

WCDMA

Hemant K Rath

Research Scholar

Department of Electrical Engineering

IIT-Bombay

hemantr@ee.iitb.ac.in

Outline

- Introduction
- Generations of Mobile Networks
- 3G Standards
- Introduction to UMTS and WCDMA
- WCDMA Concepts
 - Spreading, Scrambling
 - Power Control
 - Handover
- WCDMA Channels
- WVDMA Packet Access

Generations of Mobile Networks

■ 1G Networks

- NMT, C-Nets, AMPS, TACS
- First analog cellular systems, started in early 1980s

■ 2G Networks

- Mainly Voice Traffic
- GSM, cdmaOne(IS-95), DAMPS launched in early 1990s

■ 2.5G Networks

- Enhanced versions of 2G networks
- GPRS, IS-95B, cdma2000 1x

■ Comments

- Need of a better system
 - To support High bit rate services
 - Web and multimedia access

Technical Requirements of 3G

■ Bit Rate

- Rural outdoor 144 kbps (Vehicular)
- Suburban outdoor 384 kbps (Pedestrian)
- Indoor 2 Mbps

■ Variable bit rate capability

- Granularity, circuit and packet bearers

■ Service Multiplexing

■ Varying delay and quality of service requirements

- Traffic Priorities

Technical Requirements of 3G

■ Handover

- Seamless between cells and different operators
- Co-existence with and handover to 2G systems
 - With WCDMA to GSM

■ Support of asymmetric traffic

■ High spectrum efficiency

■ Coexistence of FDD and TDD modes

Generations of Mobile Networks (contd.)

■ 3G Networks

- UMTS (FDD & TDD), cdma2000 1x EVDO, cdma2000 3x, TD-SCDMA, EDGE
- Data Rates of 144kbps, 384kbps and up to 2 Mbps

■ 4G is a marketing buzzword at the moment

- Some basic 4G research is done
- No frequencies have been allocated
- Could be ready for implementation around 2012

3G Standards

■ Approved by ITU

■ CDMA 2000

- Backward compatibility with cdmaOne (IS-95)
- Mainly backed by USA

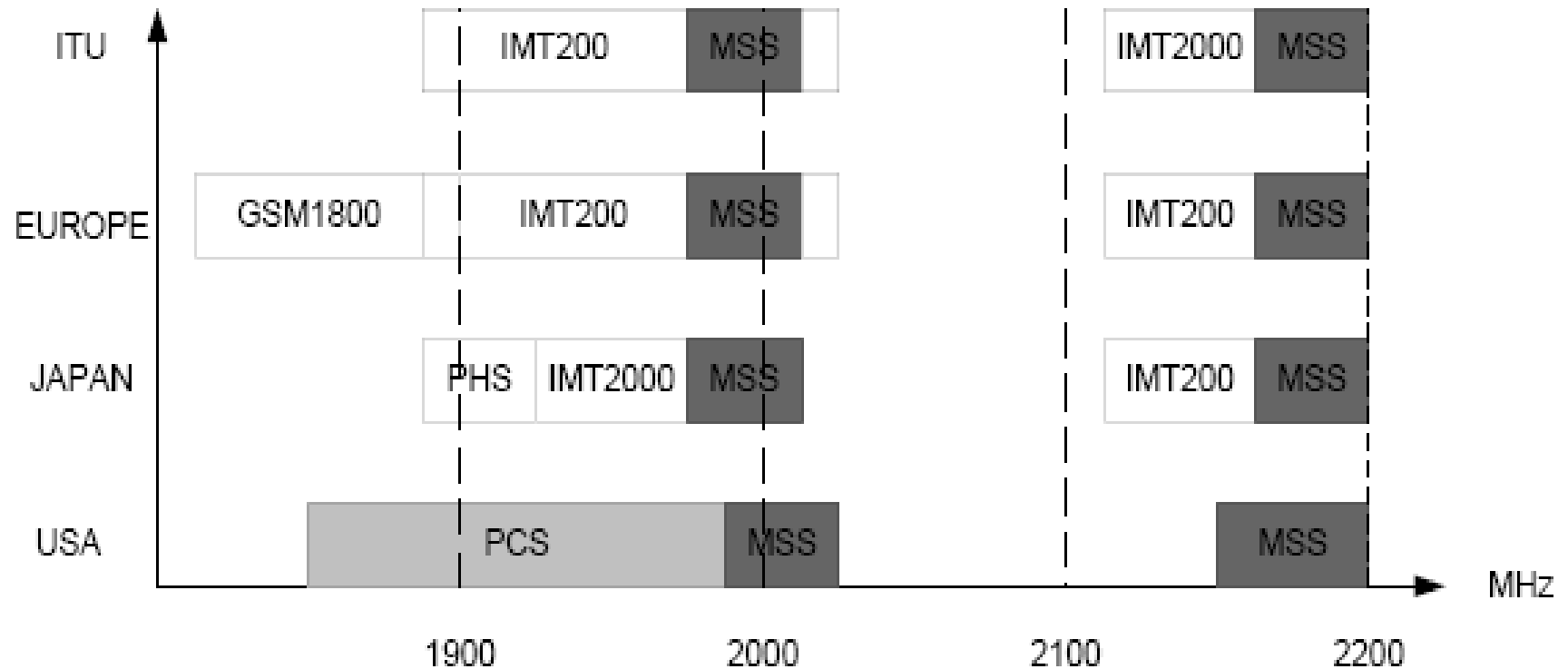
■ UMTS

- Developed for Europe with GSM networks
- New frequency band and new technology
 - Need of new radio access network to be build
- Advantages
 - New frequency range gives plenty of new capacity for operators
- Optional backward compatible with GSM systems
 - SIM card and the phone can be of dual mode

3G Spectrum Assignment

- Different country has different frequency scheme
- European allocation scheme is used in India
 - 1810-1880 MHz : GSM
 - 1880-1900 MHz : DECT
 - 1900-1920 MHz : UTRA TDD
 - 2020-2025 MHz : UTRA TDD
 - 1920-1980 MHz : W-CDMA FDD (UL)
 - 2110-2170 MHz : W-CDMA FDD (DL)
 - $2 \times 60 = 120$ MHz
 - 50 x 2 MHz is reserved for mobile switching station operations

3G Spectrum Assignment : Summary



Introduction: UMTS

- Evolution in terms of capacity, data rates and new service capabilities from 2G mobile networks
 - More than 60 3G/UMTS networks using WCDMA technology
 - More than 25 countries are operating commercially
- Integrated solution for mobile voice and data with wide area coverage
- Symmetry between uplink and downlink data rates
 - Ideally suited for applications such as real-time video telephony

Introduction: UMTS

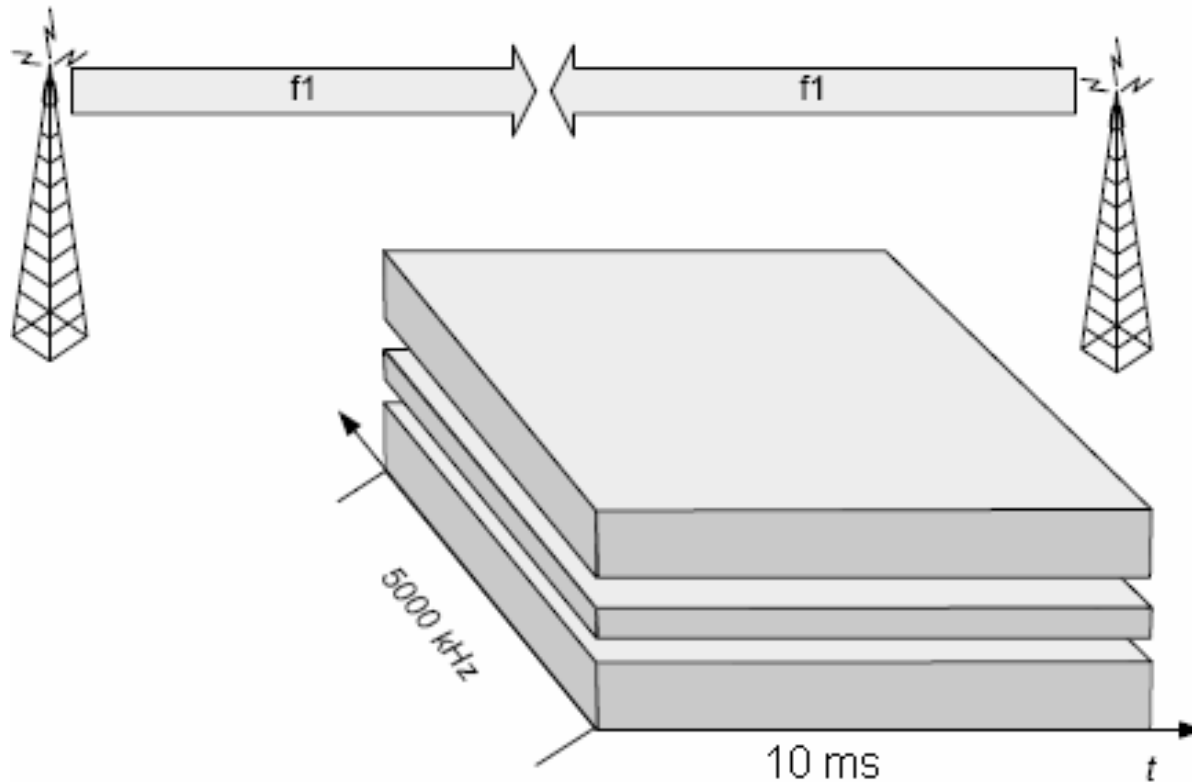
- End-to-end mobile system, with additional benefits
 - Automatic international roaming, integral security, billing
 - Migration from 2G to 3G while retaining many of their existing back-office systems
- Gives operators the flexibility to introduce new multimedia services
 - Brand-based relationships with the customers
 - New revenue opportunities by encouraging additional traffic
 - New usage patterns and strengthen customer loyalty

Introduction: WCDMA

■ WCDMA - Wideband CDMA

- Why the term *wideband*?
- Radio access technology for one of the UMTS access modes (UTRA FDD) using 5 MHz duplex channels
 - Frame length is of 10 msec, Chip rate is 3.84 Mcps
 - All users share the same frequency and time domain
 - Users separated by the codes
 - Codes are orthogonal
- UMTS is a system and WCDMA is the radio access technology in UMTS

WCDMA Based System

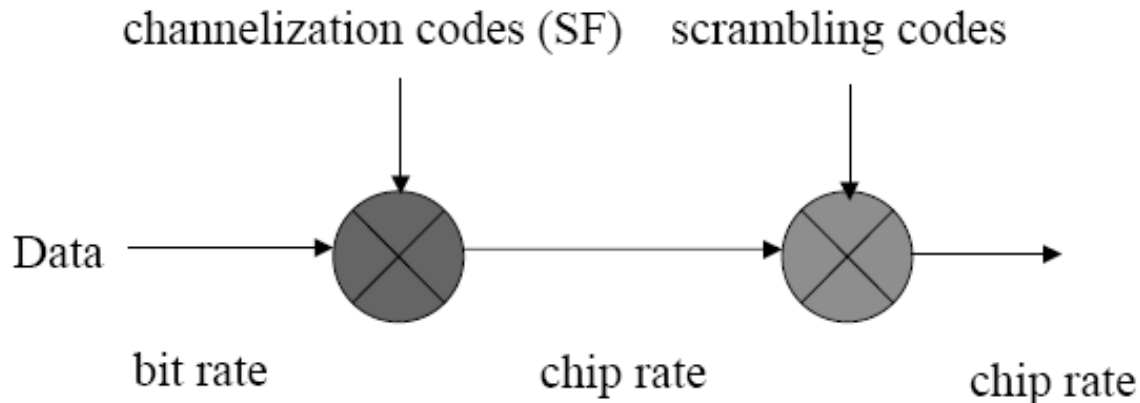


WCDMA Based System

- Supports bandwidth on demand
 - Variable data rate
- Supports asynchronous BSs
 - No need of GPS
- Coherent detection in UL and DL
- Advantages of CDMA are also available
 - Multi user detection
 - Smart adaptive antenna

Spreading in WCDMA

- Spreading means increasing the signal bandwidth
- Spreading includes two operations
 - Channelization (increases signal bandwidth)
 - Orthogonal Spreading
 - Scrambling (does not affect the signal bandwidth)
 - Use pseudo-noise codes



Benefits of Spreading

- Processing gain with wideband freq results in re-use of 1 between cells
 - High spectral efficiency
- No of users are more
 - Interference diversity
 - Interference averaged out
- Need of tight power control and Handover
 - In both UL and DL
 - Soft and Softer hand over
- Higher BW results in higher accuracy
 - Higher diversity content against fading
 - Because of Multi-path diversity

Channelization in WCDMA

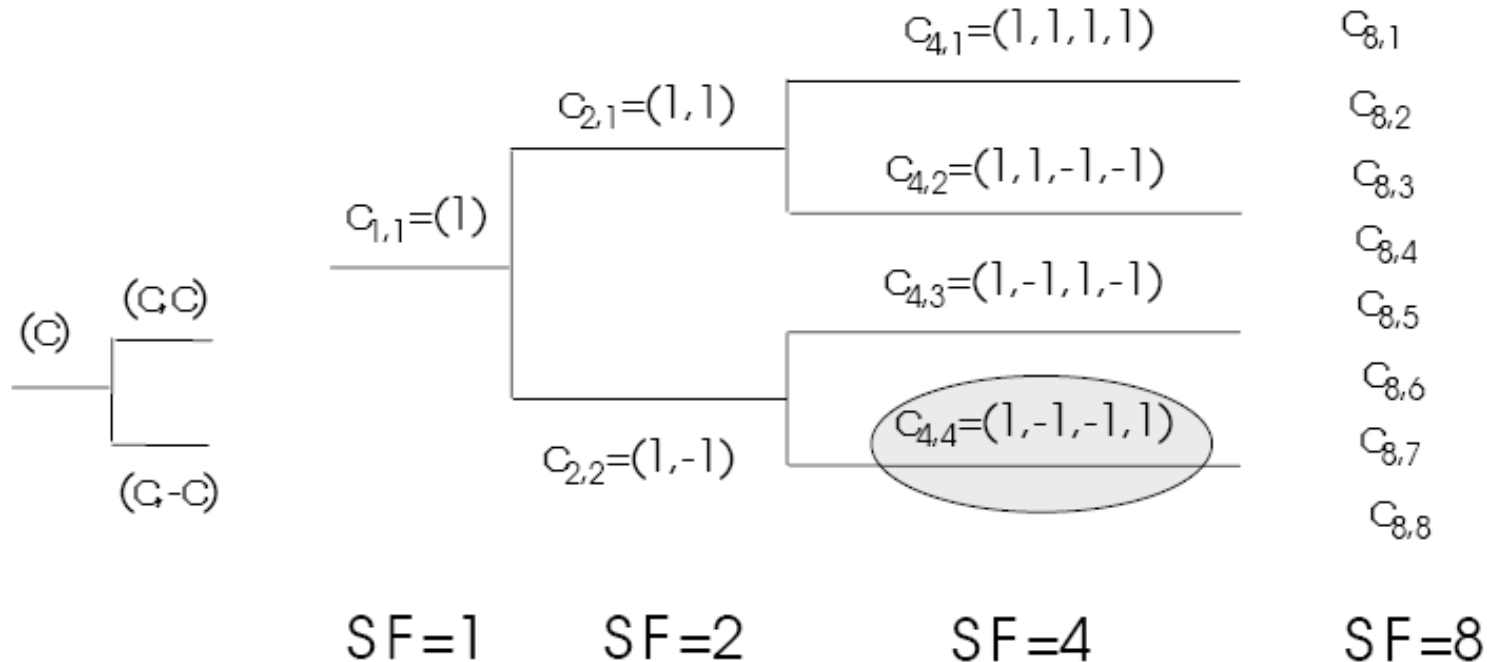
- Channelization codes are orthogonal codes
 - Based on Orthogonal Variable Spreading Factor (OVSF)
 - Codes are fully orthogonal, i.e., they do not interfere with each other
 - Only if the codes are time synchronized
 - It can separate the transmissions from a single source
 - In DL, it can separate different users within one cell/sector
- Limited orthogonal codes must be reused in every cell
 - **Problem:** Interference, if two cells use the same code
 - **Solution:** Scrambling codes to reduce inter-base-station interference

Channelization in WCDMA

- UL: it separates the physical channels/services of one user
 - Mobiles are not synchronized in time
 - Two mobiles can use the same code
 - Scrambling codes are used to separate different users in the UL
- The Channelization codes are picked up from the code tree
- One code tree is used with one scrambling code on top
- Different terminals and BSs may operate their code trees independent of each other
 - No need to co-ordinate the code tree resource usage between BSs or terminals

Channelization in WCDMA – Code Tree

If $c_{4,4}$ is used, no codes from its sub-tree can be used ($c_{8,7}$, $c_{8,8}$, ...).



Scrambling in WCDMA

- Code sequence is multiplied with a pseudo-random code
- The scrambling code can be a long code or short code
 - Code period is of 10 ms
 - Gold code with 10 ms period or short code S(2) code
- DL: scrambling codes are used to reduce inter-BS interference
 - Node B has only one scrambling code for UEs to separate base stations
 - A code tree under one scrambling code is used by all users in its cell
 - Proper code management is needed
 - DL: No short codes, only long codes
 - Number of codes in the DL – 512
 - Code planning is needed in the DL

Scrambling in WCDMA

- UL: scrambling codes are used to separate terminals
 - UL: Both short and long codes
 - Number of codes in the UL – Millions
 - Code planning is not needed in the UL
- Long scrambling codes are used if BS uses Rake Rxr
- Short scrambling codes can be used, if multi-user detector is used at the BS
- One scrambling code should be used per cell or sector
 - Maintains orthogonally between different down link channels

Channelization and Scrambling in WCDMA

	Channelization Code	Scrambling Code
Usage	UL: Separation of physical and control channels from same UE DL: Separation of different users within one cell	UL: Separation of terminals DL: Separation of cells/sectors
Length	UL: 4-256 chips same as SF DL: 4-512 chips same as SF	UL: 38400/256 chips (25-degree) DL: 38400 chips (18-degree)
No. of Codes	No of codes under one scrambling code = SF	UL: several million DL: 512
Code Family	Orthogonal variable spreading factor	Long 10 ms code: Gold code Short code: Extended S(2) family
Spreading	Increase Transmission BW	Does not affect Transmission BW

Multi-path Radio Channels

■ Multi-path propagation between Txr and Rxr

- WCDMA system chip duration at 3.84 Mcps is 0.26 μ sec
 - WCDMA Rxr can separate those multi paths and combine them coherently to obtain multi-path diversity
 - *78 m of Multi-path diversity*
 - *It is around 300 m in IS-95*

■ Counter measures of fading in WCDMA

- Multiple Rake Fingers
- Fast Power Control and inherent diversity reception of the Rake Rxr
- Strong Coding and Interleaving and re-transmission protocols
 - Redundancy and time diversity

Physical Layer Procedures

- Many procedures are essential for system operation
 - Power control (PC)
 - Handover
 - Paging
 - Random Access Procedure
 - Transmit Diversity

Power Control: Need

■ Need of Power control

- Removes near-far effect
- Changes in propagation conditions
- To decrease interference from other users
- To increase capacity of the system

■ What is near-far effect?

- Variation of power level and interference due to distance and fading
 - In the uplink
 - ◆ At the BS
 - In the downlink
 - ◆ AT the cell edge

Power Control: Types

■ Uplink power control

- Tight and Fast power control
 - Without this a over powered mobile could block the whole cell
- Open loop power control
 - Provide a coarse initial power setting, inaccurate
- Closed loop power control
 - BS informs mobile unit to increase or decrease the power level
 - Faster than any changes of path loss that could happen

■ Downlink power control

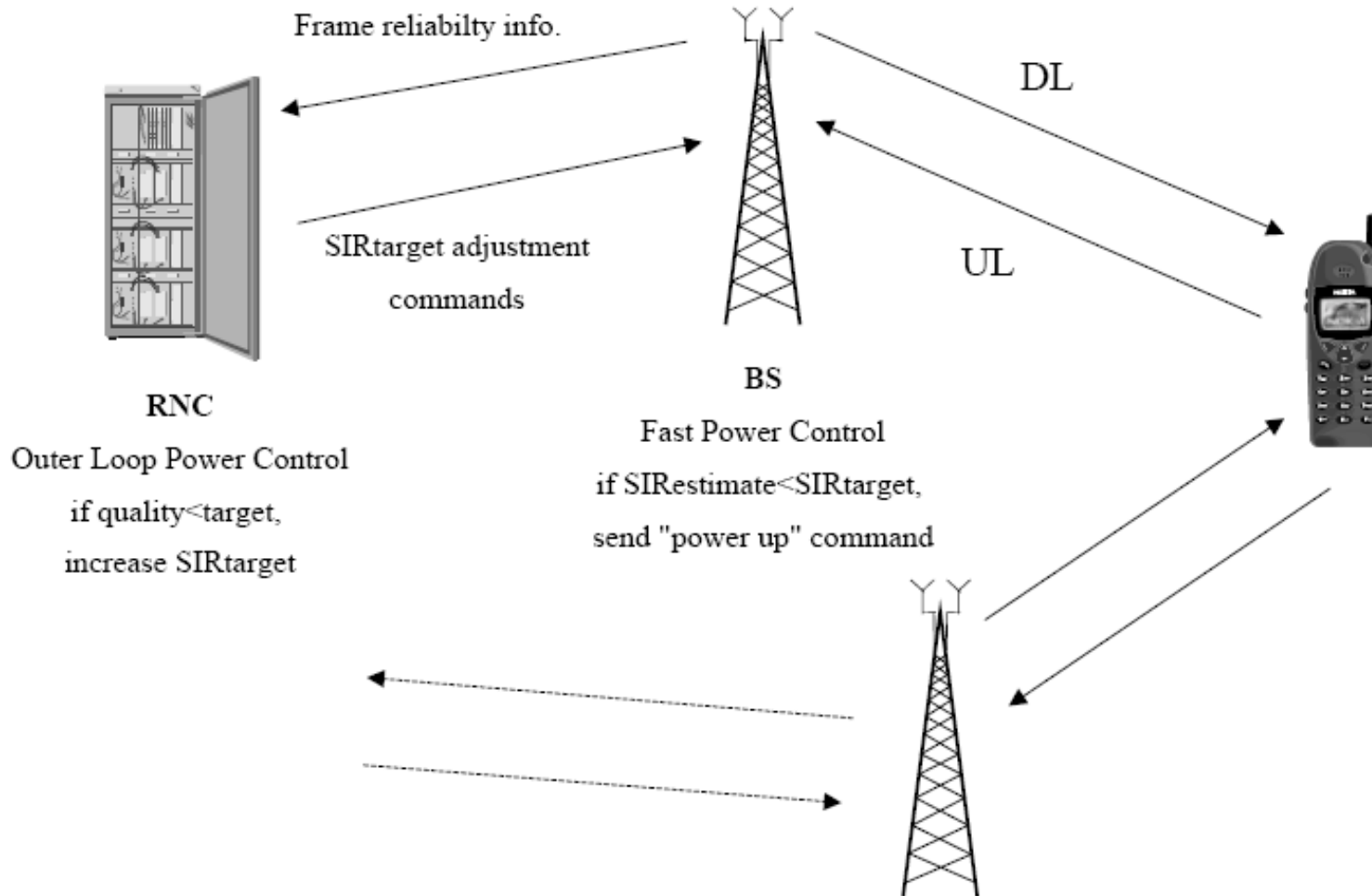
- More power may require at the cell edge
- Similar to uplink power control
- No near-far effect
- Motivation is different
 - One to Many (BS to mobile units)

Power Control

■ Outer Loop power control

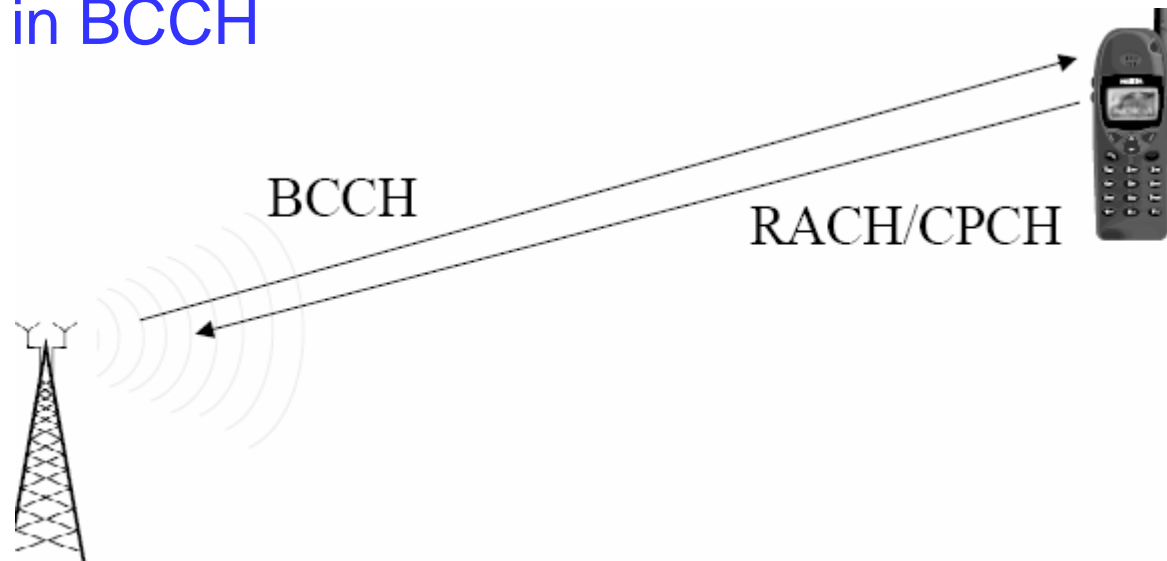
- Adjusts the target SIR set point in the BS according to the target SIR set point in the BS
- Controls of the channel by setting target Eb/No
 - Quality requirement is given as long term average of FER/BER
- UL
 - RNC sets the target value --- why?
 - Control is located in the BS for FDD
- DL
 - Located in UE, the initial control parameters are set by UTRAN
 - Receives inputs of the quality estimates of the transport channel

Power Control: Procedures



Open Loop Power Control

- No feedback information
- Make a rough estimate of the path loss by means of a DL beacon signal
- Provide a coarse initial power setting of the mobile at the beginning of a connection
- Apply only prior to initiating the transmission on RACH or CPCH
- The BS transmits in BCCH



Closed Loop Power Control

- Uses channel in other direction for transmitting the order for power change
- Applied only to dedicated channels
- Makes E_b/N_0 requirements lower
- PC speed 0.666 ms
 - Compensates the fading for slow and medium speed

Handover: Types

■ Intra-system handovers

- Intra-frequency handovers
 - MS handover within one cell between different sectors:
 - ◆ softer
 - MS handover between different BS
 - ◆ Soft
- Inter-frequency handovers
 - Hard

■ Inter-system handovers:

- Handover between WCDMA <--> GSM (Hard)
- Handover between WCDMA/FDD <--> TDD (Hard)

Handover: Types

■ Soft Handover

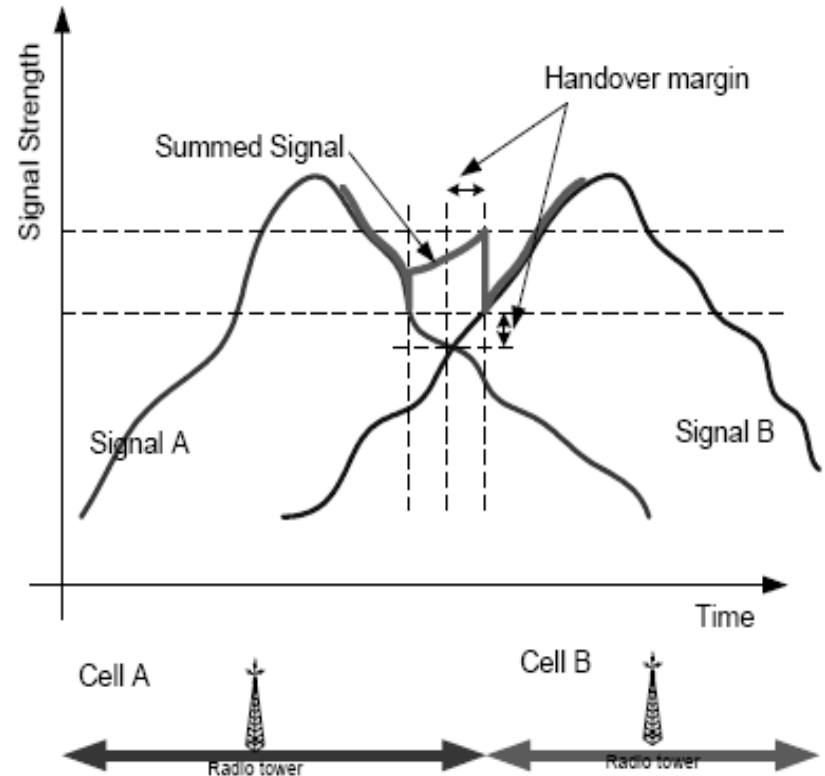
- Handover between two BSs
- 20-40% connections
- 2 PC loops per connection is active, each for one BS
- Use of additional Rake Rxr channels at the BS
- Soft and softer handover can take place in combination with each other

■ Softer Handover

- Handover between two sectors of one BS
- 5-15% connections
- Only one power control loop per connection

Soft Handover

- Strength of the A becomes equal to defined lower threshold
- The neighboring B signal has adequate strength.
 - B is added to Active Set
- Quality of signal B starts to become better than signal A
 - RNC keeps that point as starting point for handover margin calculation
- The strength of signal B becomes equal or better than the defined lower threshold
- As a result, RNC deletes signal A from the Active Set



Handover: Comments

- Avoidance of near-far situation for circuit switched connections
 - For high mobility users shadow fading + (slow) hard handovers would create near far situations.
- Soft/Softer handovers will improve cell capacity
 - Around 40-60 %
- Soft/Softer provide macro-diversity gain
 - compared the hard handover larger cell range
 - Gain against shadow fading (1 -3 dB)
 - Gains against fast fading, typically 0.5 - 2 dB assumed

WCDMA Channels

Concepts of Channels

- Our aim is to transfer data
 - Type of data to be transferred
 - How to transport (end-to-end)
 - How to transmit physically
- Data carried by the UMTS / WCDMA transmissions is organized into frames, slots and channels
 - UMTS uses WCDMA for multiple access technology
 - Time division techniques with a slot and frame to provide channel structure

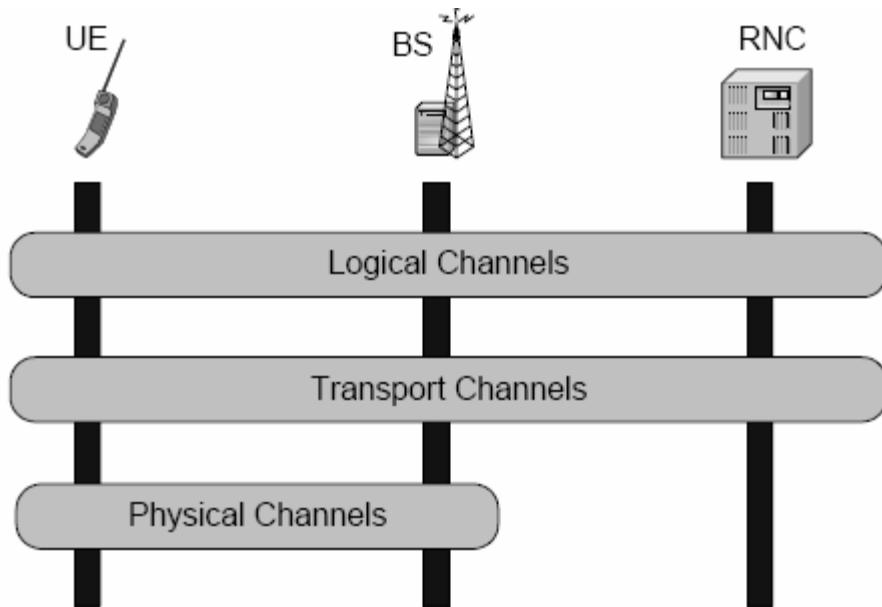
Concepts of Channels

- A channel is divided into 10 ms frames
 - Each Frame has 15 time slots of 0.666 ms each
 - DL: time is subdivided into time slots
 - Used for either user data or control messages
 - Discontinuous transmission needs I-Q Multiplexing
 - UL: Transmitted simultaneously
- Longer period is used as system frame period
 - Needs System Frame No (SFN) – 12 bit
 - Paging and Random access need longer period than 10 ms for correct definition

Concepts of Channels

- **Dual channel modulation is used in the UL**
 - Both data and control are transmitted simultaneously
- **Control elements contain**
 - A pilot signal, Transport Format Combination Identifier (TFCI), Feed Back Information (FBI) and Transmission Power Control (TPC)
- **Three types of channels**
 - Logical Channels
 - What type of data to be transferred
 - Transport Channels
 - How and with which type of characteristic the data is transferred by the Physical Layer
 - Physical Channels
 - Exact Physical characteristics of the radio channel

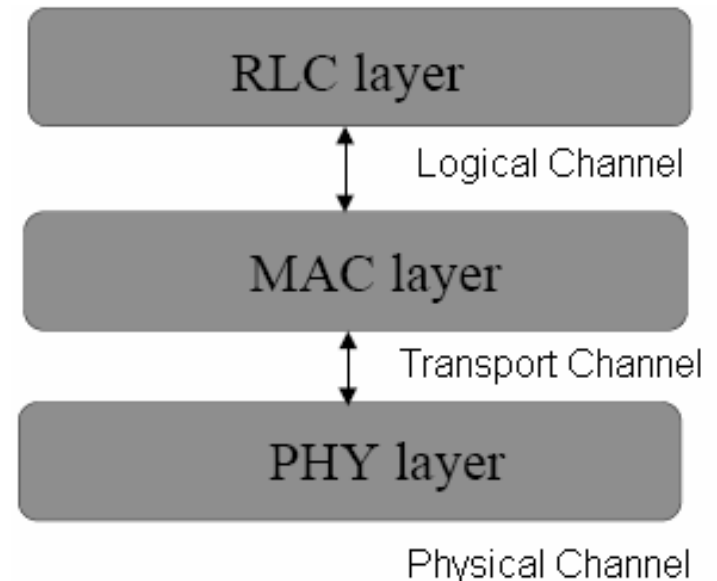
Concepts of Channels



- Transport channels are mapped in the Physical Layer to physical channels

- Support variable bit rate transport channels to offer bandwidth on demand services and multiplexing

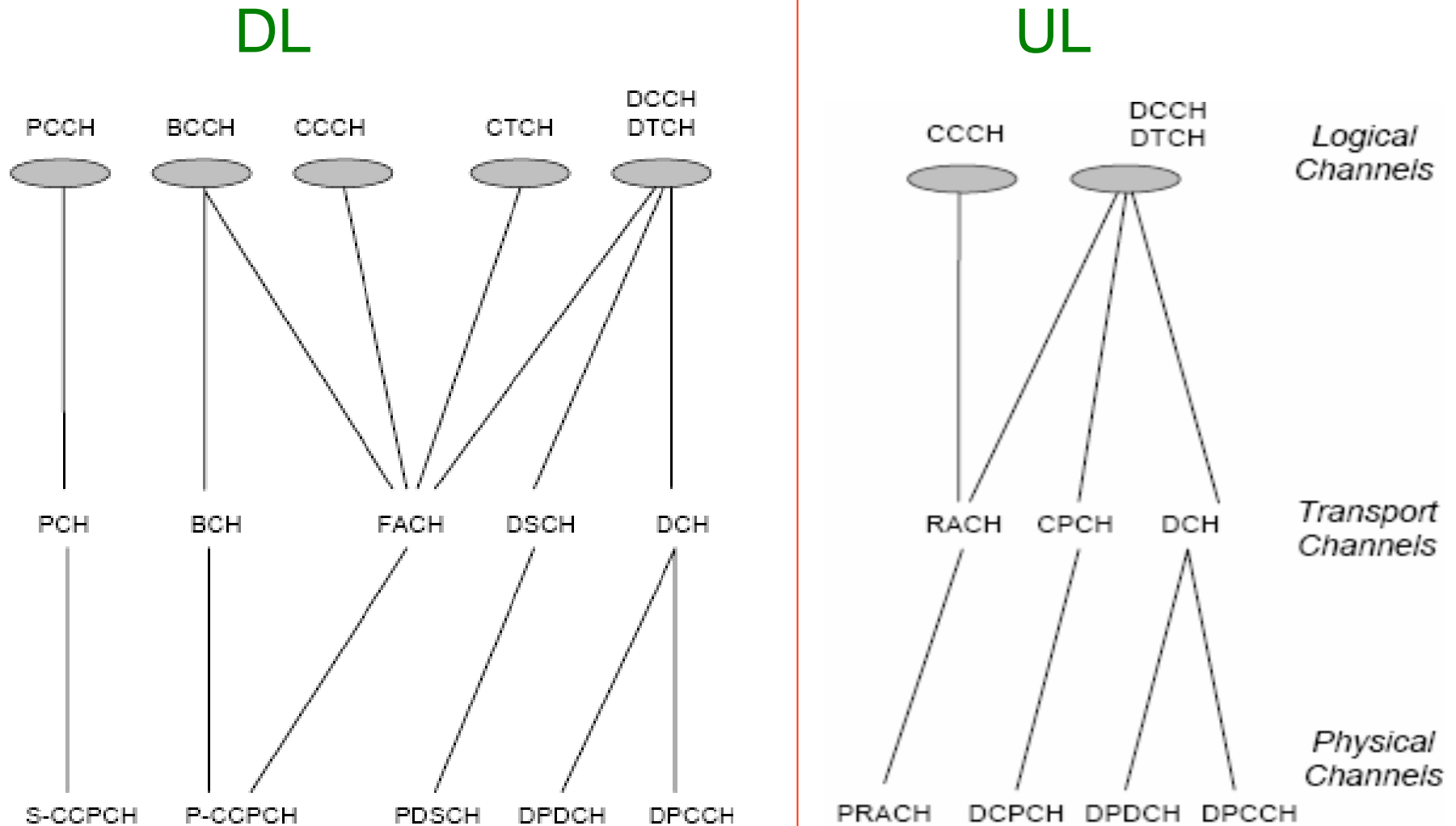
- Logical channels are mapped to transport channel based on the type of data to be transferred
 - Logical to Transport channel conversion happens in MAC Layer



Mapping from Transport to Physical

Transport Channels	Physical Channels
DCH (Dedicated Channels) – UL/DL	Dedicated physical data channel (DPDCH) Dedicated physical control channel (DPCCH)
Broadcast Channel (BCH) – DL	Primary Common Control Physical Channel (PCCPCH)
Forward Access Channel (FACH) - DL Paging Channel (PCH) – DL	Secondary Common Control Physical Channel (SCCPCH)
Random Access Channel (RACH) – UL	Physical Random Access Channel (PRACH)
Downlink Shared Channel (DSCH) - DL	Physical Downlink Shared Channel (PDSCH)
Common Packet Channel (CPCH) – UL	Physical Common Packet Channel (PCPCH)

Mapping of Channels: Summary



Paging

- A Paging group is allocated to a terminal once it is registered
- Paging indicators (PI) appear periodically on the Paging Indicator Channel (PICH)
 - If any paging messages for any of the terminals belong to that group needs to be sent
- After a PI is detected, terminal decodes the next PCH frame transmitted on the secondary CCPCH
- Less often the PIs appear, the less often the terminal needs to wake up from the sleep mode
 - Longer the battery life becomes
 - Response time for network originated call increases

WCDMA Packet Access

Types of Packet Data Traffic

- Four basic types of traffic classes
 - Conversational class
 - Real-time connection, performed between human users, really low delay, nearly symmetric
 - ◆ Speech
 - Streaming class
 - Real-time connection, transferring data as a steady and continuous, low delay, asymmetric
 - ◆ Video

Types of Packet Data Traffic

■ Four basic types of traffic classes (contd.)

● Interactive class

- Non-real-time packet data, response requested from other end-user, reasonable round-trip delay
 - ◆ Web browsing

● Background class

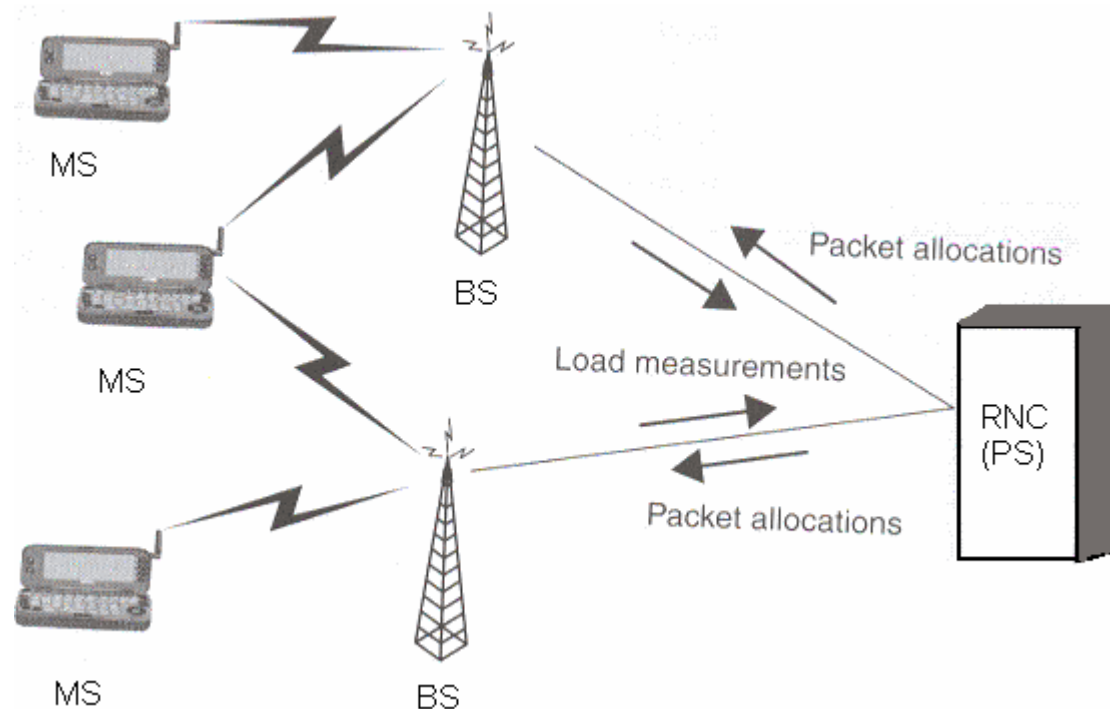
- Non-real-time packet data, no immediate action expected, less sensitive to delivery time
 - ◆ E-mail

Types of Packet Data Traffic

- Packet data traffic is a non-real-time packet services including Interactive and Background traffic classes
- Properties of Packet Data Traffic
 - Packet data is bursty
 - Required bit rate can change rapidly
 - Packet data tolerates longer delay than real-time services
 - It is controllable traffic from the RNC
 - RNC can decide when and how to send the data
 - Packets can be transmitted by the radio link control layer which provides retransmission and error correction services
 - It allows high frame error rate with low transmission power

WCDMA Packet Access

- In WCDMA packet allocations, time and bit rate are controlled by the Packet Scheduler (PS)
 - PS is located in RNC – why?



WCDMA Packet Access

■ Packet Scheduler functions

- Allocates the available resources (time, code or power) between the packet data users
- Decides the allocated bit rates and the length of the allocation
- Decides to use the transport channel
- PS can allocate common, dedicated or shared channels to users
- Can change the bit rate during active connection
 - Can increase or decrease the network load by increasing or decreasing the bit rates of the packet bearers

2G vs. 3G: GSM vs. WCDMA

	GSM	WCDMA
Carrier Spacing	200 kHz	5 MHz
Freq. Reuse Factor	1-18	1
Freq. Diversity	Frequency hopping	5 MHz BW results multi-path diversity
Planning	Frequency planning	Radio resource management
Scheduling	Time slot based	Load based
DL Tx. Diversity	Not supported (can be applied)	Supported
Power Control Freq	2 Hz or slower	1500 Hz

2G vs. 3G: CDMA vs. WCDMA

	IS-95	WCDMA
Carrier Spacing	1.25 MHz	5 MHz
Chip Rate	1.2288 Mcps	3.84 Mcps
BS Synchronization	Yes, via GPS	Not needed
Power Control Freq	UL: 800 Hz, DL: Slow power control	1500 Hz, both UL and DL
Inter Freq Handover	Possible, but not specified	Yes, with slotted mode
Efficient Radio Resource Management	Not needed (voice only)	Yes, provides QoS
DL Tx. Diversity	Not supported	Supported
Packet Data	As short circuit switched calls	Load based packet scheduling

Thanks