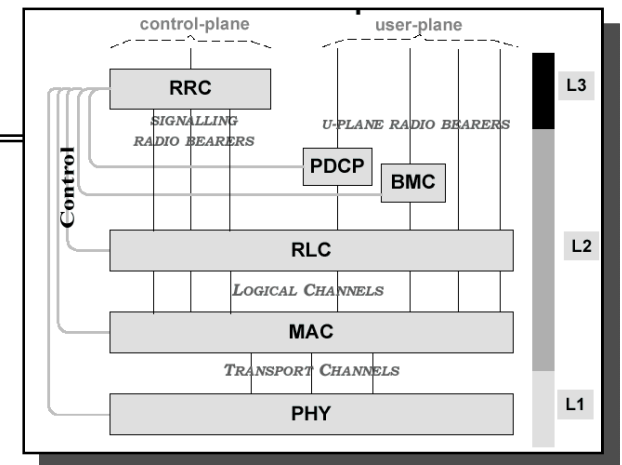


Radio Interface –PDCP

- » PDCP, Packet Data Convergence Protocol
- » (De) compression of IP headers
 - TCP/IP
 - RTP/UDP/IP
- » Re-localization with no losses



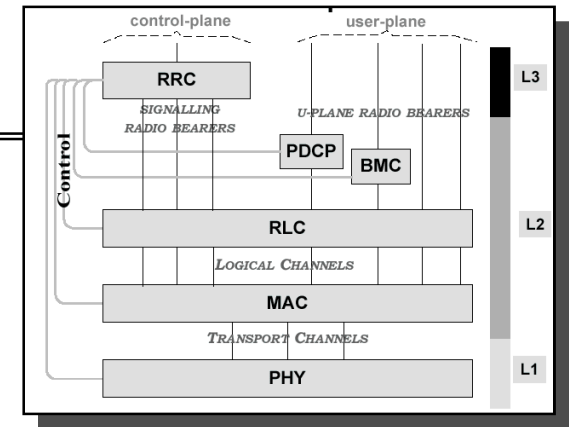
Interface de Rádio – Nível BMC



- ◆ BMC, Broadcast/Multicast Protocol
 - » Serviço de difusão de informação comum em modo não confirmado

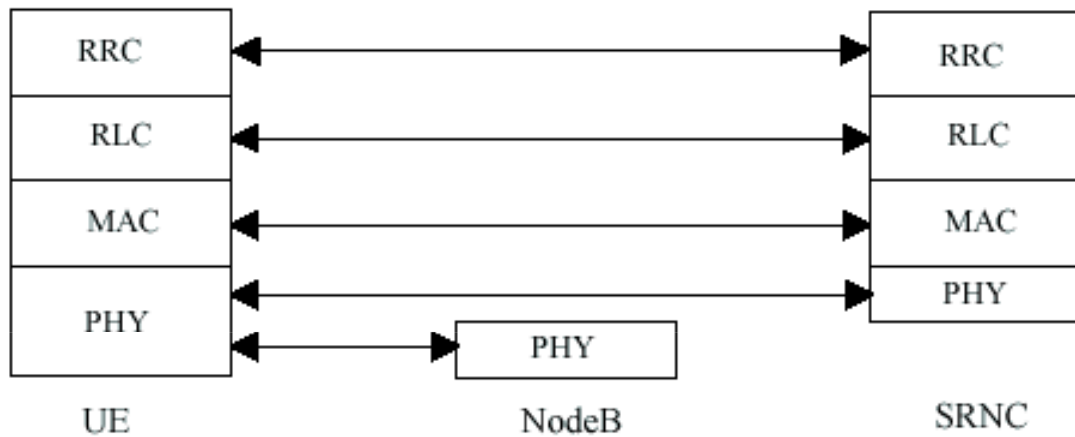
Radio Interface –RRC

- » RRC, Radio Resource Control
- » Function
 - Broadcast of system information. Paging. Cell selection
 - Establishment and termination of the RRC connection (UE \leftrightarrow UTRAN)
 - Channel control
 - Security control
 - Mobility of the RRC connection
 - Power control in downlink. Open loop power control
- » Services
 - SAP generic control \rightarrow broadcast of information for users in an area
 - SAP notification \rightarrow broadcast of information for one terminal in one area
 - SAP dedicated control \rightarrow establishment/termination of a radio channel with QoS

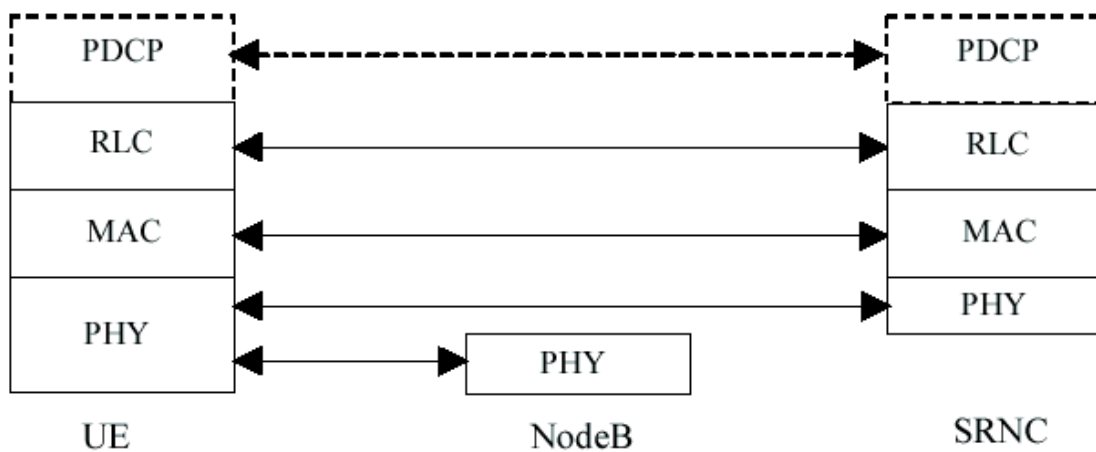


Interface de Rádio – Terminação dos Protocolos

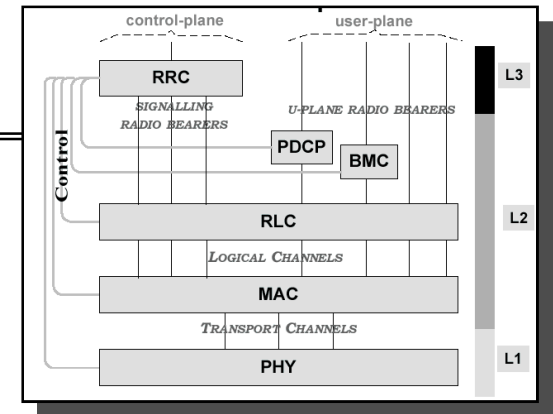
UMTS 58



Plano de Controlo



Plano de Utilizador



Interface de Rádio – RRM

◆ RRM, Radio Resource Management

- Procedimentos e algoritmos de gestão da interface rádio
- Implementado no RRC
- Recursos a gerir em WCDMA → potência transmitida, códigos

» Selecção de células

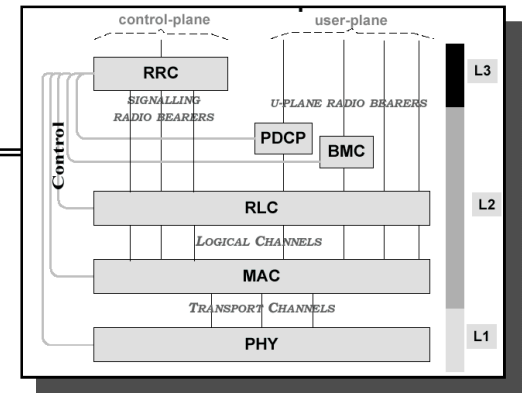
- Terminal servido por uma estação base.
- Selecção da estação que implique menor potência transmitida

» Controlo de admissão

- Em CDMA, número de sessões aumenta → qualidade global baixa
- Decisão de entrada de novas sessões

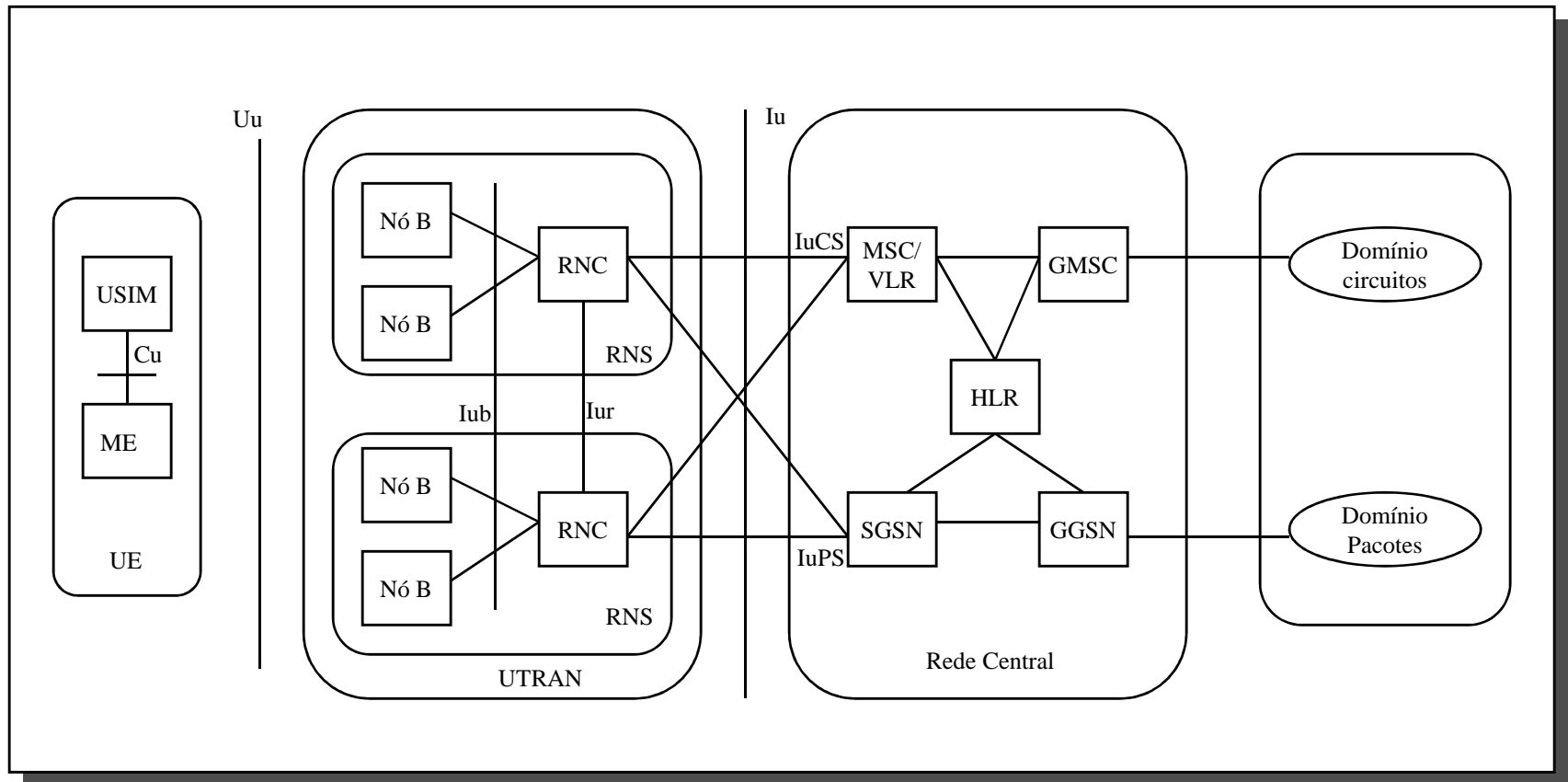
» Soft handover (entre células)

- Controlo do processo



4. Rede Central

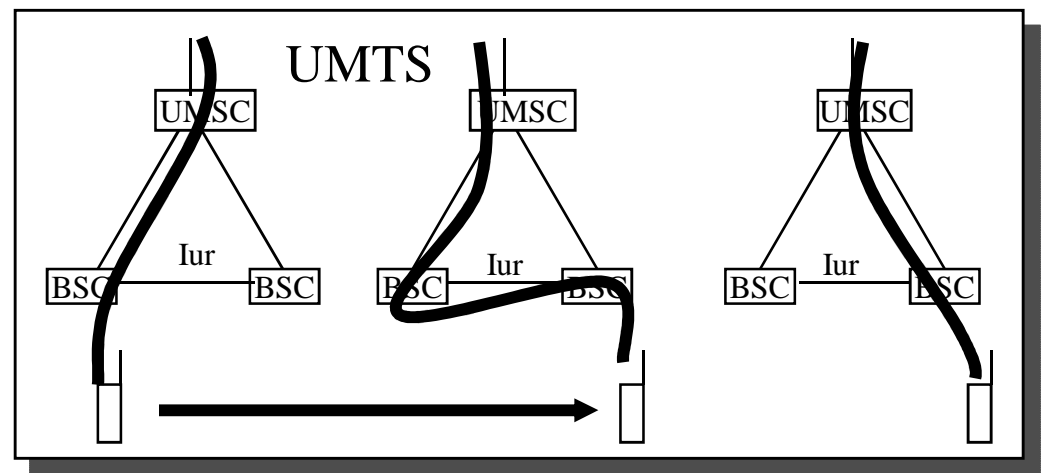
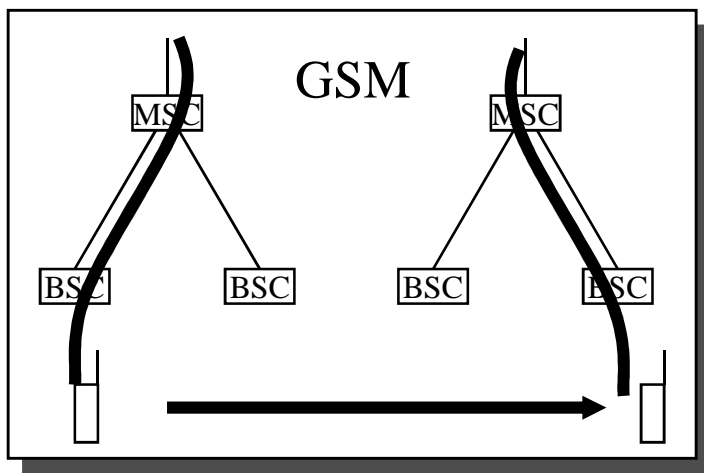
UMTS Network Architecture



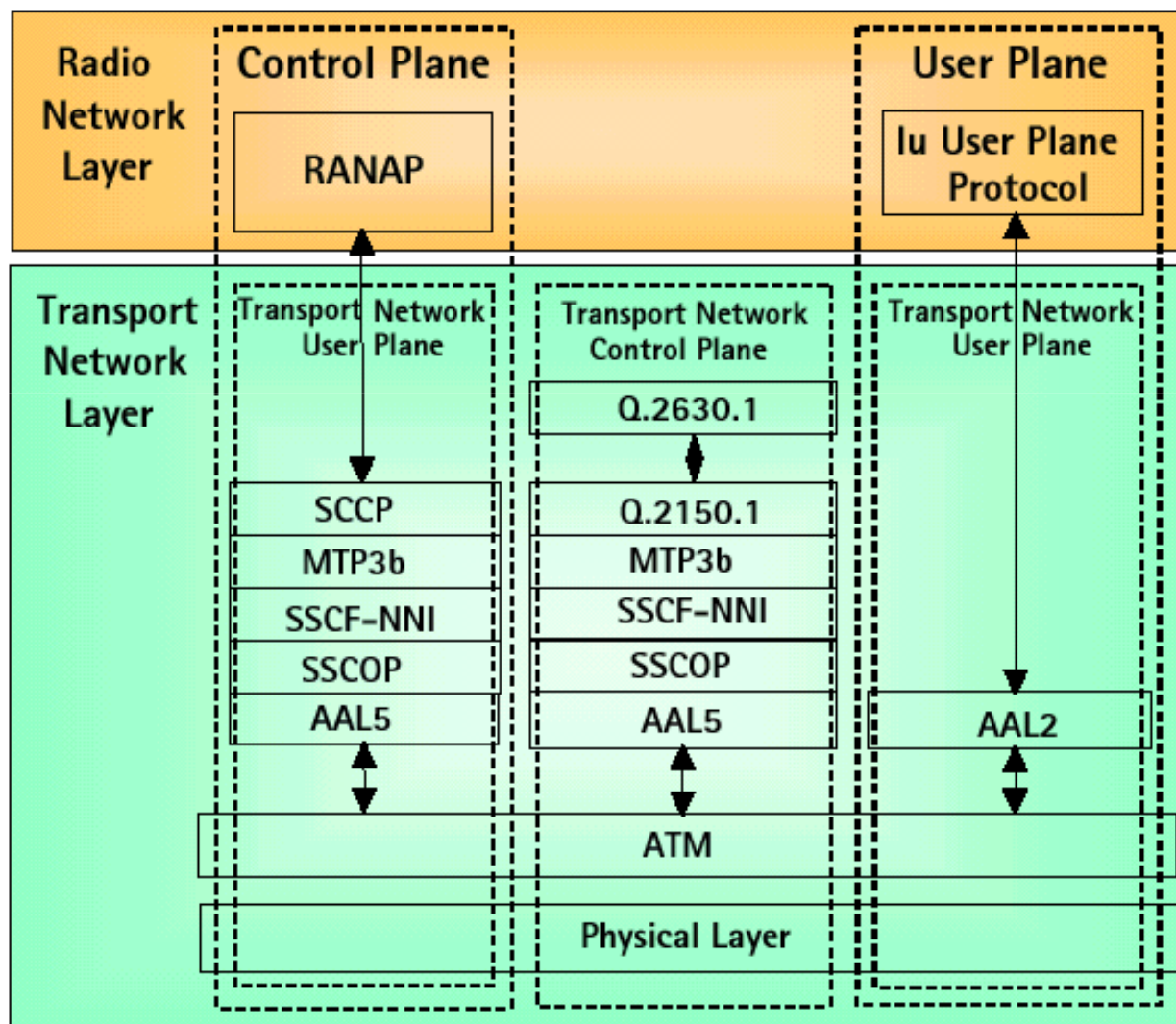
- » Architecture UMTS → UTRAN + core network
- » Core network
 - Circuit domain (CS) → MSCs, GSM, ISDN, voice, video
 - Packet domain (PS) → xGSNs, GPRS, IP, data

Rede Central de Comutação de Circuitos - Aspectos Inovadores

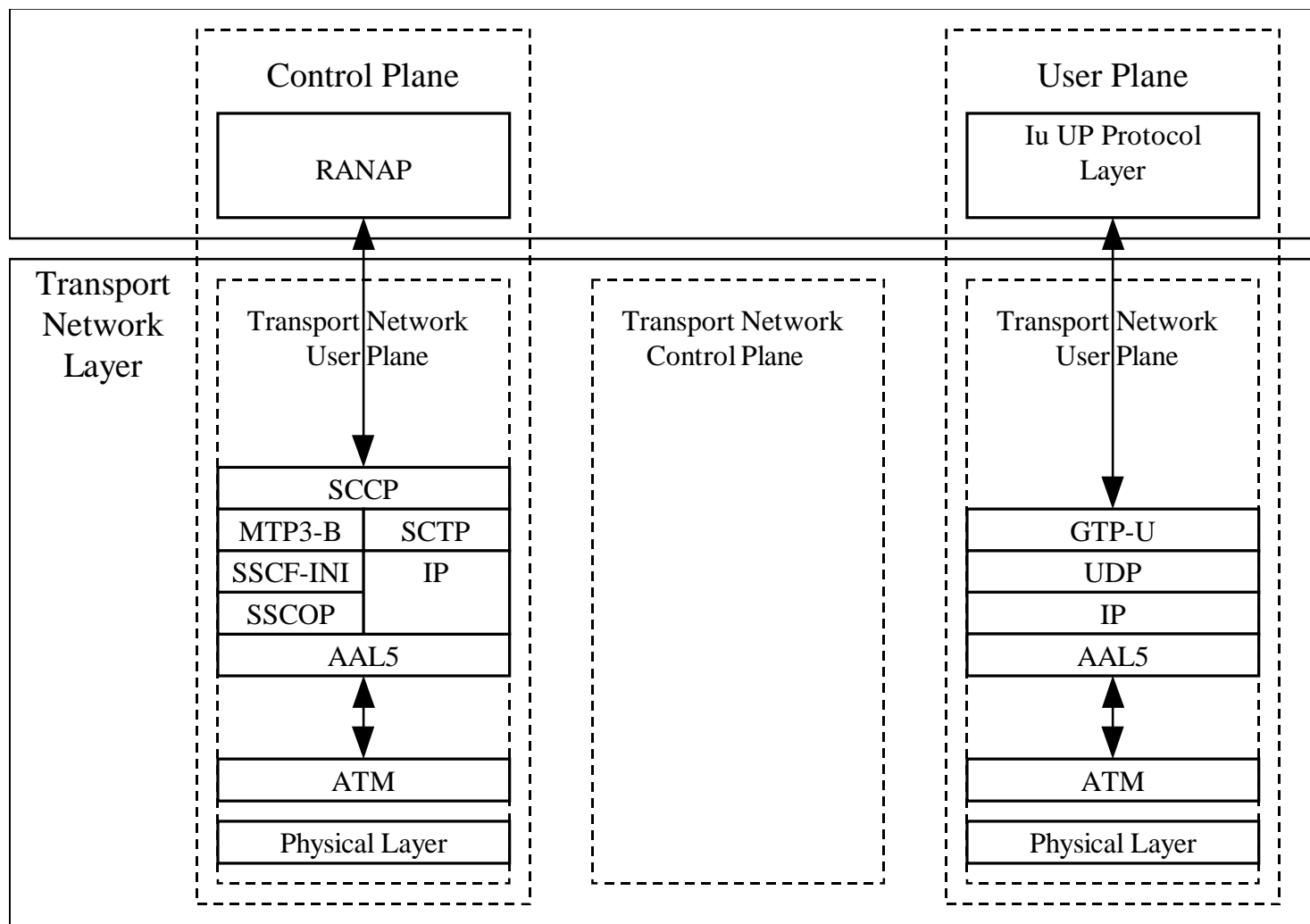
- ◆ Adopção ATM como rede de transporte
 - Suporte de circuitos com débitos entre 4 kbit/s a 2 Mbit/s
 - Suporte de circuitos com débitos variáveis
- ◆ Handover
 - Interface Iur → handover em 2 passos
 - Mais simples para rede; mais rápido para utilizador



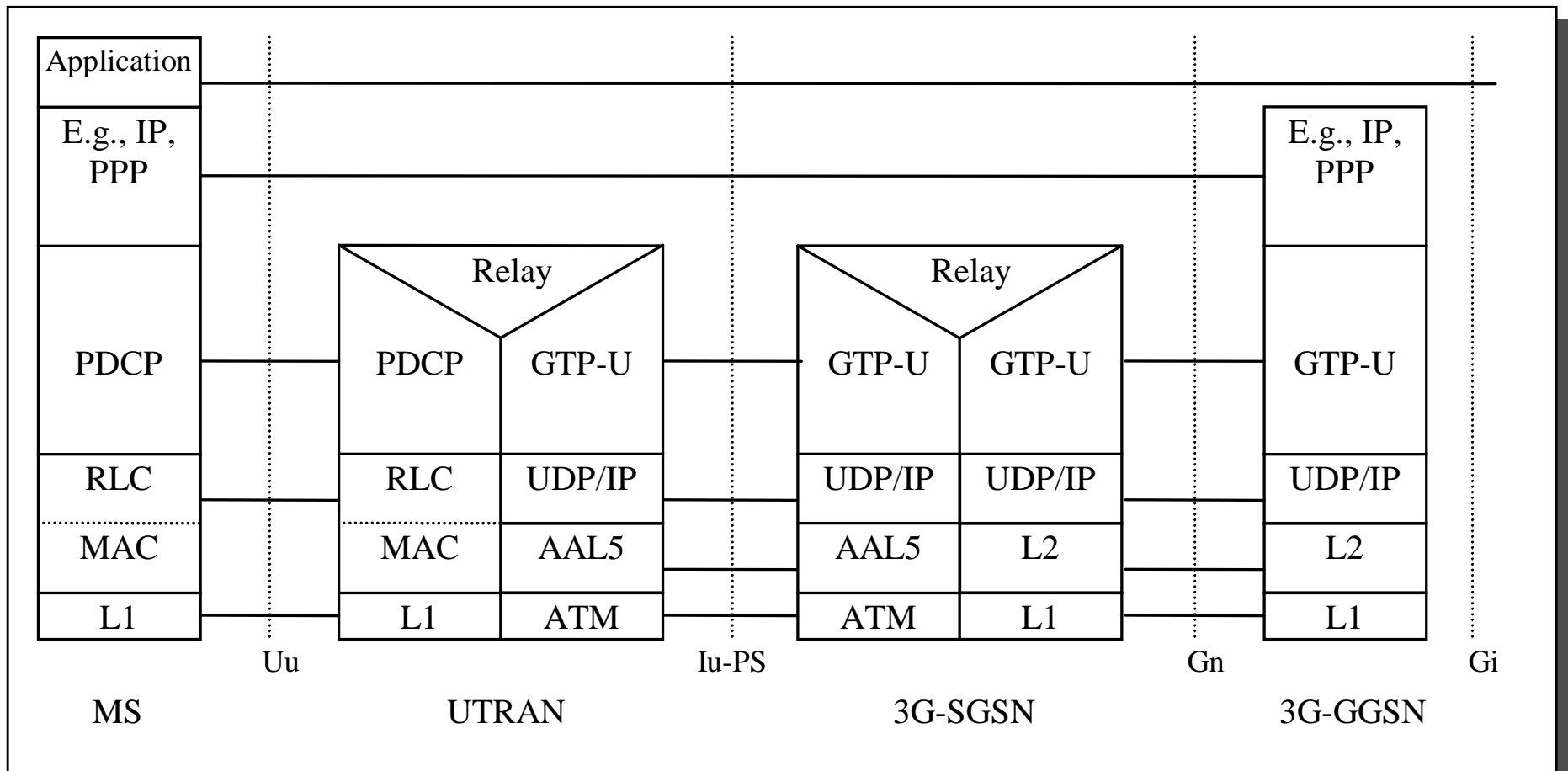
Iu CS



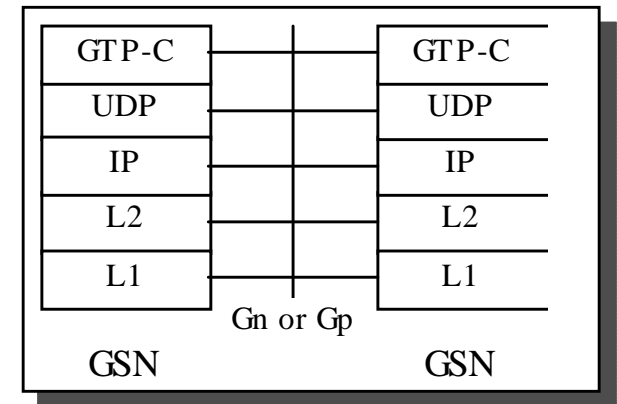
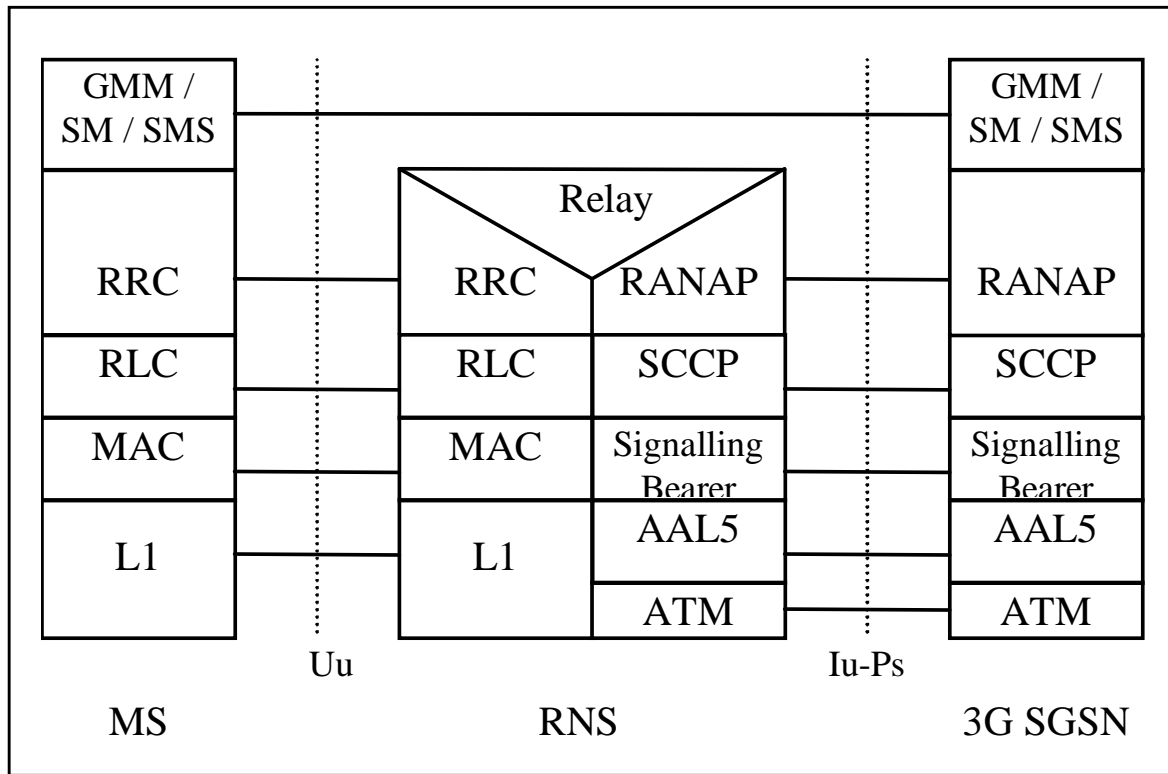
Iu PS



Packet Domain – Protocols, User Plane



Rede Central de Comutação de Pacotes – Protocolos, Plano de Controlo



Serviços Básicos

