ELEC0102 – Mobile Communications Systems (MCS) [previously referred to as ELECGT19]

3G / UMTS

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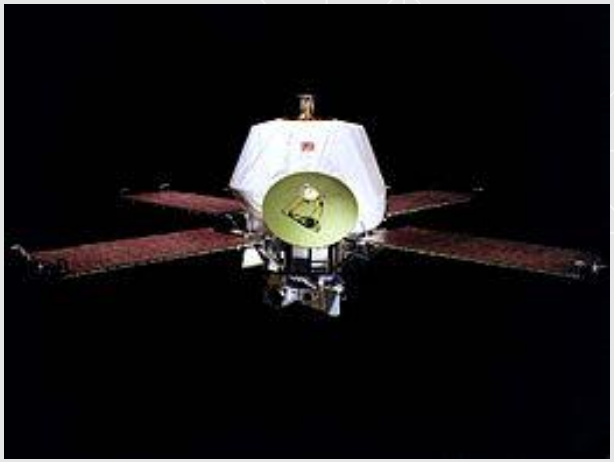
Before we get started…have a think…



How are they related to this session?

Outline

- **Part 1: UMTS Basics**
  - History and standardisation
  - System architecture
- **Part 2: UMTS Radio Interface**
  - Frequency bands and duplexing
  - Channel structure and mapping
  - Spreading, modulation, multiplexing and coding
- **Part 3: UMTS Physical Layer Procedures**
  - Cell search and synchronisation
  - Radio link establishment
  - Power control
  - Handover

HEALTH WARNING:

You are about to experience an explosion of acronyms and abbreviations!

NOTE:

The reference “radio-electronics.com” is now “electronics-notes.com”

PART 1: UMTS BASICS

Part 1: UMTS Basics – History and Standardisation

Third Generation (3G) Standards

- Goals for a 3G system defined by ITU in late 1990's.
  - ITU: International Telecommunication Union.
- Referred to as IMT-2000 by the ITU.
  - IMT: International Mobile Telecommunications
- Key differentiator from GSM was support of multimedia services.
- Eventually multiple, different 3G systems made up IMT-2000.
  - Not a single standard.
- Development now led by 3GPP.
  - 3GPP: Third Generation Partnership Project.

    http://www.3gpp.org/about-3gpp/partners
- UMTS is part of 3G family of systems (IMT-2000).
  - A separate standard within the 3G standards.

3GPP Standards (Releases)

3GPP RELEASES		
3GPP RELEASE	**RELEASE DATE**	**DETAILS**
Phase 1	1992	Basic GSM
Phase 2	1995	GSM features including EFR Codec
Release 96	Q1 1997	GSM Updates, 14.4 kbps user data
Release 97	Q1 1998	GSM additional features, GPRS
Release 98	Q1 1999	GSM additional features, GPRS for PCS 1900, AMR, EDGE
Release 99	Q1 2000	3G UMTS incorporating WCDMA radio access
Release 4	Q2 2001	UMTS all-IP Core Network
Release 5	Q1 2002	IMS and HSDPA
Release 6	Q4 2004	HSUPA, MBMS, IMS enhancements, Push to Talk over Cellular, operation with WLAN
Release 7	Q4 2007	Improvements in QoS & latency, VoIP, HSPA+, NFC integration, EDGE Evolution

Source: Radio Electronics, http://www.radio-electronics.com/info/cellulartelecomms/3gpp/standards-releases.php

3GPP Standards (Releases) – Continued

Release 8	Q4 2008	Introduction of LTE, SAE, OFDMA, MIMO, Dual Cell HSDPA
Release 9	Q4 2009	WiMAX / LTE / UMTS interoperability, Dual Cell HSDPA with MIMO, Dual Cell HSUPA, LTE HeNB
Release 10	Q1 2011	LTE-Advanced, Backwards compatibility with Release 8 (LTE), Multi-Cell HSDPA
Release 11	Q3 2012	Heterogeneous networks (HetNet), Coordinated Multipoint (CoMP), In device Coexistence (IDC), Advanced IP interconnection of Services,
Release 12	March 2015	Enhanced Small Cells operation, Carrier Aggregation (2 uplink carriers, 3 downlink carriers, FDD/TDD carrier aggregation), MIMO (3D channel modelling, elevation beamforming, massive MIMO), MTC - UE Cat 0 introduced, D2D communication, eMBMS enhancements.
Release 13	Scheduled for March 2016	LTE-U / LTE-LAA, LTE-M, Elevation beamforming / Full Dimension MIMO, Indoor positioning, LTE-M Cat 1.4MHz & Cat 200kHz introduced
Release 14	Mid 2017	Elements on road to 5G
Release 15	End 2018	5G Phase 1 specification
Release 16	2020	5G Phase 2 specification

Source: Radio Electronics, https://www.radio-electronics.com/info/cellulartelecomms/3gpp/standards-releases.php

Universal Mobile Telecommunication System (UMTS)

- European answer to IMT-2000.
  - Standardized in 3GPP (Release 99).
- Largely based on GSM standard and (commonly) uses WCDMA.
  - WCDMA: Wideband Code Division Multiple Access.
- Packet-based transmission of data with rates up to 2 Mbps.
- Key goals:
  - Higher data capacity.
  - Better speech quality.
  - Multimedia services and application.
  - IP interconnectivity.
  - Consistent service environment even when roaming.

3G vs UMTS vs WCDMA

- WCDMA refers to the radio access technology.
- UMTS refers to the complete 3G system.
  - Encompassing the radio access technology (WCDMA) and the core network.
- 3G describes the standards for systems fulfilling IMT-2000.

3G standard	First release	Mainly used in :	Standards body	Radio interface / modulation scheme
UMTS	2001	Europe, Japan, China	3GPP	W-CDMA (TDS-CDMA in China)
CDMA2000	2001	North America, South Korea	3GPP2	CDMA

TDS-CDMA: Time Division Synchronous – Code Division Multiple Access

Moving from GSM to UMTS

- Main difference between GSM and UMTS is the use of W-CDMA.
  - Modulation on the air interface.
- UMTS Terrestrial Radio Access Network (UTRAN) includes:
  - Radio Network Controller (RNC) .
  - Radio base stations, referred to in the standards as “Node B”.
- UMTS RNC and Node B, is similar to the GSM BSC and BTS.
- A new reference point, I_{ur}, is added between RNCs.
  - For macro diversity soft handover.
- RNC has a "general purpose" I_u interface to connect to the CN.
  - CN: Core Network.

Part 1: UMTS Basics – System Architecture

UMTS Terminology

Nomenclature :

MS / UE = Mobile Station / User Equipment

UTRAN = UMTS Terrestrial Radio Access Network

CN = Core Network

Uu = Radio interface which connects the UE to the UTRAN (similar to ‘Um‘ in GSM)

Iu = Interface which connects the UTRAN to the CN (similar to ‘A‘ interface in GSM)

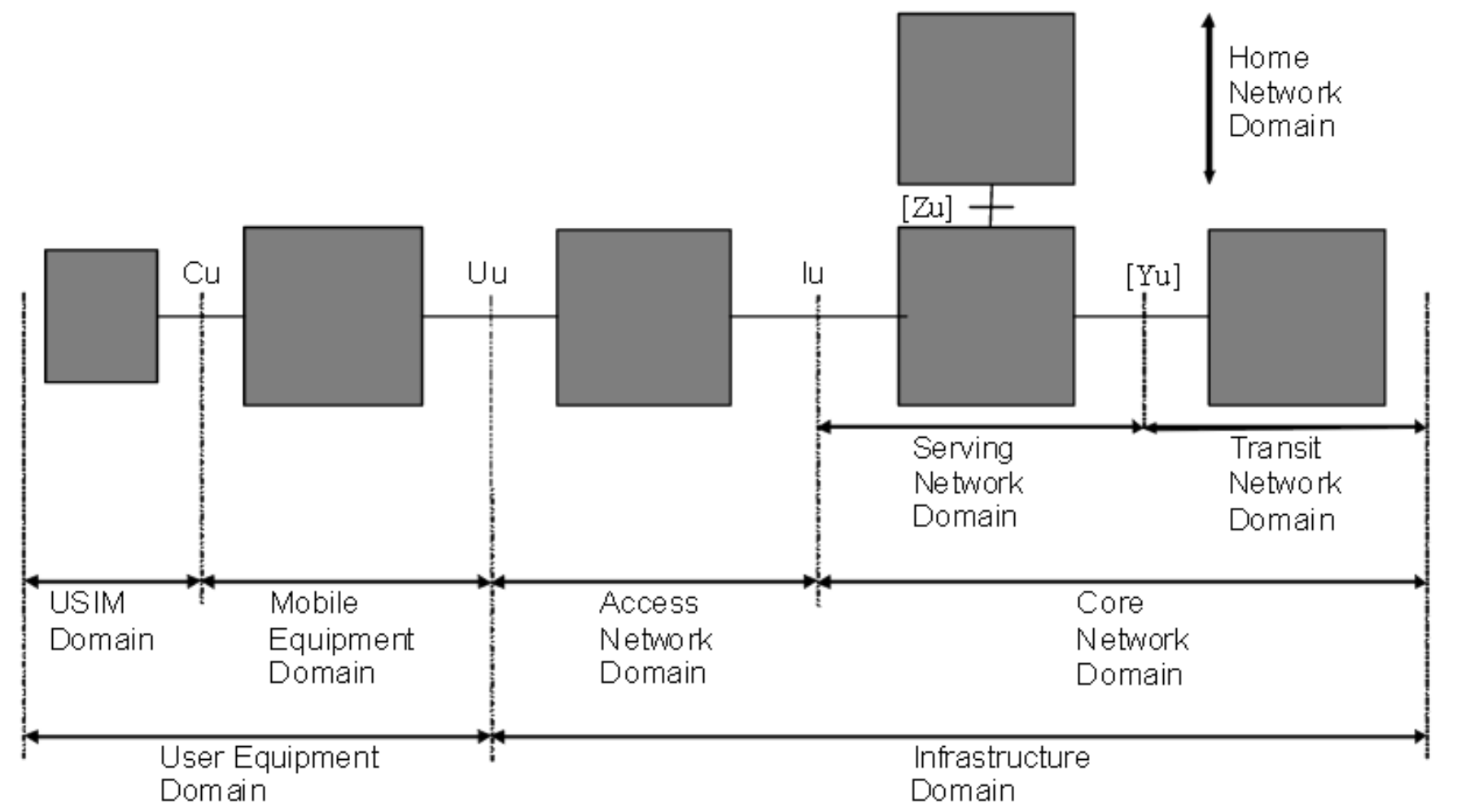
RNC = Radio Network Controller

RNS = Radio Network Subsystem

Iub = Connects the Node B and the RNC (similar to Abis in GSM)

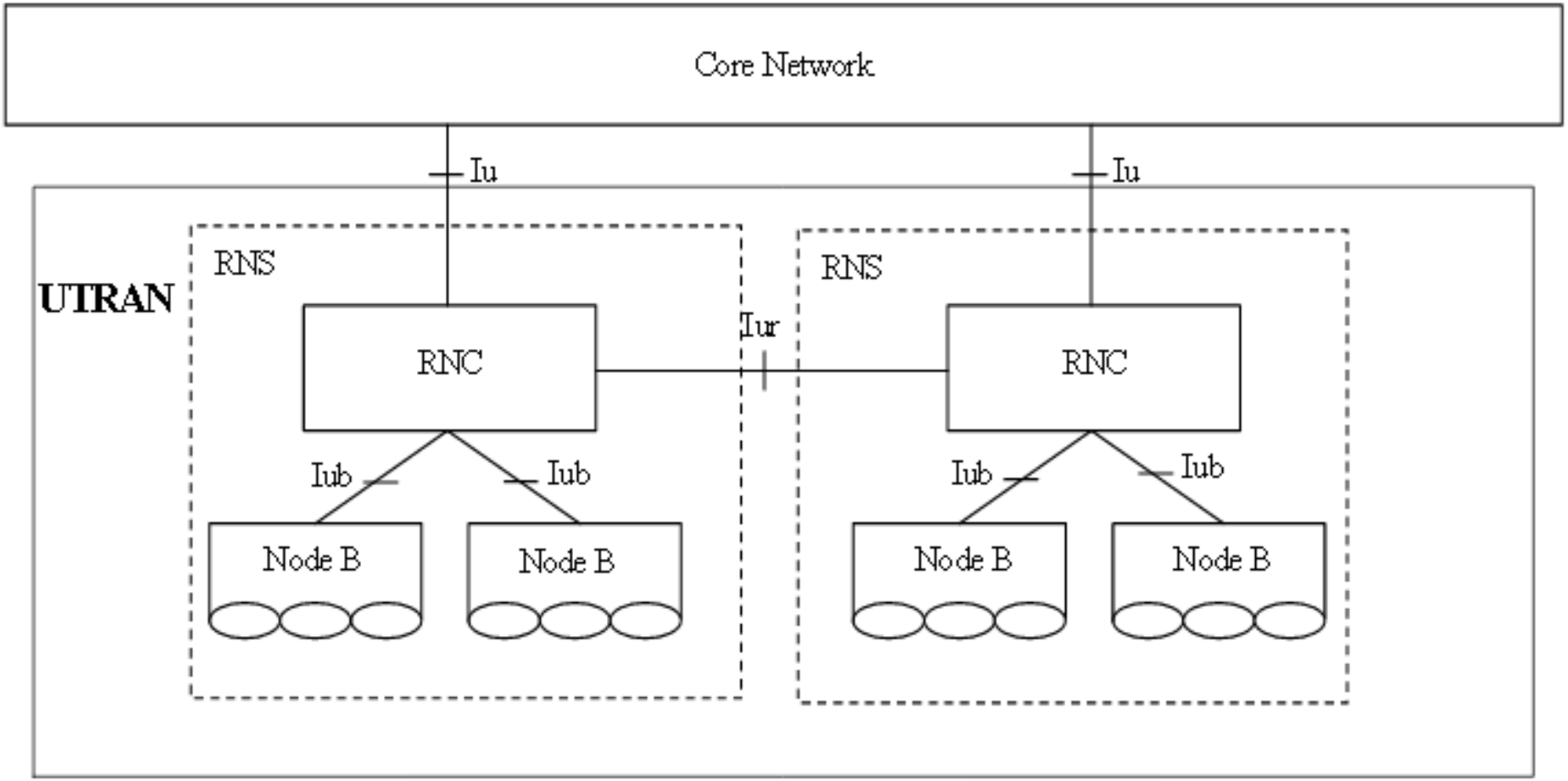
Iur = Allows RNCs to communicate between them

UMTS Architecture – Top Level



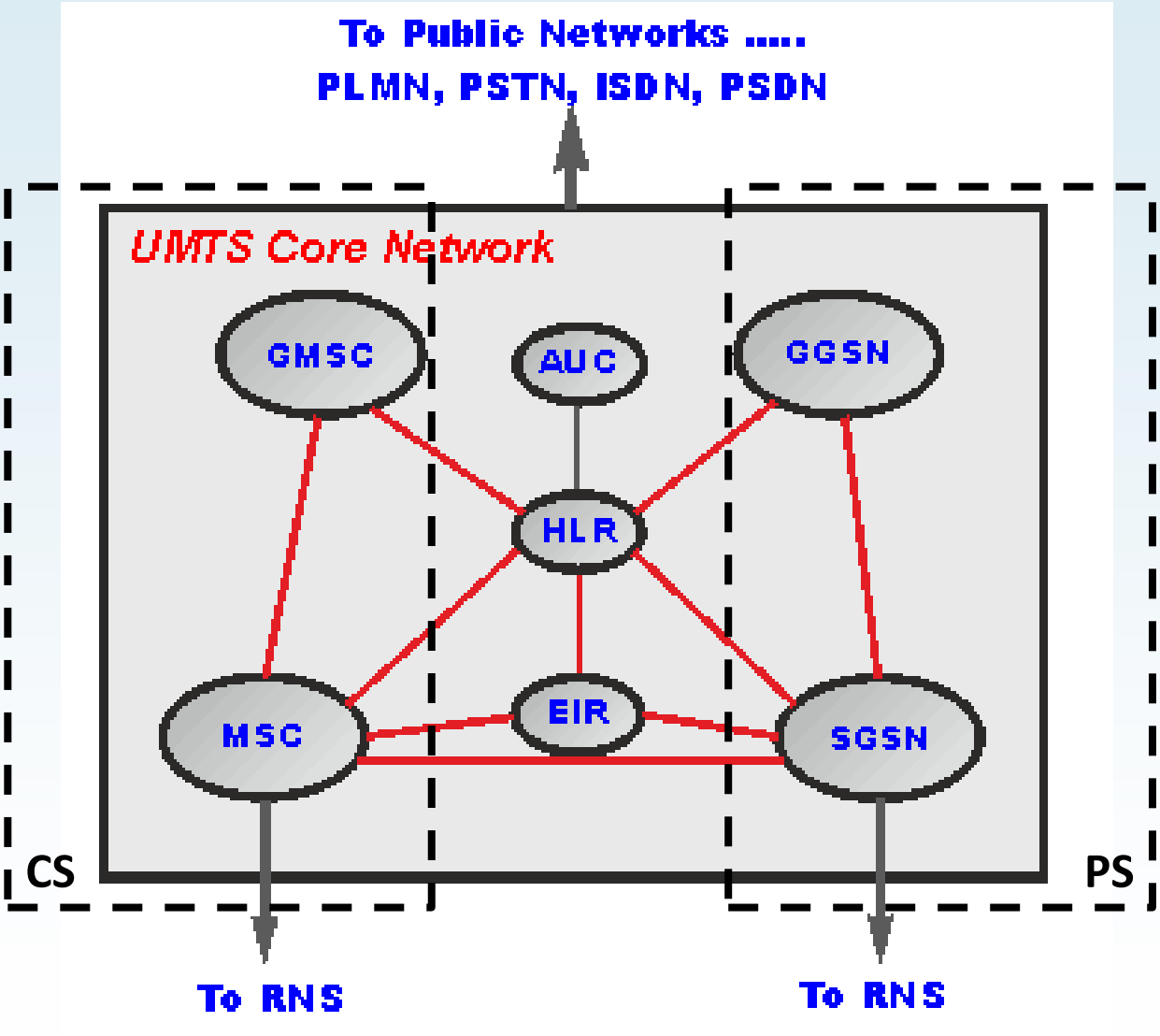
Source: http://www.etsi.org/deliver/etsi_ts/123100_123199/123101/13.00.00_60/ts_123101v130000p.pdf

UMTS Architecture – UTRAN



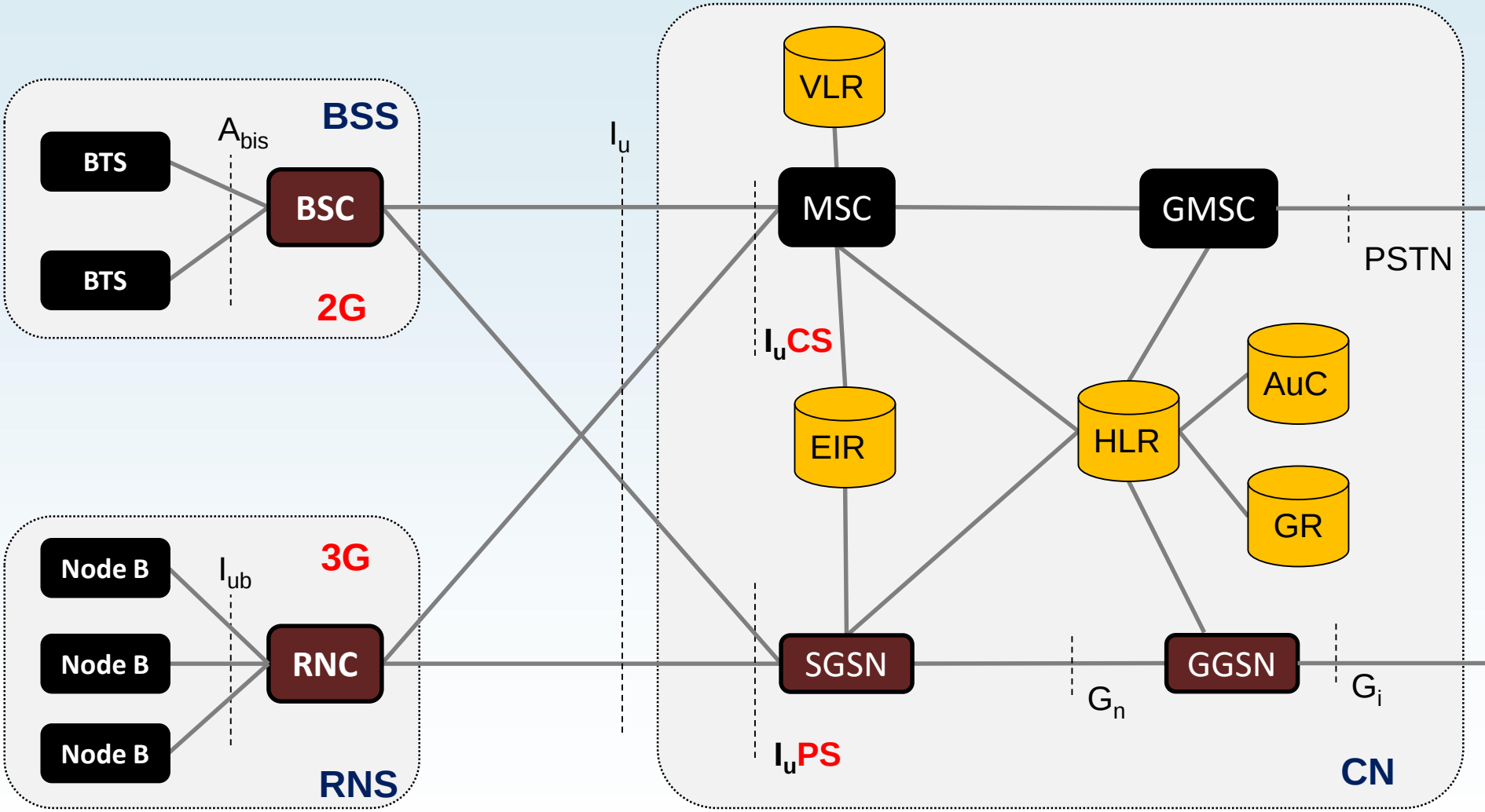
Source: http://www.etsi.org/deliver/etsi_ts/125400_125499/125401/04.02.00_60/ts_125401v040200p.pdf

UMTS Architecture – Core Network (CN)



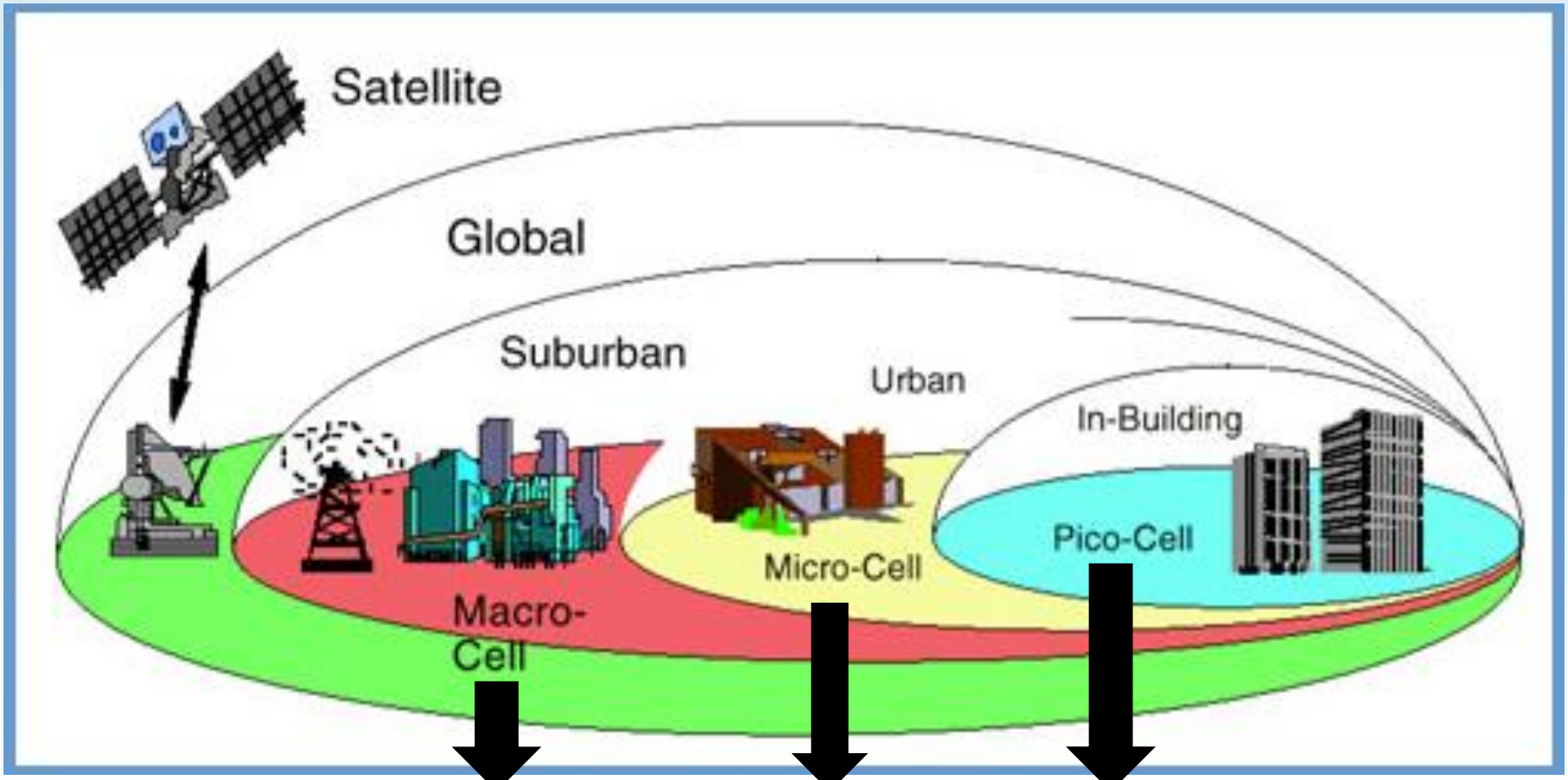
Source: Radio Electronics, Network Architecture

UMTS Architecture – UTRAN and CN



Source: Schiller, page 152

UMTS Coverage Areas



Source: https://cordis.europa.eu/infowin/acts/rus/impacts/mobile.htm

UMTS Velocities

In terms of maximum user bit rates the requirements of the first UMTS release were (according to ETSI TR 101 111):

- **Rural Outdoor**: at least 144 kbit/s (goal to achieve 384 kbit/s), max. speed: 500 km/h
- **Suburban Outdoor**: at least 384 kbps (goal to achieve 512 kbit/s), max. speed: 120 km/h
- **Indoor/Low range outdoor**: at least 2Mbps, max. speed: 10 km/h

Source: https://www.etsi.org/technologies/mobile/3g

UMTS Services

1. **Bearer* services**
   - Different QoS for maximum transfer delay, delay variation and BER.
   - Offered data rate targets are:
     - 144 kbits/s satellite and rural outdoor.
     - 384 kbits/s urban outdoor.
     - 2048 kbits/s indoor and low range outdoor.

2. **Network services**
   - Have different QoS classes for four types of traffic:
     - Conversational class (voice, video telephony, video gaming).
     - Streaming class (multimedia, video on demand, webcast).
     - Interactive class (web browsing, network gaming, database access).
     - Background class (email, SMS, downloading).

***Bearer = A "messenger", a person or thing that holds or carries something**

PART 2: UMTS RADIO INTERFACE

Part 2: UMTS Radio Interface – Frequency Band and Duplexing

UMTS Air Interface Parameters

KEY SPECIFICATIONS FOR UTRAN OPERATION FOR FDD & TDD		
PARAMETER	UTRA FDD	UTRA TDD
Multiple access method	CDMA	TDMA, CDMA
Channel spacing	5 MHz	5 MHz (and 1.6MHz for TD-SCDMA)
Carrier chip rate	3.84 Mcps	3.84 Mcps
Spreading factors	4 .. 512	1 .. 16
Time slot structure	15 slots / frame	15 / 14 slots / frame
Frame length (ms)	10	10
Multirate concept	Multicode, and OVSF[1]	Multicode, multislot and OVSF[1]
Burst types	N/A	(1) traffic bursts (2) random access burst (3) synchronisation burst
Detection	Coherent based on pilot symbols	Coherent based on mid-amble
Dedicated channel power control	Fast closed loop 1500 Hz rate	Uplink: open loop 100 Hz or 200 Hz rate Downlink: closed loop max 800 Hz rate

UMTS uses frequencies from 1,900 to 2,025 MHz for the uplink and from 2,110 to 2,200 MHz for the downlink

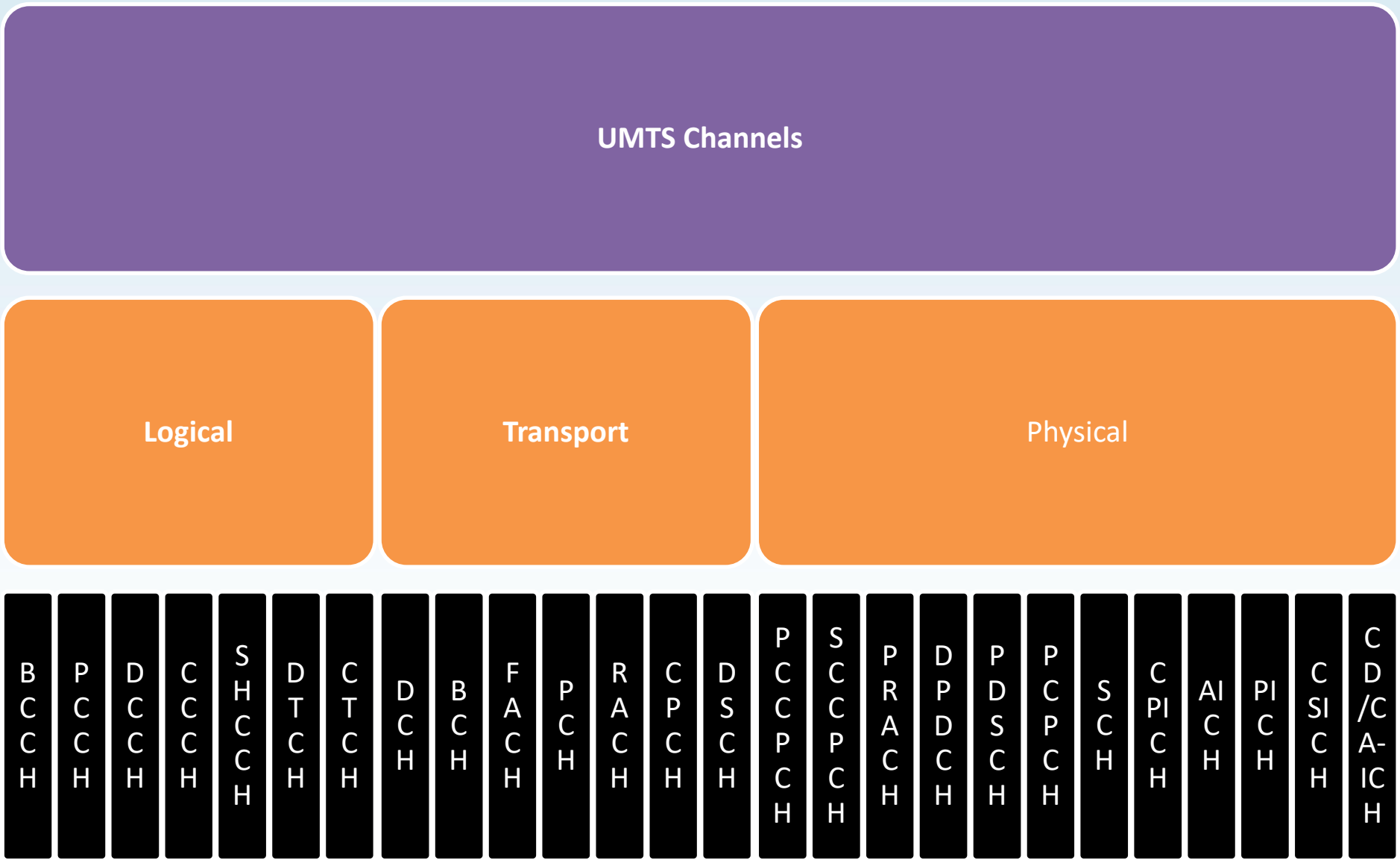
Source: Radio Electronics, UTRA/UTRAN

UMTS Duplexing

- UMTS has two types of duplex protocol defined.
- Frequency Division Duplexing (FDD)
  - Used in paired frequency bands
  - Targeted at outdoor applications
- Time Division Duplexing (TDD)
  - Used in unpaired bands
  - Targeted mainly at indoor WLAN-like applications

Part 2: UMTS Radio Interface – Channel Structure and Mapping

UMTS Channel Hierarchy



Logical versus Transport versus Physical

- Physical: Carry the actual payload. Describe the physical characteristics of the signal.
  - How the data will be transported physically.
- Logical: Define the type of data that will be transferred.
  - Traffic or control.
- Transport: Define how and with which type of characteristics the data will be transferred.
  - Describe the basic message format within a MAC frame.
  - Logical channels multiplexed onto transport channels via the MAC layer.

UMTS Logical Channels

Seven logical channels are used to transmit different types of data

Downlink

- Broadcast Control Channel (BCCH)
- Paging Control Channel (PCCH)
- Common Traffic Channel (CTCH)

Bi-directional

- Common Control Channel (CCCH)
- Dedicated Control Channel (DCCH)
- Dedicated Traffic Channel (DTCH)
- Shared Channel Control Channel (SHCCH)

UMTS Transport Channels

Logical channels are mapped onto (seven) Transport channels via MAC layer

Uplink

- Random Access Channel (RACH)
- Common Packet Channel (CPCH)

Downlink

- Broadcast Transport Channel (BCH)
- Paging Channel (PCH)
- Forward Access Channel (FACH)
- Downlink Shared Channel (DSCH)

Bi-directional

- Dedicated Transport Channel (DCH)

UMTS Physical Channels

Transport channels are then mapped onto 13 physical channels

Uplink

- Physical Random Access Channel (PRACH)
- Physical Common Packet Channel (PCPCH)

Downlink

- Primary Common Control Physical Channel (P-CCPCH)
- Secondary Common Control Physical Channel (S-CCPCH)
- Synchronization Channel (SCH)
- Common Pilot Channel (CPICH)
- Physical Downlink Shared Channel (PDSCH)
- Acquisition Indication Channel (AICH)
- Page Indication Channel (PICH)
- Common Packet Channel Status Indication Channel (CSICH)
- Collision Detection/Channel Assignment Indication Channel (CD/CA-ICH)

Bi-directional

- Dedicated Physical Data Channel (DPDCH)
- Dedicated Physical Control Channel (DPCCH)
- Coded Composite Traffic Channel (CCTrCH): Combination of DPDCH and DPCCH

Dedicated Physical Channel

- Data and control channels are transmitted in the uplink.
  - At the same time using dual channel modulation (I- and Q- multiplexing)
- Control elements include:
  - **Pilot bits**: For channel estimation and equalization
  - **Transmit Power Control (TPC) bits**: To change transmission power
  - **Feed Back Information (FBI) bits**: Feedback the antenna weights to Node-B
  - **Transport Format Combination Indicator (TFCI) bits**: Determine the structure of the data that are transmitted over the DPDCH

Part 2: UMTS Radio Interface – Spreading, Modulation, Multiplexing and Coding

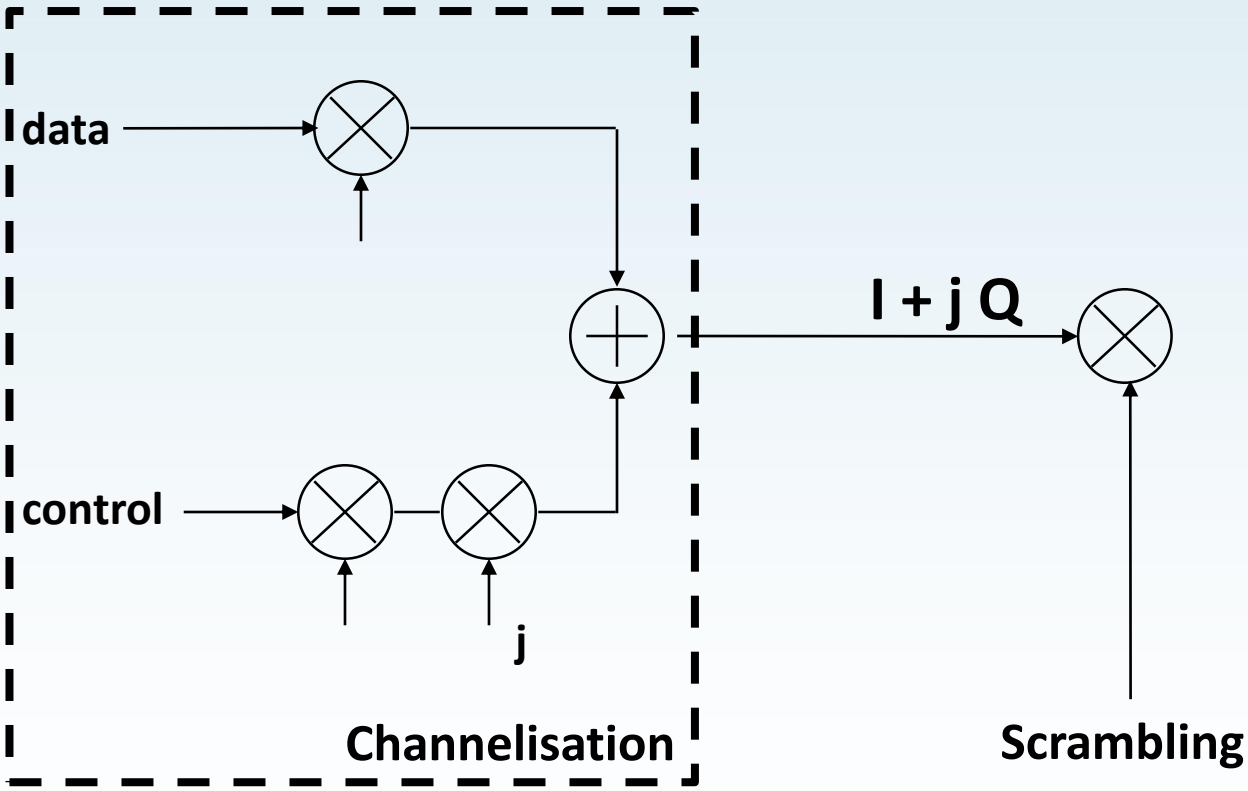
Spreading and Multiple Access in UMTS

- Wideband-CDMA (WCDMA) was chosen for UMTS.
- WCDMA uses Code Division Multiple Access (CDMA).
- CDMA employs Direct Sequence Spread Spectrum (DSSS).
  - Message is multiplied by a code sequence before modulating the carrier.
  - Message is recovered by correlating received signal with code sequence.
  - The remaining interference and noise are spread.
- CDMA uses codes to separate different users.

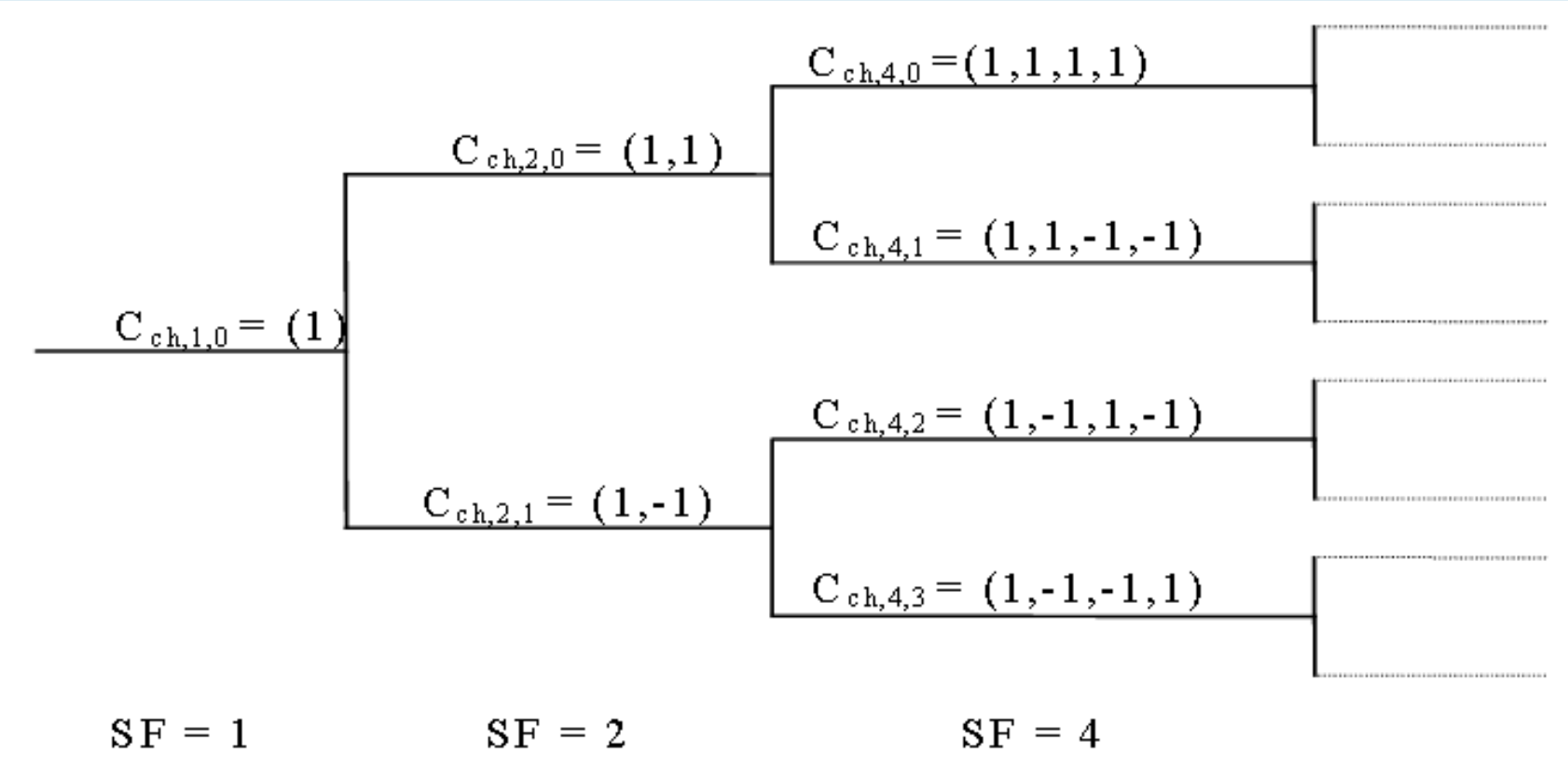
Spreading Factors and Operations

- Spreading is applied to the physical channels in two steps:
  - **Channelisation**: Transforms slow data sequence into fast chip sequence.
  - **Scrambling**: A scrambling code is applied to the spread signal.
- Spreading Factor (SF) : The number of chips per data symbol.
  - Also referred to as **processing gain** expressed in decibels (dB).
- Channelisation codes lead to bandwidth expansion.
- Good codes have two key characteristics:
  - Sharp autocorrelation: For good robustness against multipath fading.
  - Zero cross-correlation: To mitigate interference between users.
- UMTS uses codes of various families:
  - Orthogonal Variable Spreading Factor (OVSF) codes.
  - Kasami and Gold codes.

Channelisation and Scrambling



Channelisation Codes for Spreading



Source: http://www.etsi.org/deliver/etsi_ts/125200_125299/125213/12.00.00_60/ts_125213v120000p.pdf

Scrambling Codes for Separation

Scrambling codes are repeated for every 10 ms radio frame.

Uplink data and control channels are scrambled by 2^{24} of either:

- Long codes from a set of Gold sequences of 38400 chips.

OR

- Short codes from the family of periodically extended S(2) codes.

Downlink: $2^{18} - 1$ scrambling codes can be generated.

- Only 8192 of these scrambling codes are used.
- Scrambling codes are divided into 512 sets:
  - One primary scrambling code.
  - 16 secondary scrambling codes.
- These are segments of a different set of the Gold sequences.

For more info: J. S. Blogh and L. Hanzo, Third-Generation Systems and Intelligent Wireless Networking: Smart Antennas And Adaptive Modulation, Wiley, 2002.

Channel Coding in UMTS

Type of TrCH	Coding scheme	Coding rate
BCH	Convolutional coding	1/2
PCH		
RACH		
CPCH, DCH, DSCH, FACH		1/3, 1/2
	Turbo coding	1/3

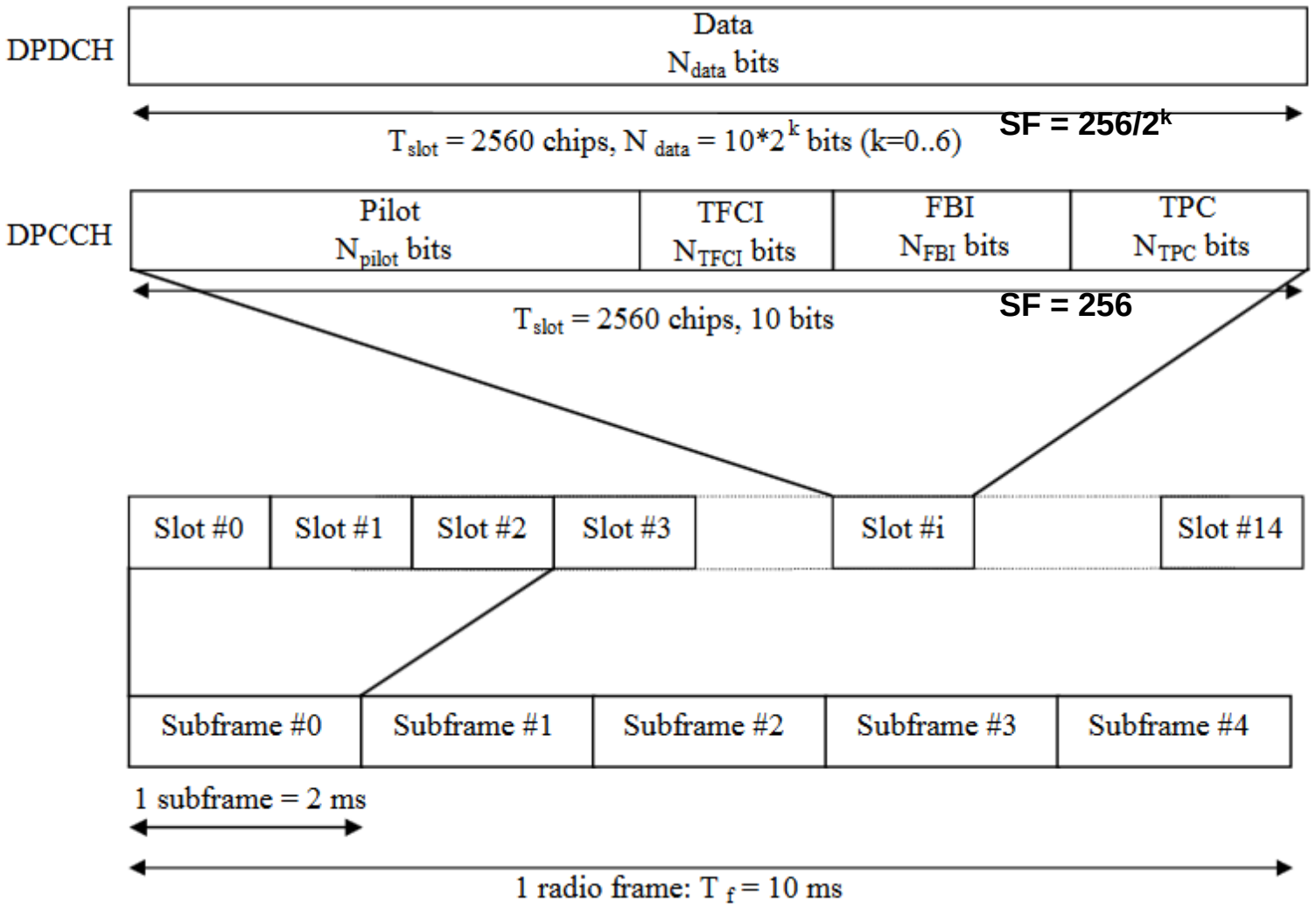
Source: http://www.etsi.org/deliver/etsi_ts/125200_125299/125212/05.01.00_60/ts_125212v050100p.pdf

Speech Coding in UMTS

Bit 8…Bit 1 CoID	Codec_Type	Name
0000.0000	GSM Full Rate (13.0 kBit/s)	GSM FR
0000.0001	GSM Half Rate (5.6 kBit/s)	GSM HR
0000.0010	GSM Enhanced Full Rate (12.2 kBit/s)	GSM EFR
0000.0011	Full Rate Adaptive Multi-Rate	FR AMR
0000.0100	Half Rate Adaptive Multi-Rate	HR AMR
0000.0101	UMTS Adaptive Multi-Rate	UMTS AMR
0000.0110	UMTS Adaptive Multi-Rate 2	UMTS AMR 2
0000.0111	TDMA Enhanced Full Rate (7.4 kBit/s)	TDMA EFR
0000.1000	PDC Enhanced Full Rate (6.7 kBit/s)	PDC EFR
other codes	reserved for future use.	

Source: http://www.etsi.org/deliver/etsi_ts/126100_126199/126103/04.01.00_60/ts_126103v040100p.pdf

UMTS FDD uplink frame structure



Slot structure NOT for user separation but for synchronisation of periodic functions

FBI: Feedback Information

TPC: Transmit Power Control

TFCI: Transport Format Combination Indicator

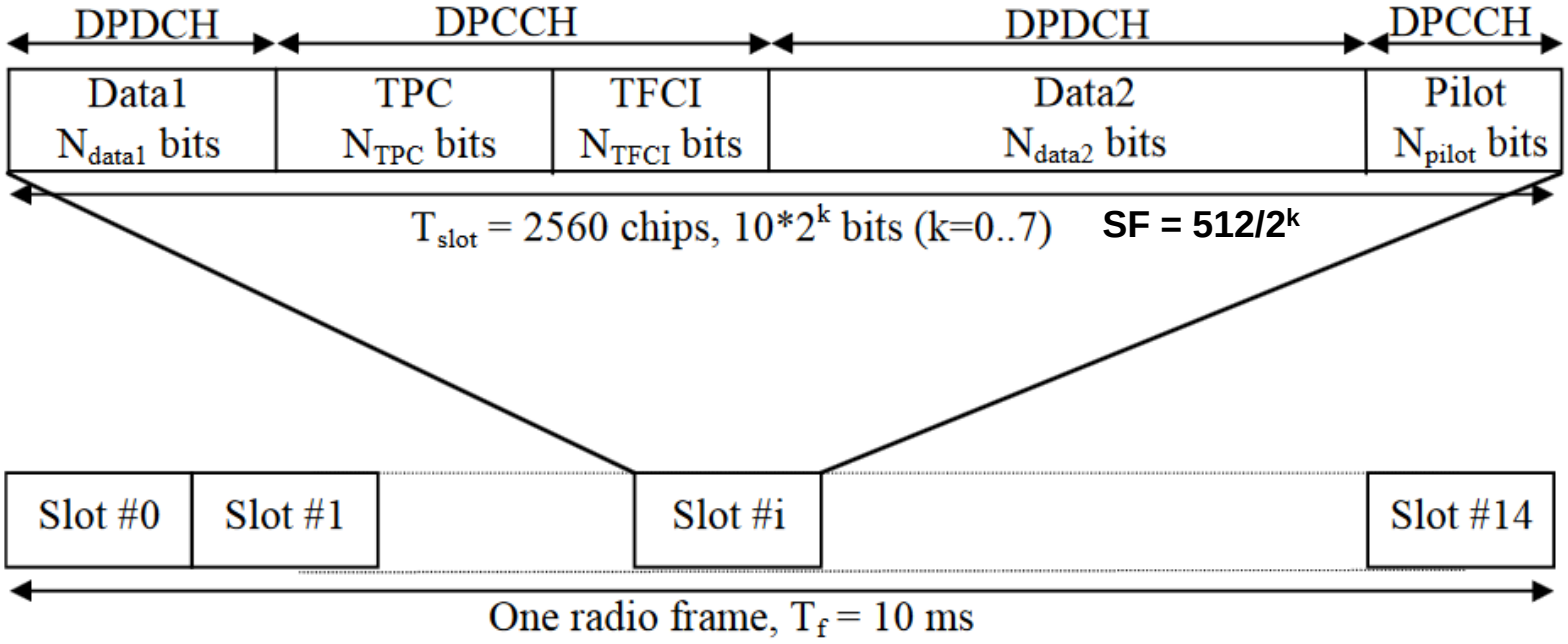
DPCCH: Dedicated Physical Control Channel

DPDCH: Dedicated Physical Data Channel

DPCH: Dedicated Physical Channel

Source: http://www.etsi.org/deliver/etsi_ts/125200_125299/125211/08.07.00_60/ts_125211v080700p.pdf

UMTS FDD downlink frame structure



FBI: Feedback Information

TPC: Transmit Power Control

TFCI: Transport Format Combination Indicator

DPCCH: Dedicated Physical Control Channel

DPDCH: Dedicated Physical Data Channel

DPCH: Dedicated Physical Channel

Source: http://www.etsi.org/deliver/etsi_ts/125200_125299/125211/08.07.00_60/ts_125211v080700p.pdf

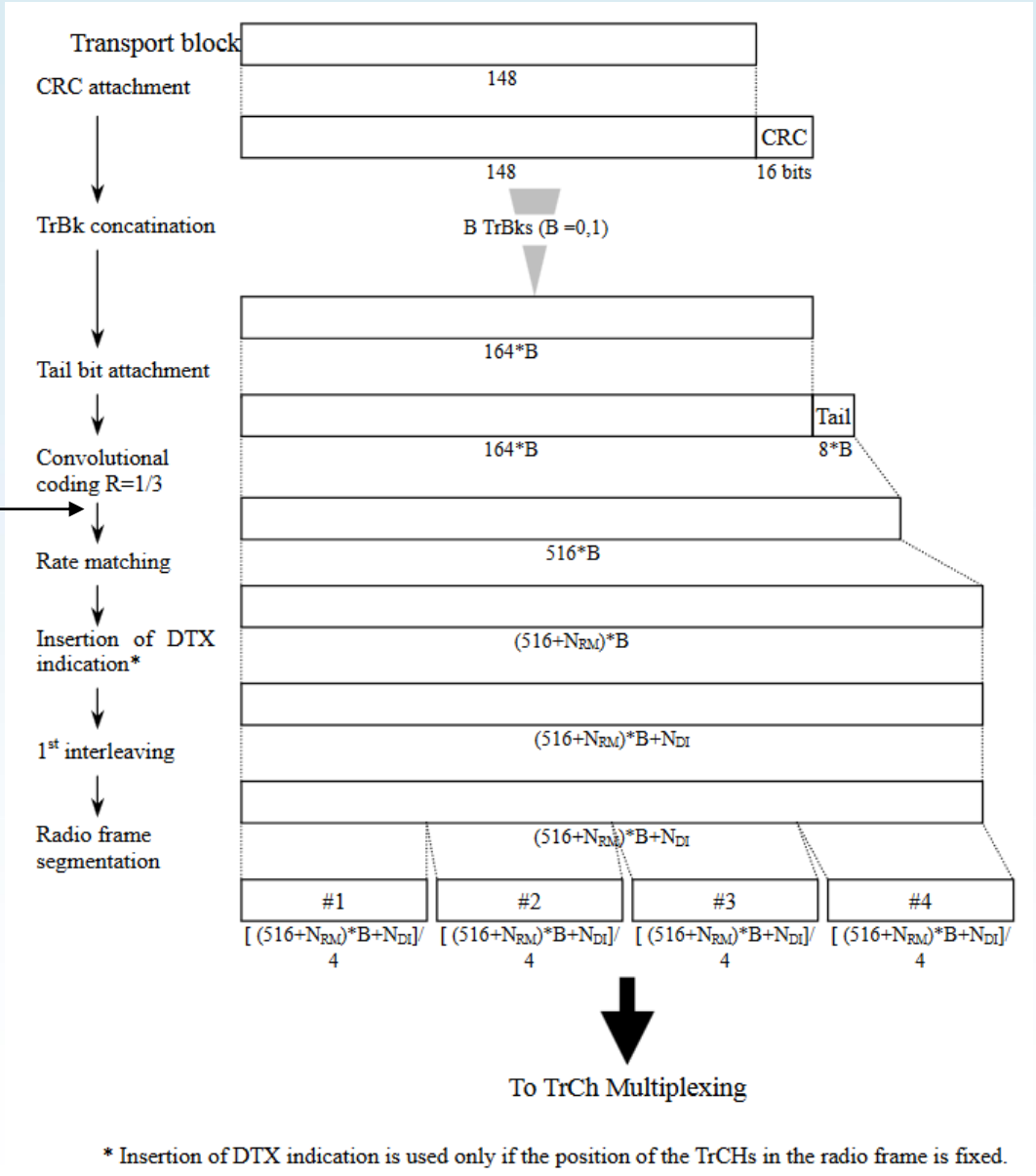
Multiplexing, channel coding and interleaving

The following processes take place to offer transport services over the radio link:

- CRC attachment (to each transport block).
- Concatenation and segmentation.
- Channel coding.
- Frame equalisation.
- Rate matching.
- Insertion of discontinuous transmission (DTX).
- Interleaving.
- Frame segmentation.
- Multiplexing (of transport channels).
- Physical channel segmentation.
- Mapping to physical channels.

Source: http://www.etsi.org/deliver/etsi_ts/125200_125299/125212/11.06.00_60/ts_125212v110600p.pdf

Example for DCCH: 3.4 kbps data

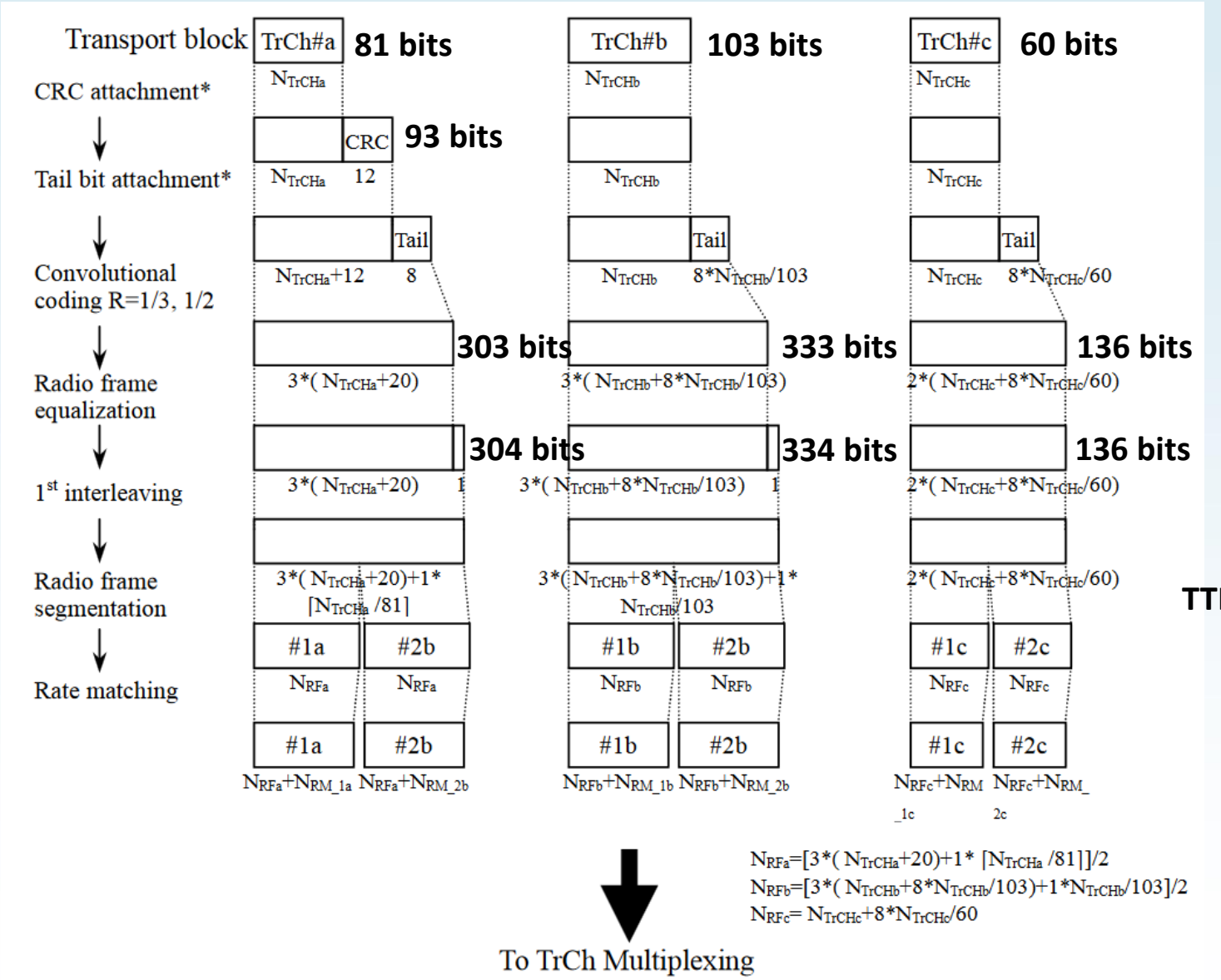


Frame equalisation

TTI = 40ms

Source: http://www.etsi.org/deliver/etsi_tr/125900_125999/125944/04.01.00_60/tr_125944v040100p.pdf

Example for AMR Speech: 12.2 kbps



$N_{RFa}=[3*(N_{TrCHa}+20)+1*[N_{TrCHa}/81]]/2$

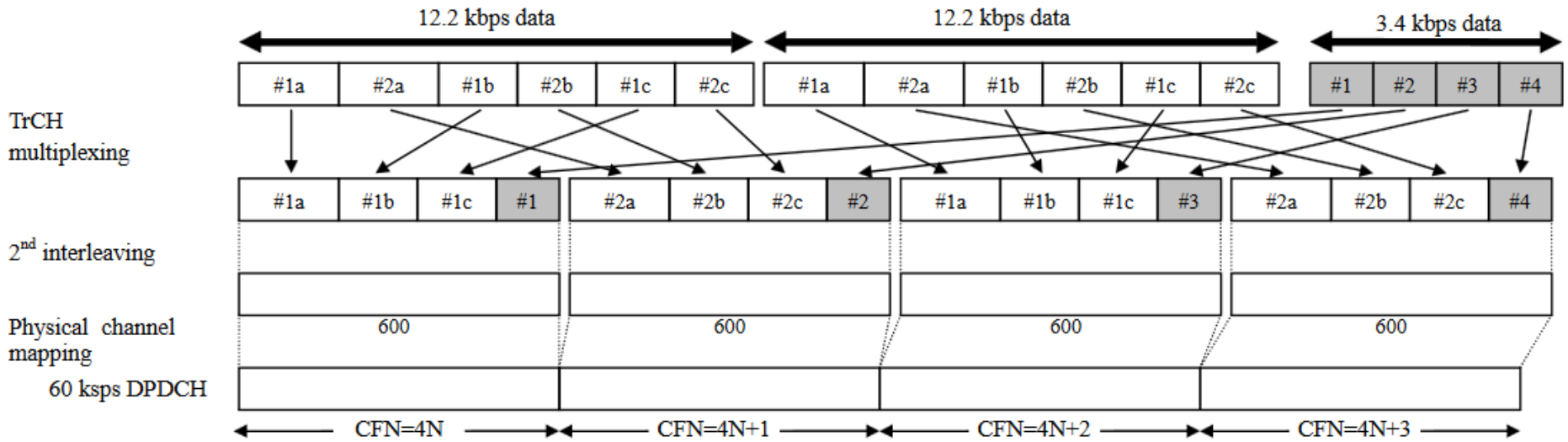
$N_{RFb}=[3*(N_{TrCHb}+8*N_{TrCHb}/103)+1*N_{TrCHb}/103]/2$

$N_{RFc}=N_{TrCHc}+8*N_{TrCHc}/60$

TTI = 20ms

Source: http://www.etsi.org/deliver/etsi_tr/125900_125999/125944/04.01.00_60/tr_125944v040100p.pdf

Multiplexing different types of data

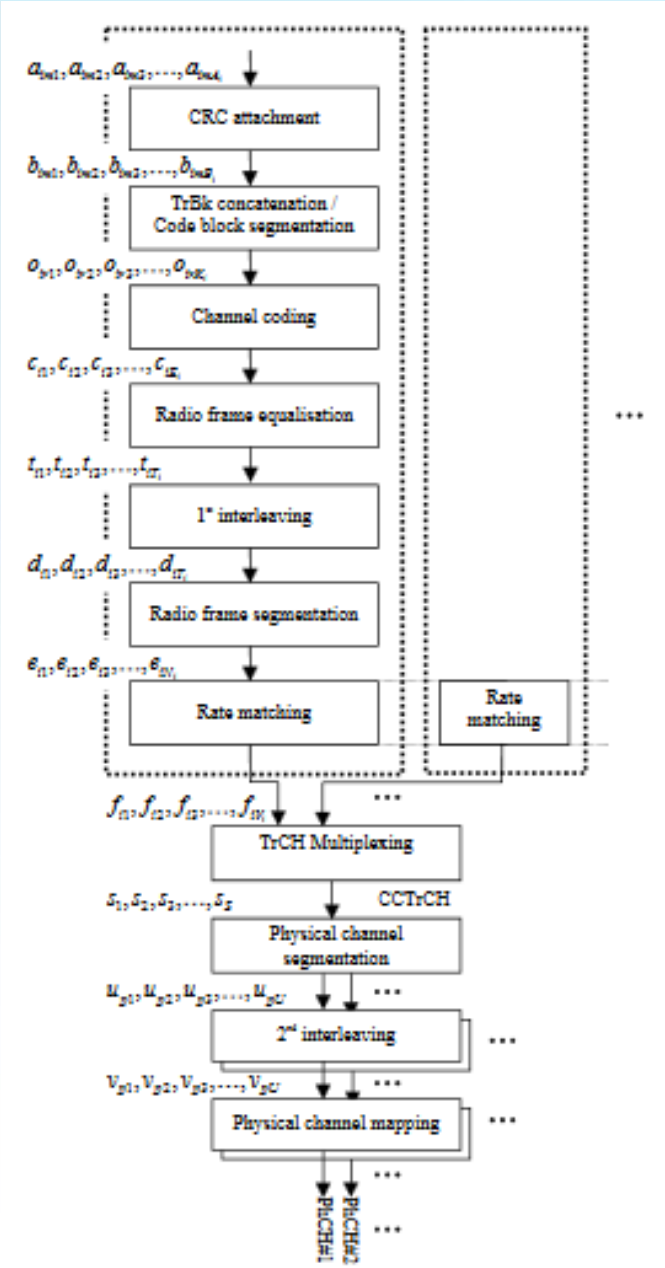


CFN: Connection Frame Number

Example of multiplexing 12.2 kbps data (AMR) with 3.4 kbps data (DCCH)

Source: http://www.etsi.org/deliver/etsi_tr/125900_125999/125944/04.01.00_60/tr_125944v040100p.pdf

Coding and multiplexing of uplink channels



Source: http://www.etsi.org/deliver/etsi_ts/125200_125299/125212/11.06.00_60/ts_125212v110600p.pdf

UMTS Air Interface Parameters

KEY SPECIFICATIONS FOR UTRAN OPERATION FOR FDD & TDD		
PARAMETER	UTRA FDD	UTRA TDD
Multiple access method	CDMA	TDMA, CDMA
Channel spacing	5 MHz	5 MHz (and 1.6MHz for TD-SCDMA)
Carrier chip rate	3.84 Mcps	3.84 Mcps
Spreading factors	4 .. 512	1 .. 16
Time slot structure	15 slots / frame	15 / 14 slots / frame
Frame length (ms)	10	10
Multirate concept	Multicode, and OVSF[1]	Multicode, multislot and OVSF[1]
Burst types	N/A	(1) traffic bursts (2) random access burst (3) synchronisation burst
Detection	Coherent based on pilot symbols	Coherent based on mid-amble
Dedicated channel power control	Fast closed loop 1500 Hz rate	Uplink: open loop 100 Hz or 200 Hz rate Downlink: closed loop max 800 Hz rate

UMTS uses frequencies from 1,900 to 2,025 MHz for the uplink and from 2,110 to 2,200 MHz for the downlink

Source: Radio Electronics, UTRA/UTRAN

WCDMA versus GSM Air Interface

	W-CDMA	GSM
Carrier Spacing	5MHz	200kHz
Frequency reuse factor	1	1-18
Power control frequency	1500Hz	2Hz or lower
Quality control	Radio resource management algorithms	Network planning (frequency planning)
Frequency diversity	5MHz 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

Source: https://telecomstudy18.blogspot.co.uk/2015/09/differences-between-wcdma-and-second.html

PART 3: UMTS PHYSICAL LAYER PROCEDURES

Physical Layer Procedures

- Cell Search and Synchronisation
- Radio Link Establishment
- Power Control
- Handover

Part 3: UMTS Physical Layer Procedures – Cell Search and Synchronisation

Cell Search and Synchronisation

Goal: Search for cell with strongest signal and synchronise to it.

Steps:

1. Slot synchronisation.
2. Frame synchronisation and code-group identification.
3. Scrambling-code identification.

Part 3: UMTS Physical Layer Procedures – Radio Link Establishment

Radio Link Establishment

Goal: Establish a connection between the UE and the network.

Steps:

1. Synchronise to the network.
2. Read the broadcast channel.
3. Select preamble spreading code.
4. Select message scrambling code.
5. Calculate uplink transmission power.
6. Transmit message if ACK received, else increase transmit power.
7. If access grant message not received, repeat procedure.

Part 3: UMTS Physical Layer Procedures – Power Control

Power Control in UMTS

- Soft Capacity
- Near-Far Effect
- Power Control
  - Inner / Outer.
  - Open / Closed.
  - Uplink / Downlink.

Soft Capacity

- TDMA / FDMA:
  - Number of users limited by number of timeslots / channels.
- CDMA:
  - Number of users limited by interference (soft capacity).
  - Increasing power leads to increased interference (in and between cells).
- Limit on capacity:
  - Signal to interference ratio (SIR) becomes too high.
  - No more power at NodeB to serve more users.
  - No more codes to assign to users (rare situation).

Near-Far Effect

- In CDMA systems, all users transmit their signals simultaneously.
- Imperfect orthogonality limits interference mitigation.
- Near-far effect:
  - Users close to NodeB may drown users at cell edge.
  - Users at cell edge may not be heard due to high interference.
- Tight power control procedures required.

Inner and Outer Loop Control

- Inner loop:
  - Adjust NodeB transmission power to maintain SIR at given target.
- Outer loop:
  - Estimate connection quality using BER and FER.
  - Adjust target SIR used by inner loop control.

Open Loop Control

- Used:
  - During initial power settings.
  - When a feedback channel is not available.
- Measure average received power of CCPCH.
- Calculate path loss from the receiving signal.
- Obtain estimate of required transmission power.

Closed Loop Control

- Used with inner and outer loops to provide fast power control.
- Transmission power is updated every 667 µs.
  - Designed to be faster than Rayleigh fading at high mobile speeds.
- Maintains UE and NodeB power levels at a minimum.
- Adjusts UE and NodeB power levels based on signal quality.

Downlink and Uplink Closed Loop Control

- Downlink:
  - Closed loop control to maintain good SNR.
  - UE measures SNR and requests power increase / decrease accordingly.
  - Request sent via TPC commands to the NodeB.
  - Ttransmission power of all other channels adjusted accordingly.
- Uplink:
  - NodeB estimates received signal power and sends TPC commands to UE.
  - UE adjusts transmission power accordingly.

Part 3: UMTS Physical Layer Procedures – Handover

Handover Causes and Strategies

Causes:

- Signal quality and measurements
- Change of service
- Directed retry
- Traffic load
- Pre-emption

Strategies:

- Intra / Inter-frequency Handover
- Inter-system (or Inter-RAT) Handover
- Hard / Soft / Softer Handover

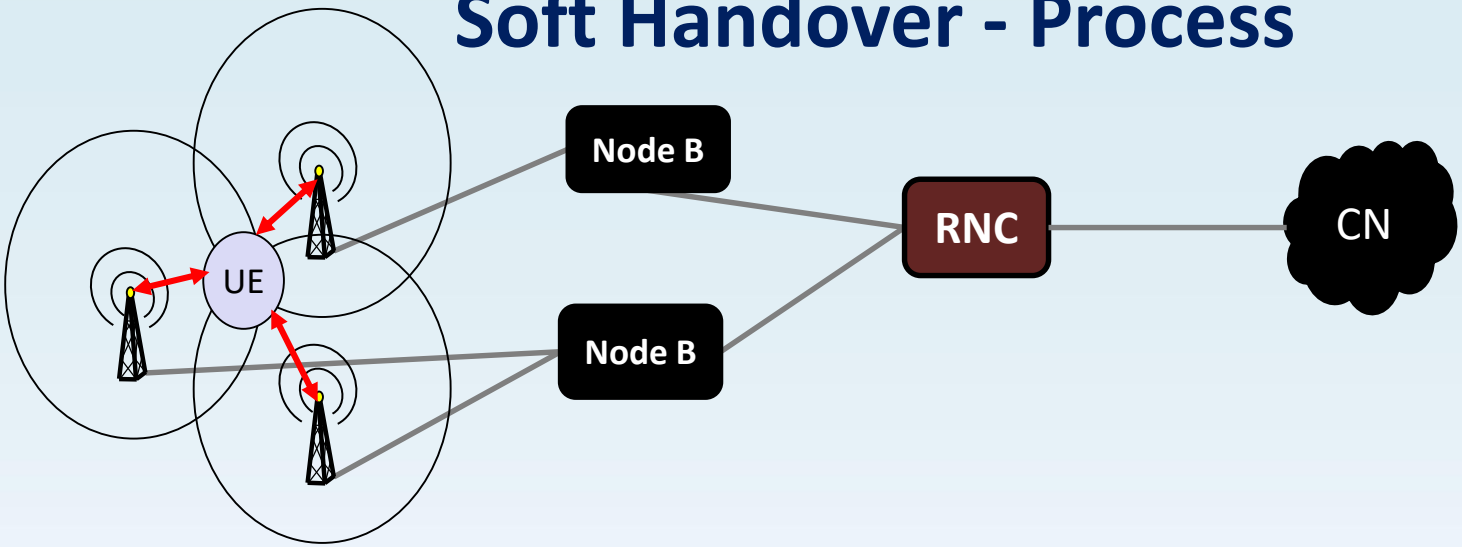
Handover Scenarios

- **Intra-frequency**: Uses soft handover.
  - UE moves between NodeBs on the same carrier frequency.
- **Inter-frequency**: Uses hard handover.
  - UE moves between cells on different carrier frequencies.
  - UE switches between modes, for example, from TDD to FDD.
  - No capacity on existing channel so UE moves to a new channel.
- **Inter-system (or Inter-RAT)**: Uses hard handover.
  - UE moves between different networks (or RATs).
  - Handover managed by different MSCs.

Handover Types

- **Hard**: Used in TDMA/FDMA systems, such as GSM.
  - Switching happens at specific point in time.
  - Existing connection terminated before new connection is established.
  - Measurements taken using two receivers or using compressed mode.
- **Soft**: Introduced in CDMA networks, such as UMTS.
  - UE always maintains at least one active link to RAN.
  - Can be performed on the same carrier frequency only (FDD mode).
- **Softer**: Special case of soft handover.
  - UE is in overlapping coverage of two sectors of the same NodeB.
  - UE connected concurrently to both sectors via separate interfaces.

Soft Handover - Process



- Less power -> Less Interference -> **More Capacity**.
- Occurs when UE is in **overlapping coverage** of two NodeBs.
- **Downlink**: Streams combined via MRC* using RAKE receiver.
  - Different scrambling codes applied to different RAKE fingers.
- **Uplink**: Streams routed to RNC for selection combining.

Source: Schiller, page 154

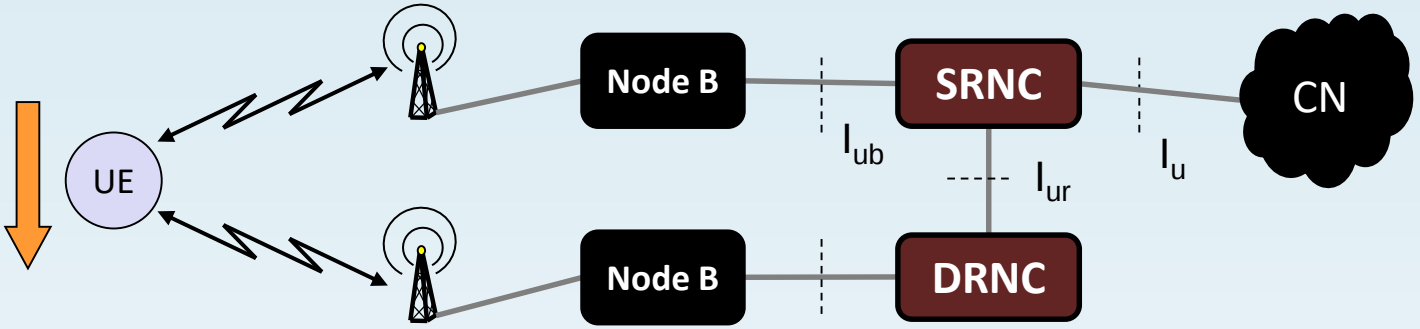
***MRC = Maximal Ratio Combining**

Soft Handover - Measurements

- UE **synchronises** to more than one cells.
- UE continuously **monitors** signals:
  - In active cells (to which UE has established a connection).
  - In neighbouring cells (to which UE is not connected to).
  - By measuring the RSSI on the CPICH.
- UE **changes** cells:
  - Neighbouring cells with sufficient RSSI* added to active set.
  - UE waits until summed signal strength exceeds upper threshold.
  - Remaining cells are then removed from active set.

***RSSI = Received Signal Strength Indicator**

Soft Handover and Macro Diversity



- **Soft handover**: Same frequency assigned to different cells.
- **Macro diversity**: Multicast data via multiple physical channels.
  - Provides robustness against multipath fading.
  - Enables users at the cell edge to be better served.
  - Downlink: UE receives data from different cells at the same time.
  - Uplink: Data from UE received by multiple NodeBs at the same time.

Source: Schiller, page 155

REFERENCES

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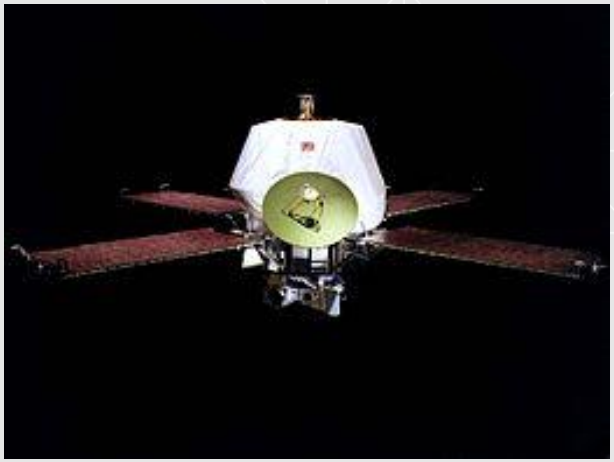
- Ian Poole, 3G UMTS / WCDMA Basics Tutorial, electronics-notes.com, Available:

  https://www.electronics-notes.com/articles/connectivity/3g-umts/what-is-umts-wcdma-tutorial.php

Did you find out?



How are they related to this session?