3G wireless systems: UMTS

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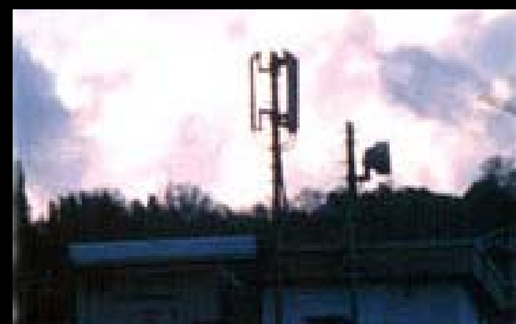

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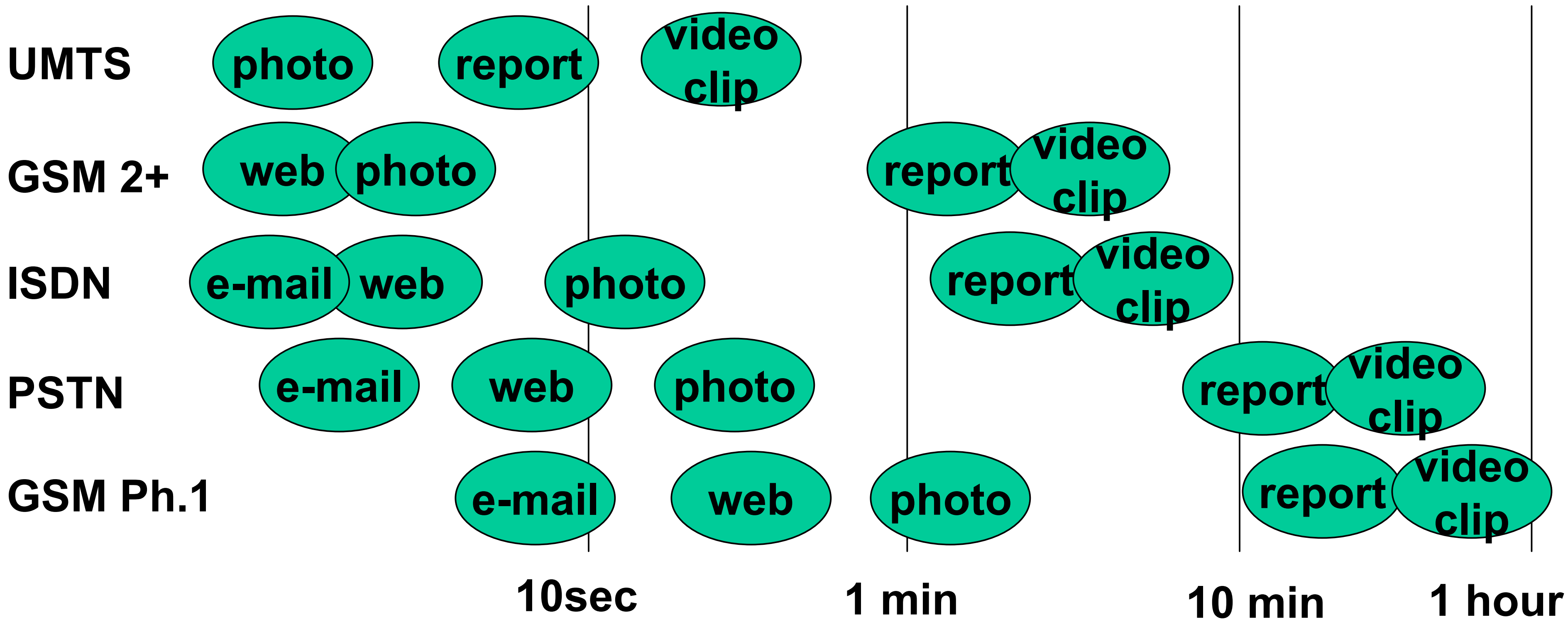
- UMTS Architecture

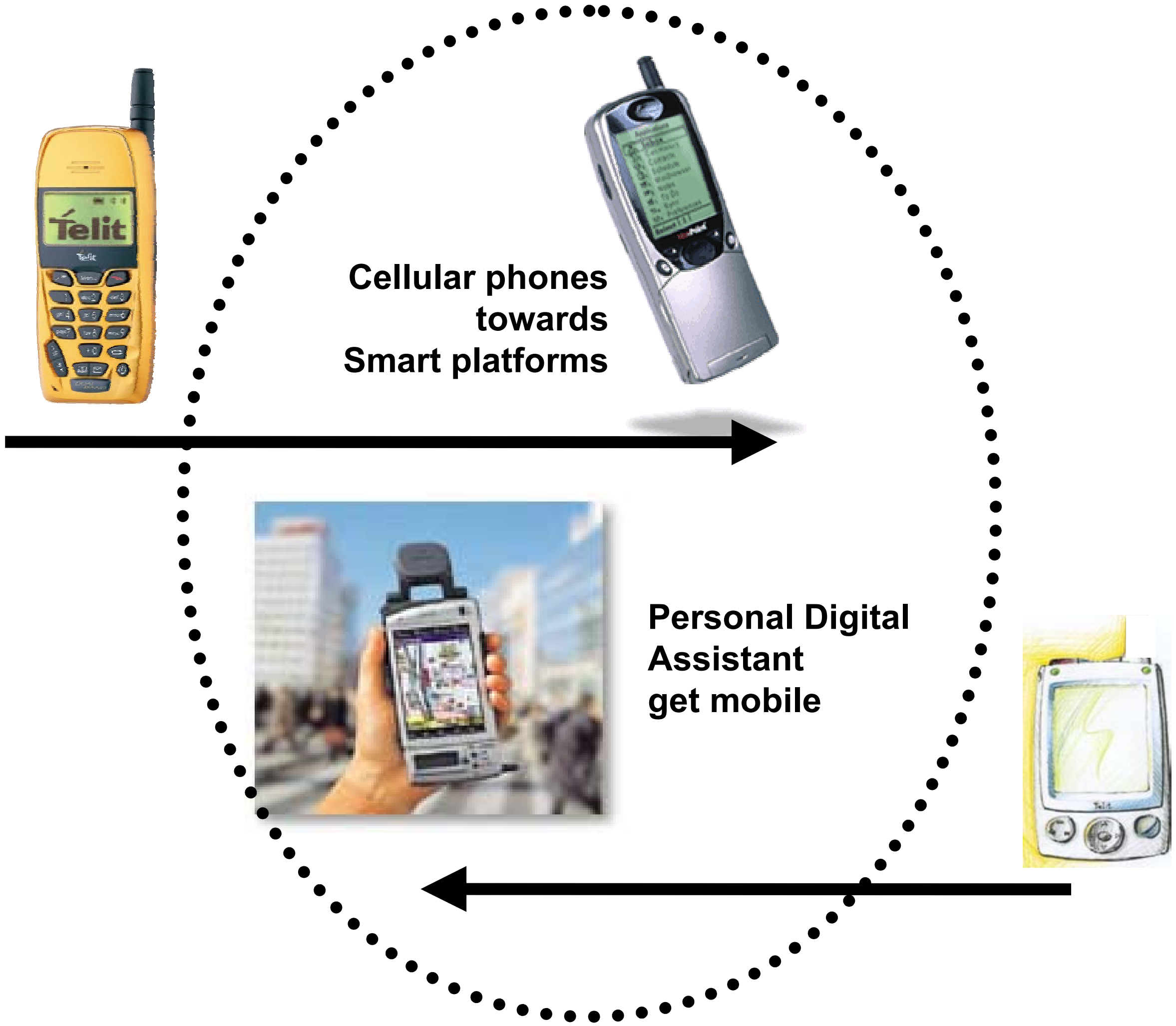
New services require high data rate capability



UMTS Service aspects and Service Capabilities

- Radio operating environments
  - indoor
  - outdoor to indoor and pedestrian
  - vehicular and fixed outdoor
  - (satellite)
- Data rates
  - up to at least 144 kbps in vehicular environment with full mobility
  - up to at least 384 kbps in suburban outdoor and outdoor to indoor environments with medium mobility
  - up to 2 Mbps with low mobility in pico cells and indoor
- Packet and circuit oriented, symmetric and asymmetric services

New services require high data rate capability

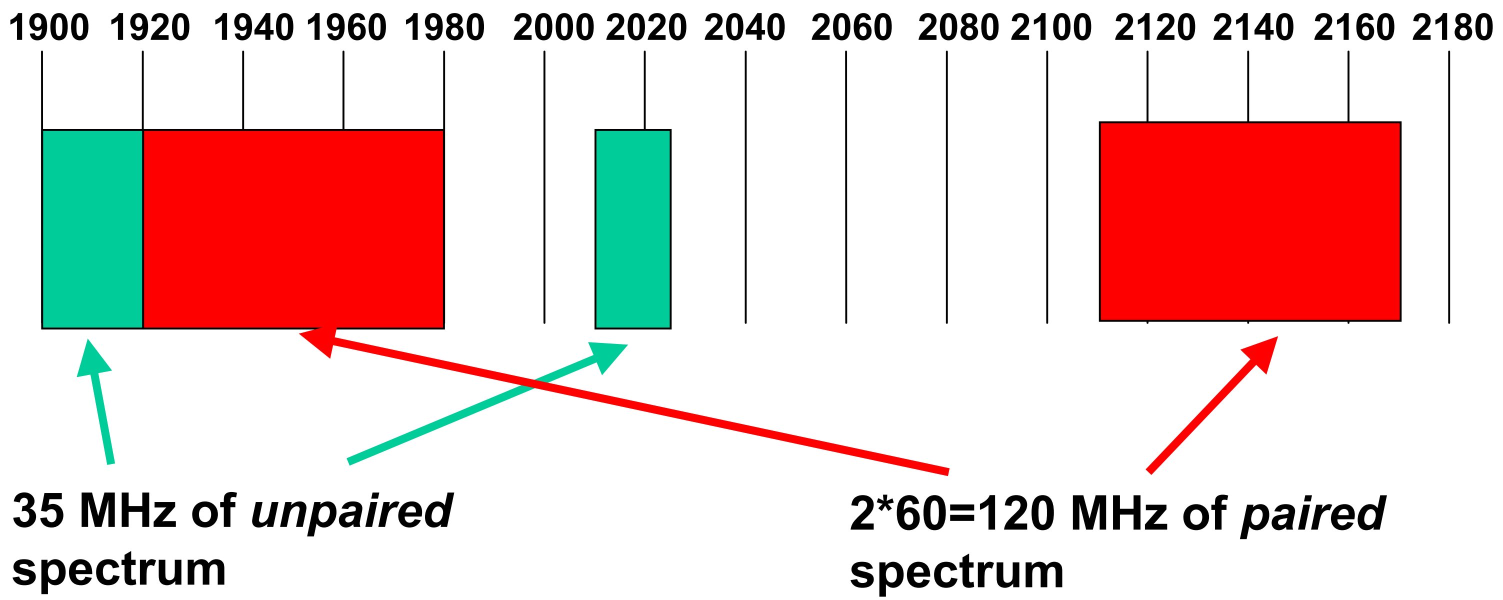


Spectrum Allocation in Europe

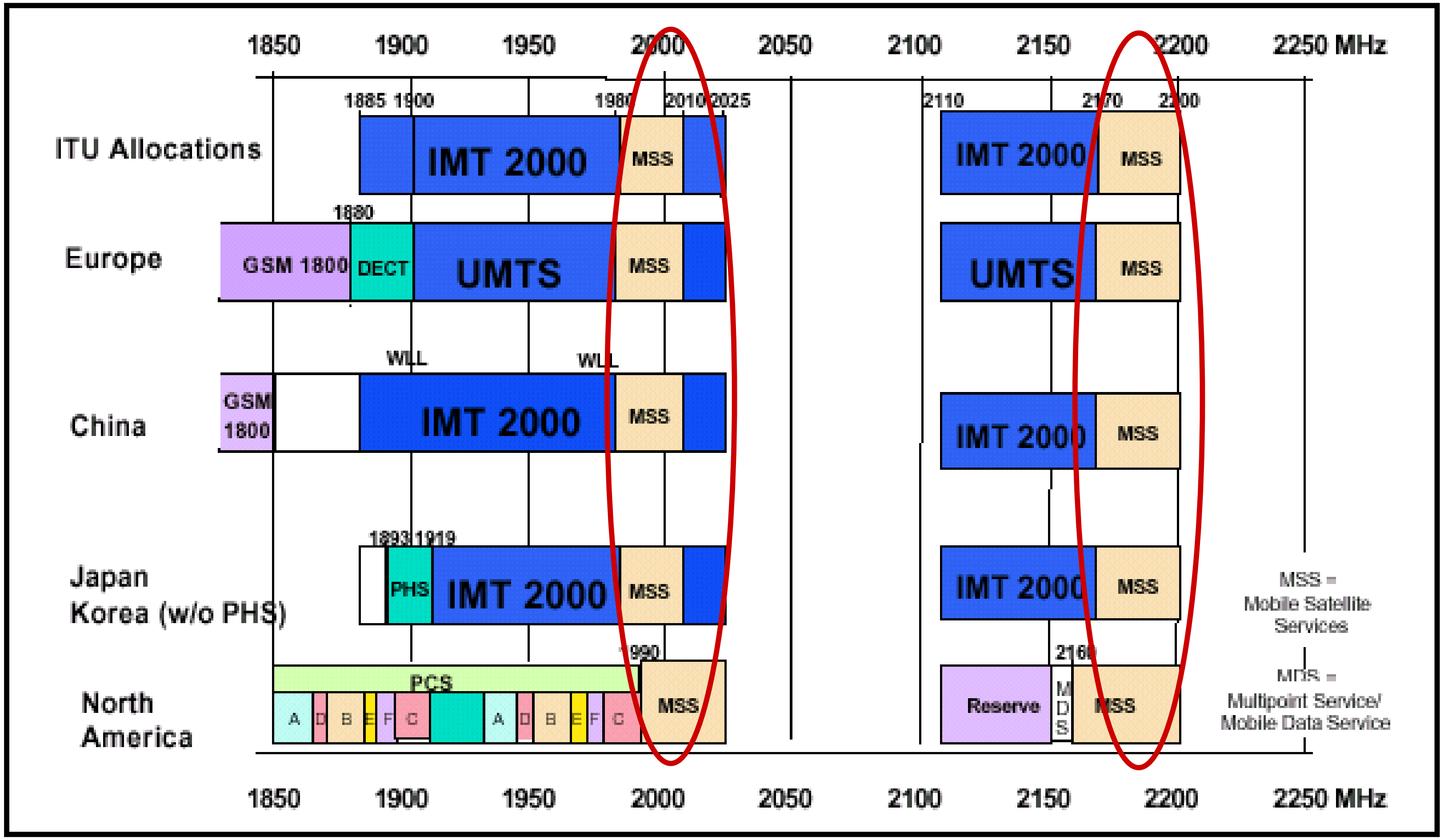
Need for Speed = Wide Band System

- The spectrum availability is a key factor for the success of 3rd generation systems
- UMTS Forum estimated a minimum need for a 3rd generation operator of
  - 2x15 MHz of paired spectrum
  - 5 MHz of unpaired spectrum

(supposing 1 UMTS carrier occupies a 5 MHz slot)



Worldwide Frequency Bands

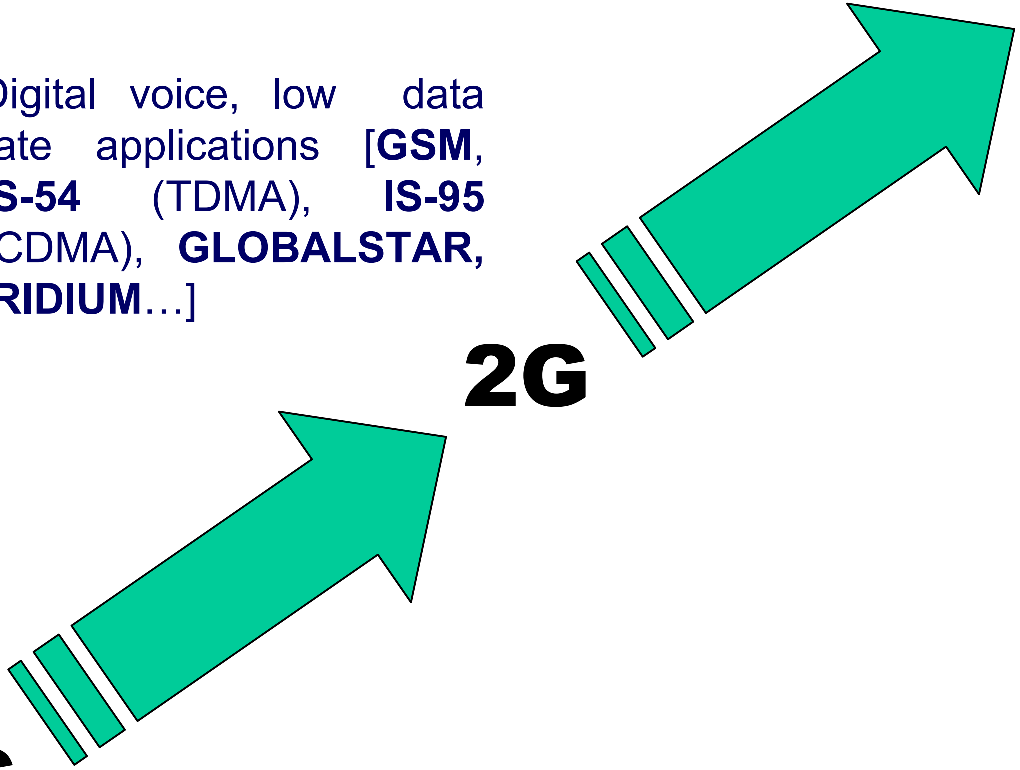


2X30 MHz in S-Band allocated to MSS, adjacent to spectrum allocation for terrestrial systems

ERC (European Radiocommunications Committee) assignments to MSS:

- 2 x 30 MHz (1980 - 2010 MHz and 2170 - 2200 MHz)
- 15 MHz available from 2000 (1995 - 2010 MHz and 2185 - 2200 MHz)
- 30 MHz available from 2005 (1980 - 2010 MHz and 2170 - 2200 MHz)
- 15 MHz assigned TDMA systems (S-PCS) (1995 - 2010 MHz and 2185 -2200 MHz)

Wireless Evolution through the Generations series



1G

Analogue voice (**AMPS**- Advanced Mobile Phone Standard, **TACS-**Total Access Communications System,...)

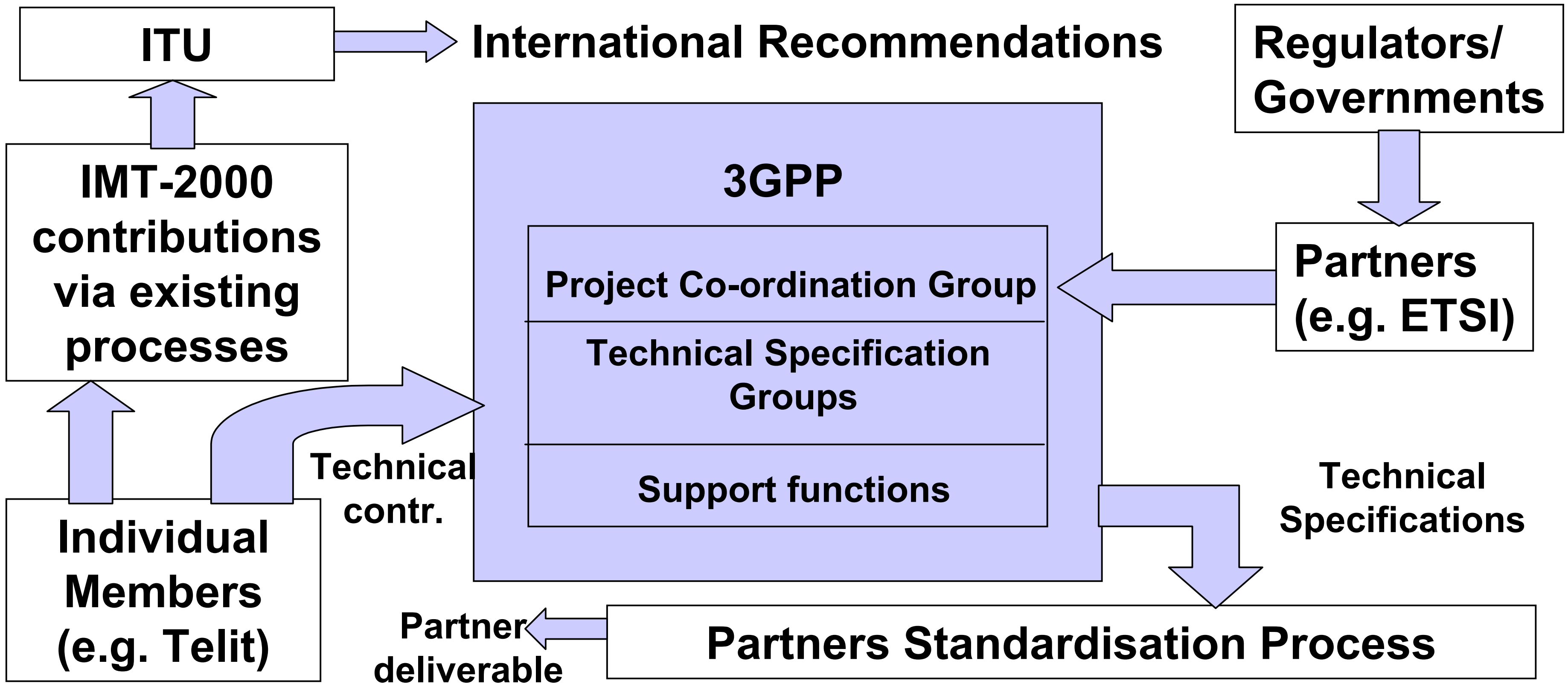
2G

Digital voice, low data rate applications [**GSM**, **IS-54** (TDMA), **IS-95** (CDMA), **GLOBALSTAR, IRIDIUM**…]

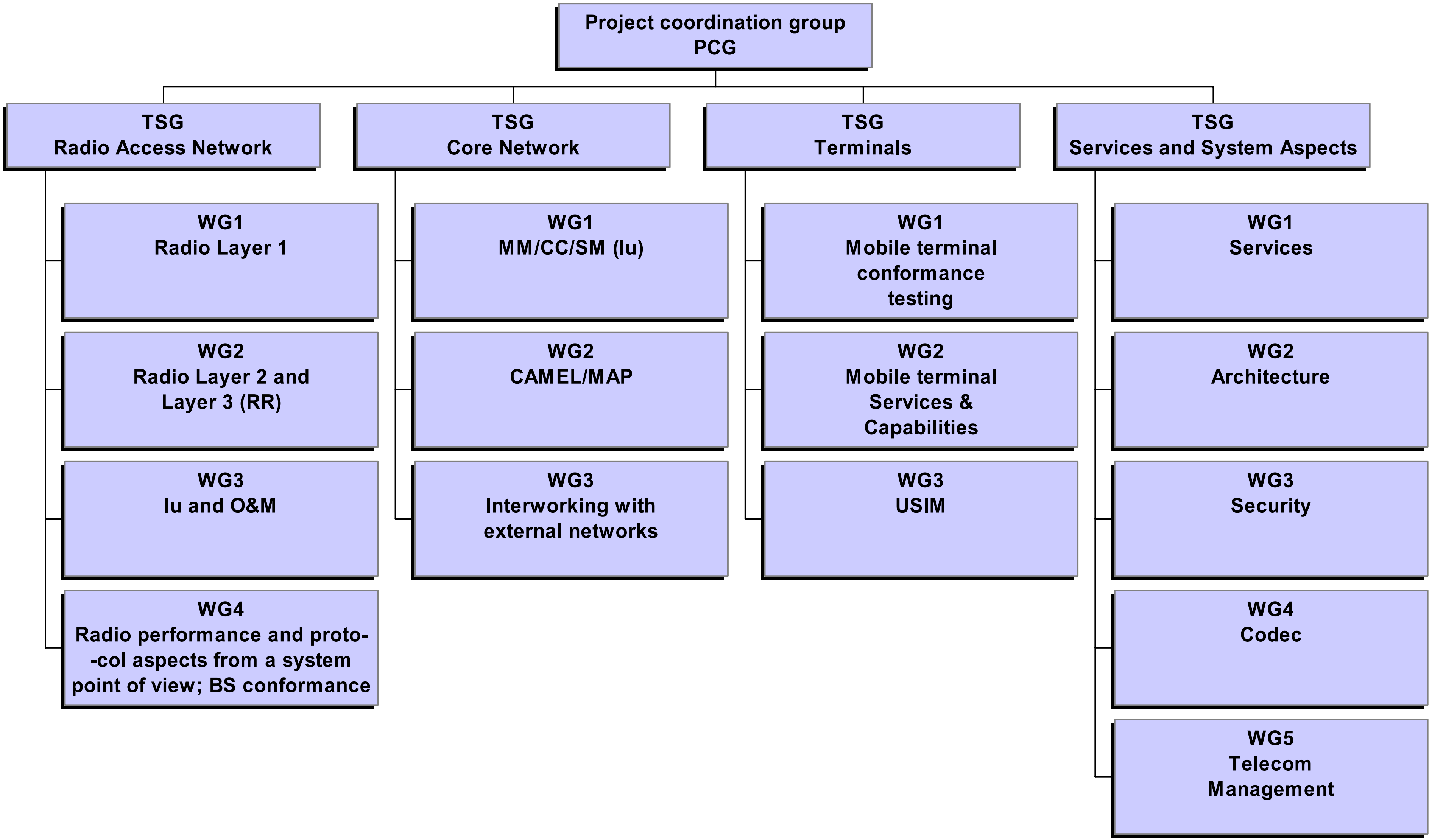
3G

UMTS/IMT 2000 Global Standard for wireless multimedia

Standartization - 3GPP Group (www.3gpp.org)



Standartization - 3GPP Group (www.3gpp.org)



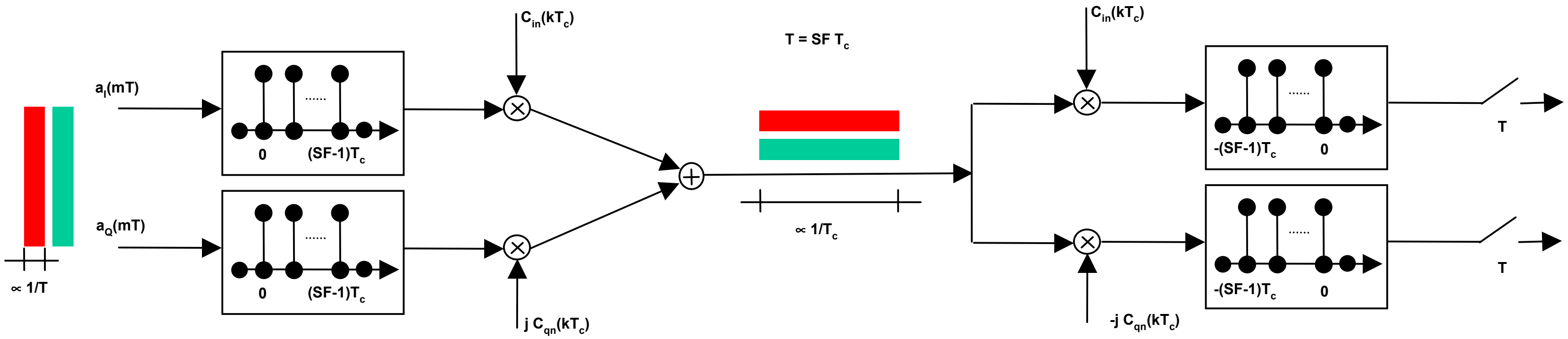
CDMA – Technology review

– spreading & de-spreading
– rake receiver
– soft handoff
– power control
– synchronous versus asynchronous networks

CDMA & spread spectrum

- CDMA = Code Division Multiple Access
- Spread spectrum is a characteristic of a signal; the signal is not necessarily intended for a multiple access of a common medium (e.g. anti-jamming)
- Signals used in CDMA are usually spread spectrum signals
- There are many types of spread spectrum, e.g.
  - Direct Sequence ⇐ this is the only one we consider here
  - Frequency hopping

Spreading & de-spreading



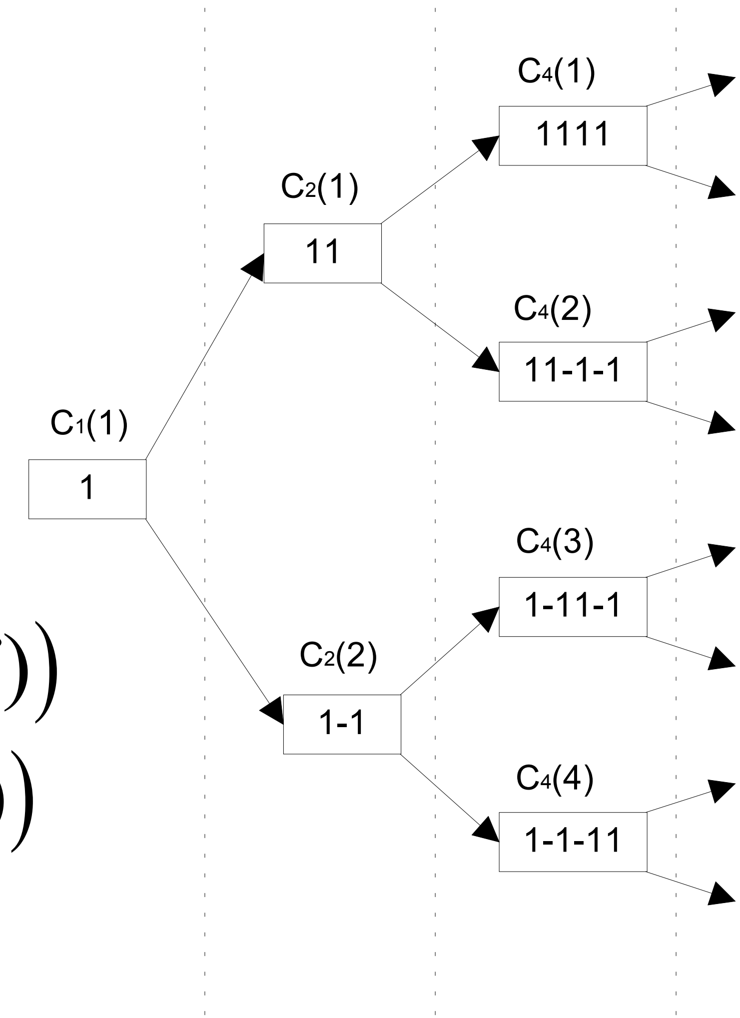
- Direct Sequence spread spectrum
- Rake receiver exploits micro-diversity
- Spreading sequences should be as much as possible
  - orthogonal each other with arbitrary shifts
  - each one orthogonal to itself with arbitrary shifts

Ortogonal Variable Spreading Factor Codes

Recursive rule

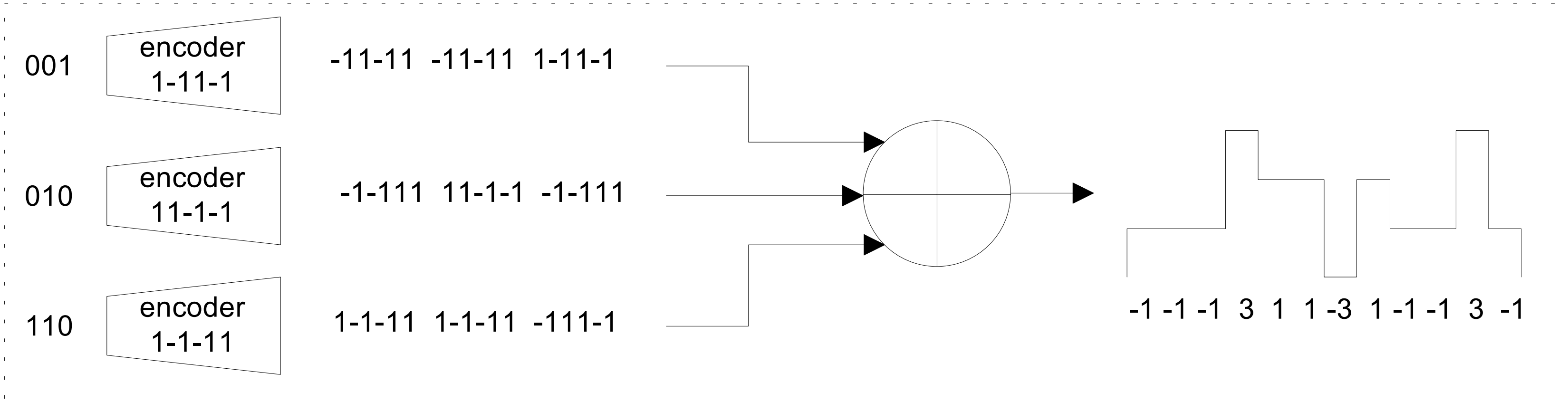
$$C_1(0) = 1$$

$$C_N(i) \rightarrow \begin{cases} C_{2N}(2i-1) = \left(C_N(i), C_N(i)\right) \\ C_{2N}(2i) = \left(C_N(i), -C_N(i)\right) \end{cases}$$

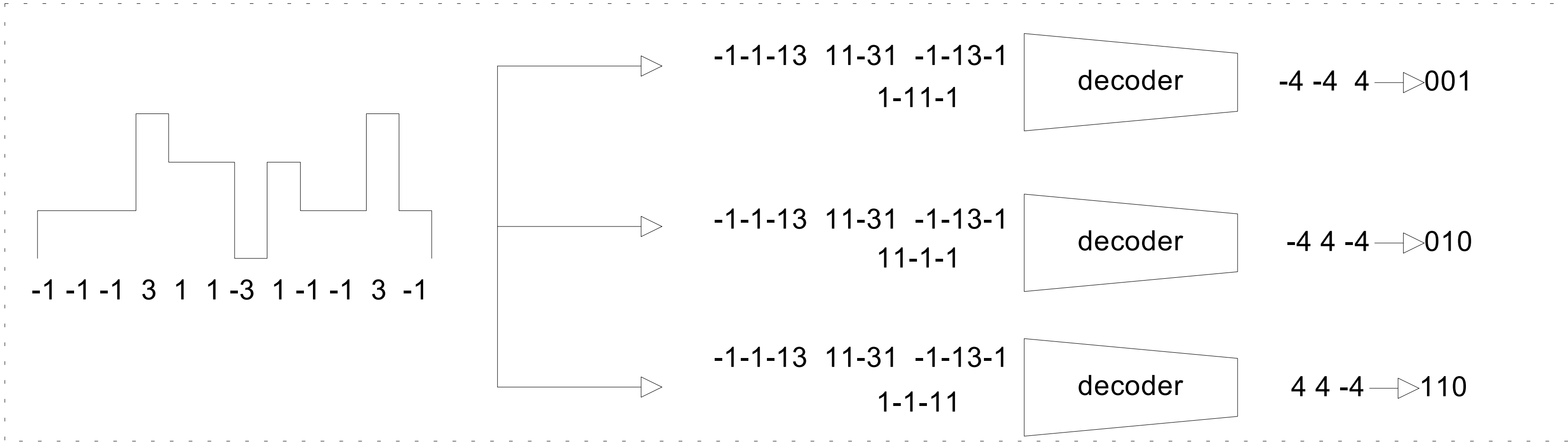


CDMA – Technology review

Spreading



De-Spreading



CDMA – Technology review

Canale1:

- Code1: 1 -1 -1 1 | 1 -1 -1 1 | 1 -1 -1 1 | 1 -1 -1 1 | 1 -1 -1 1
- Data1: -1 | 1 | -1 | 0 | 1
- Data1*Code1: -1 1 1 -1 | 1 -1 -1 1 | -1 1 1 -1 | 0 0 0 0 | 1 -1 -1 1

Canale2:

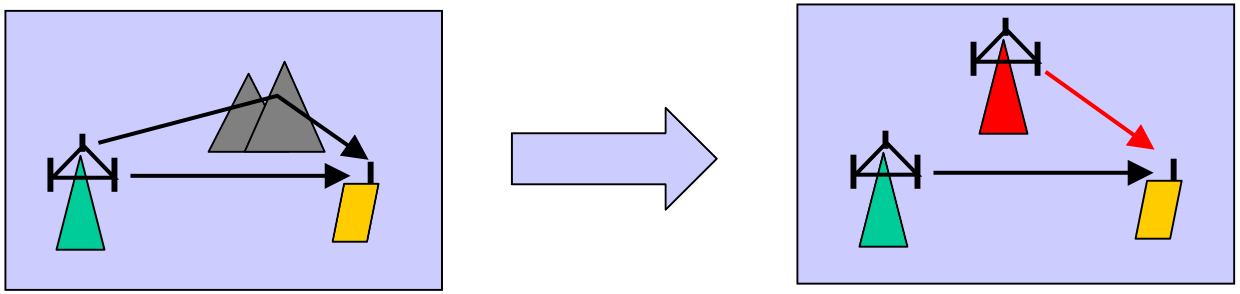
- Code2: 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 1 1
- Data2: 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0
- Data2*Code2: 1 1 | 1 1 | 1 1 | 1 1 | 1 1 | 0 0 | 0 0 | 1 1 | 1 1 | 0 0

Received data (somma dei canali): 0 2 2 0 2 0 0 2 0 2 1 -1 0 0 1 1 2 0 -1 1

- Rx*Code1: 0 -2 -2 0 | 2 0 0 2 | 0 -2 -1 -1 | 0 0 -1 1 | 2 0 1 1
- Data despreaded: -1 | 1 | -1 | 0 | 1

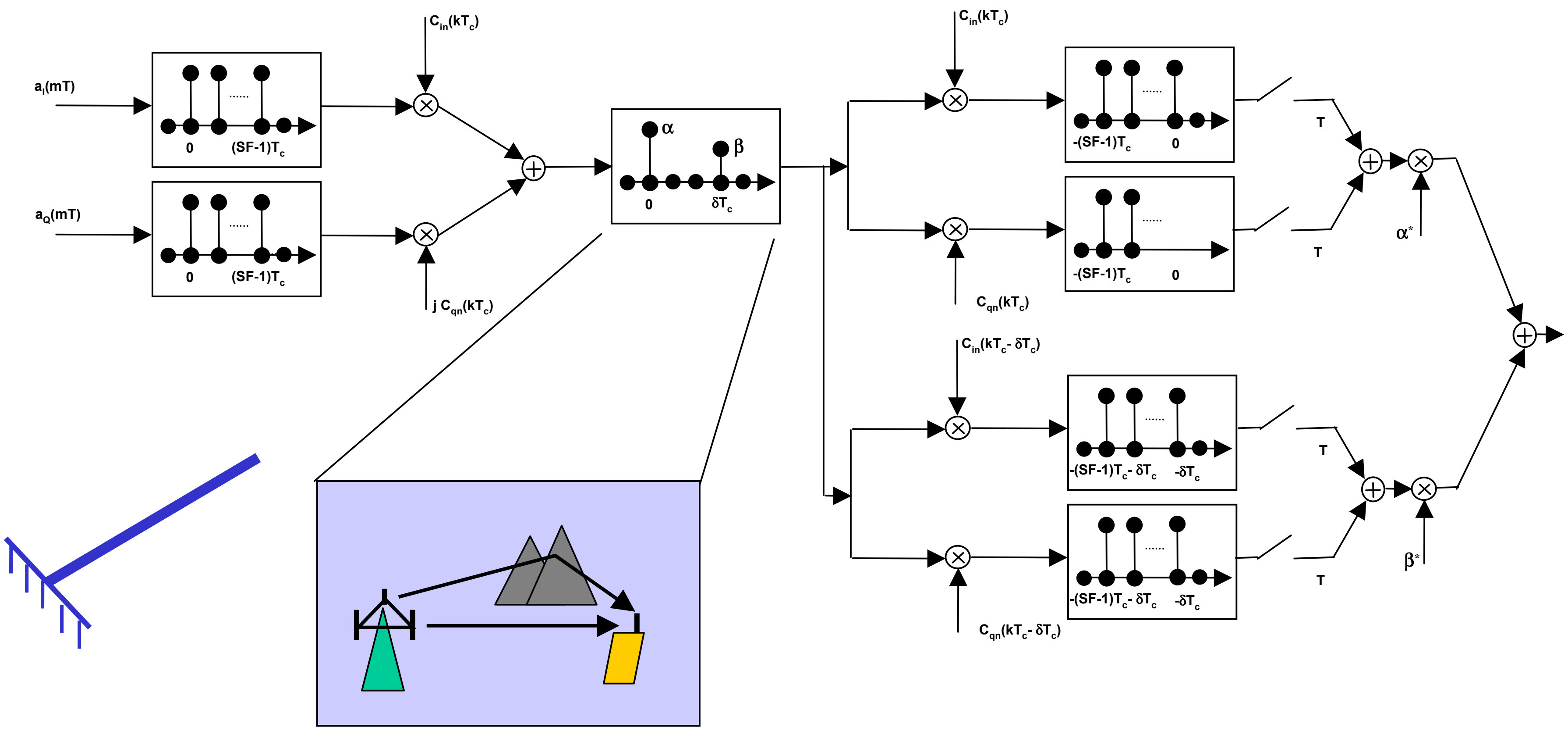
- Rx*Code2: 0 2 | 2 0 | 2 0 | 0 2 | 0 2 | 1 -1 | 0 0 | 1 1 | 2 0 | -1 1
- Data despreaded: 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0

Soft handoff (hand-over)

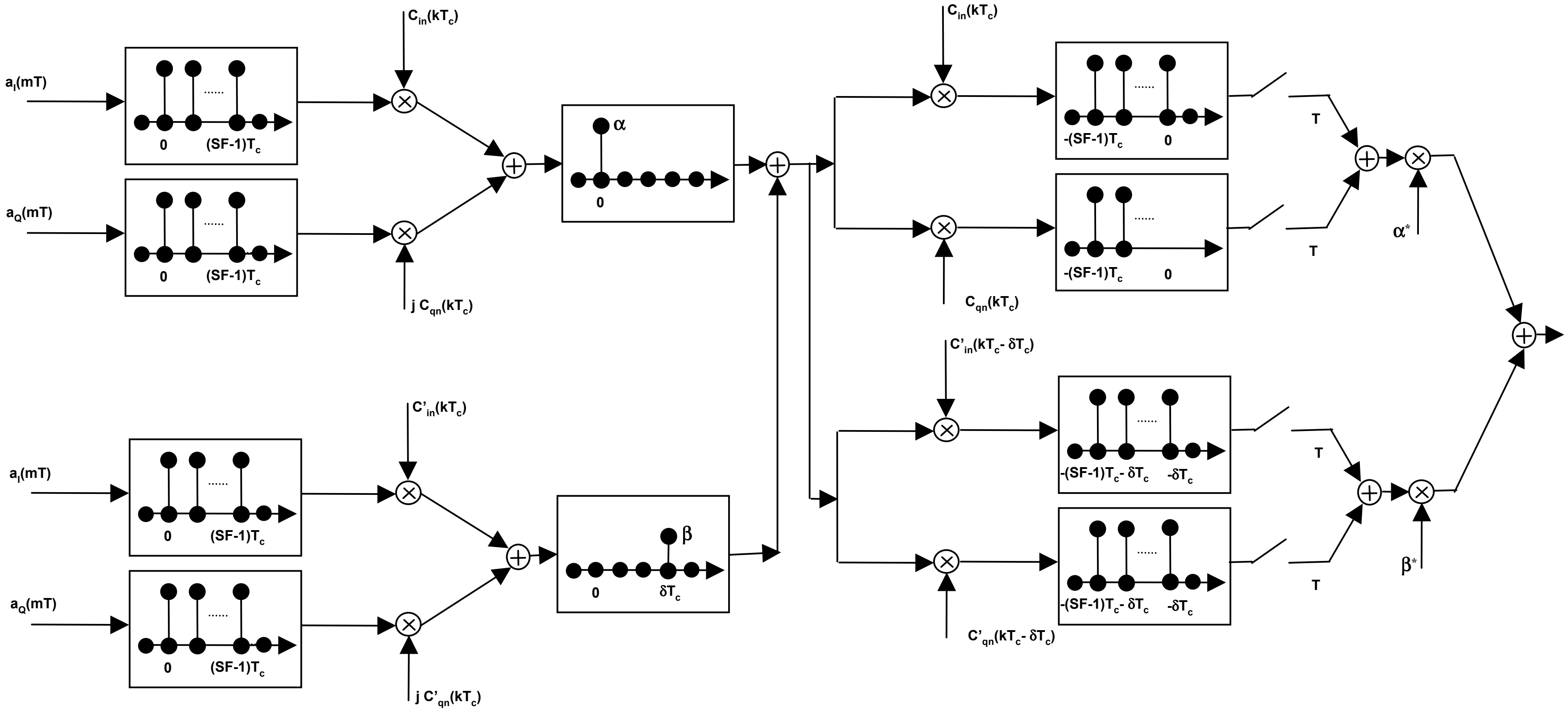


- The two Base Stations use different scrambling codes
- Soft handoff exploits macro-diversity
- Softer handoff: between two sector of the same BS
- Active Set: set of BS connected to a mobile
- Candidate Set: set of BS whose signals has been detected by the mobile but not currently connected

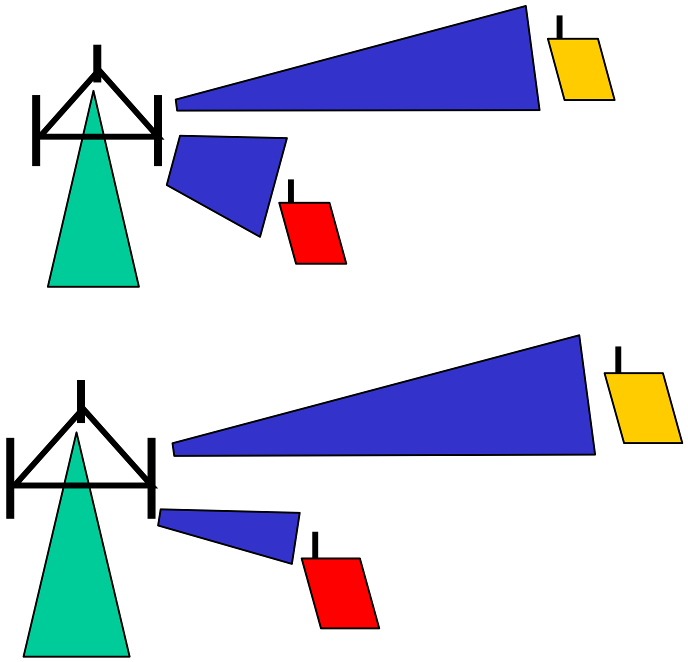
Rake receiver



Rake receiver in soft handoff



Why power control ?



- A "strong" user can cover a "weak" one (because codes are not strictly orthogonal): near far effect
- Since we want a fair system the network command the mobiles to adjust their power in order to have their signals to arrive with (almost) equal quality (minimise the interference at the base station)
- Power control is critical for CDMA systems
- If we can separate users in some way (e.g. TDD and Multi User Detection) power control become less critical

Power control & soft handoff

- Power control minimise intra-cell interference
- Inter-cell interference minimisation is achieved through soft handoff and careful selection of the BS involved in it

Codes planning

- Different Base Stations must have different scrambling codes
  - e.g. to permit to the mobile to distinguish between signals coming from different BS
- "Different" scrambling codes
  - "completely" different scrambling codes
  - scrambling codes made by shifting a unique mother code

Synchronous & asynchronous networks

- Synchronous network: all BS are tightly synchronised (e.g. through GPS)
- Asynchronous network: BS are not supposed to be synchronised
- In synchronous networks we can use a set o scrambling codes made from shifts of a unique mother code

UMTS is an asynchronous system

Logical, Transport and Physical channels

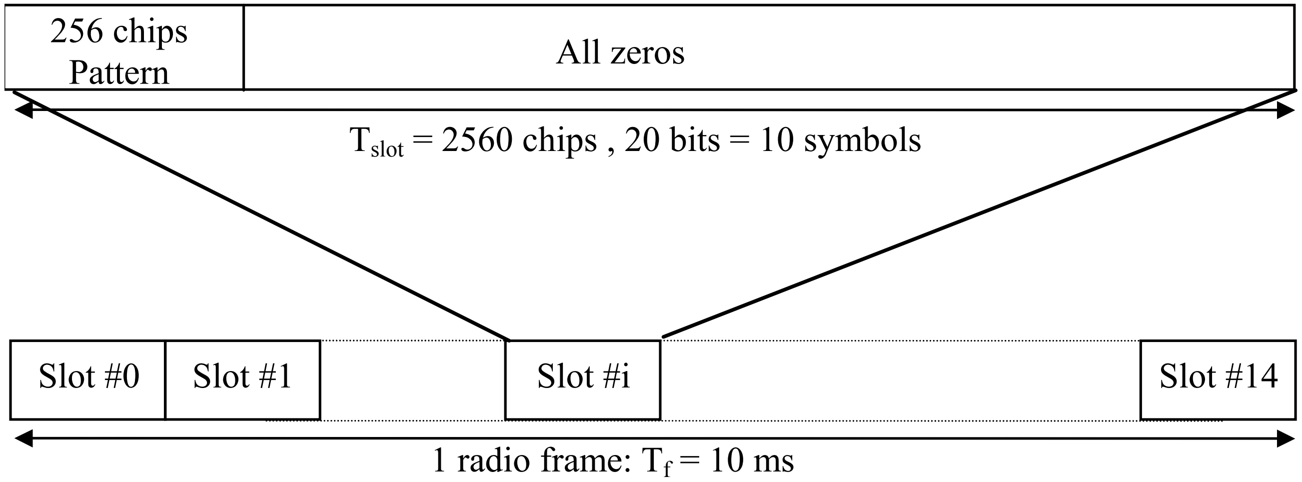
- Logical channel: an information stream dedicated to the transfer of a specific *type of information*
- Transport channel: described by *how* data are transferred
- Physical channel: defined by the *frequency, phase (I,Q) and code*

Logical channels

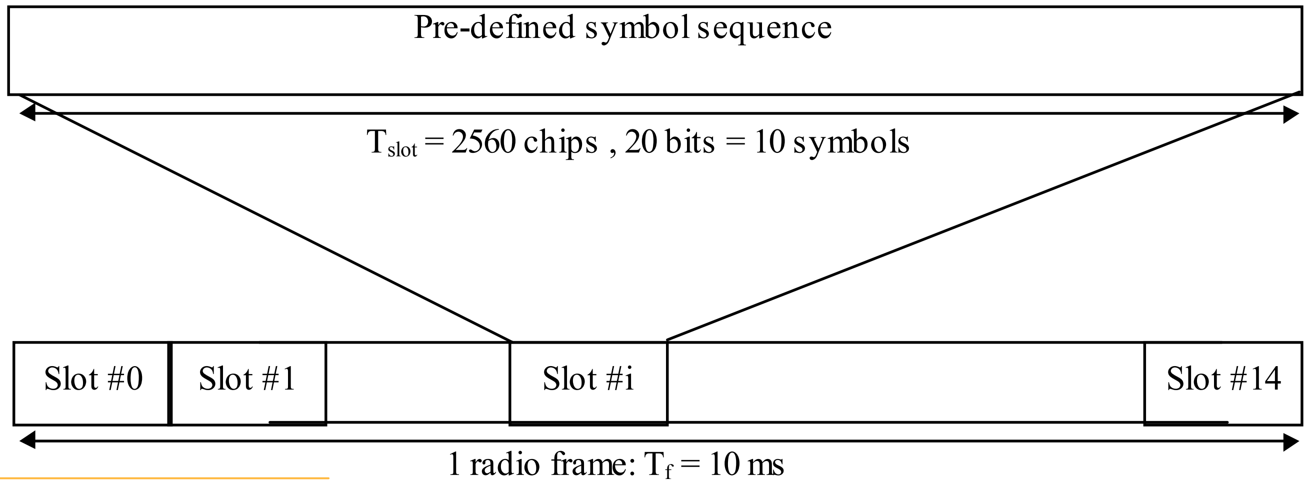
- Control channels (C-plane information)
  - **Synchronisation Control CHannel** (DL)
  - Broadcast Control CHannel (DL)
  - Paging Control CHannel (DL)
  - Common Control CHannel (UL&DL)
  - Dedicated Control CHannel (UL&DL)
  - Shared Control CHannel
  - ODMA Dedicated Control CHannel
- Traffic channels (U-plane information)
  - Dedicated Traffic CHannel (DL&UL)
  - ODMA Dedicated Traffic CHannel
  - Common Traffic CHannel
- Others channels...

UMTS – Syncronization

Primary and Secondary Syncronization Channels (PSCH, SSCH)

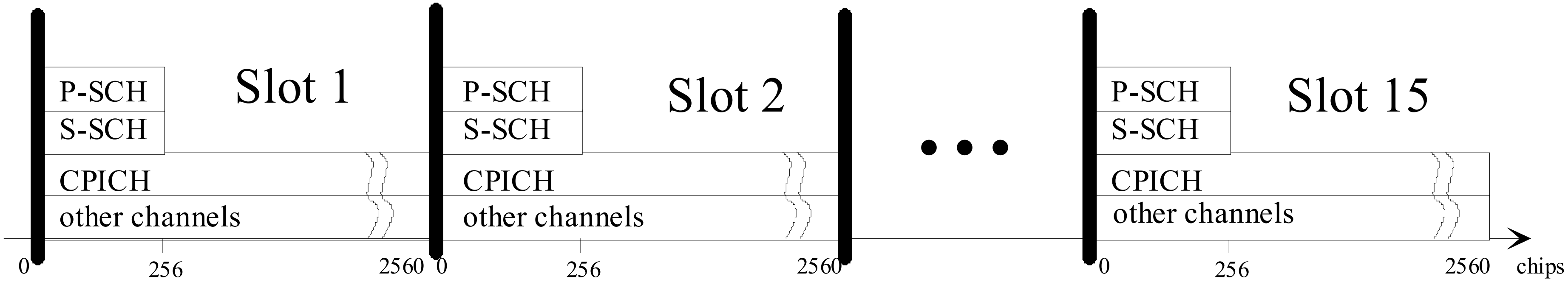


Common Pilot Syncronization Channels (CPICH)

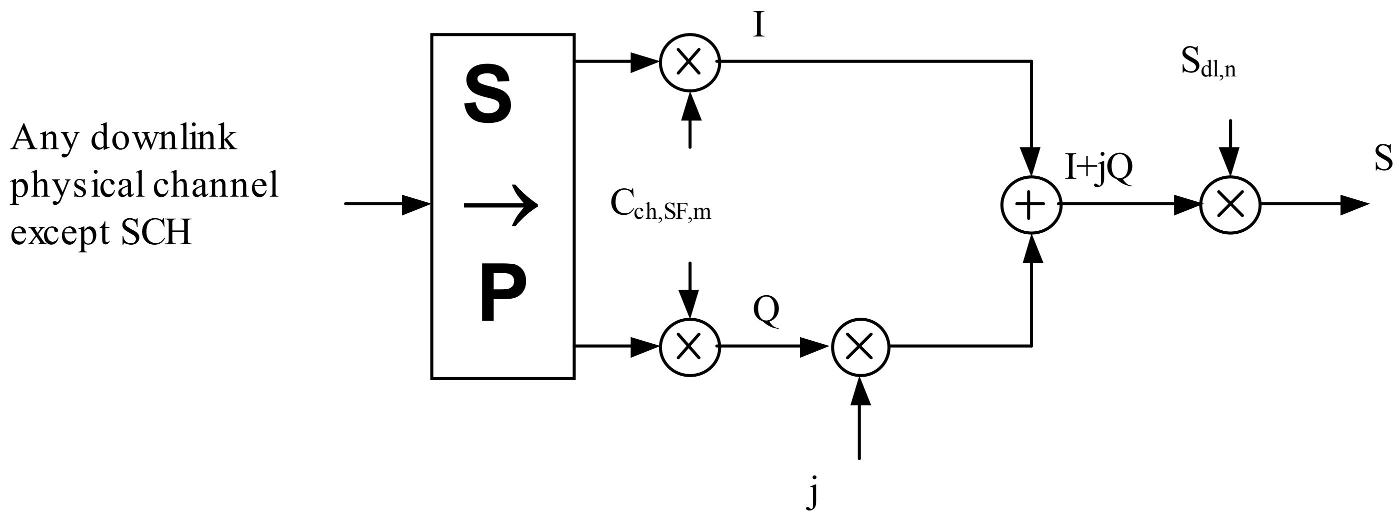


UMTS – Synchronization

- PSCH is constant over a slot and identify the UMTS cell, slot periodicity. (slot synchronization)
- SSCH is constant over a frame, each of 15 slot has its own symbol from 16 possible ones and identify the code group to use. (frame synchronization)
- CPICH has frame periodicity. Identify the sub-code from where to get the final code to use with other channels.



Down-link spreading and modulation: all channels but SCH

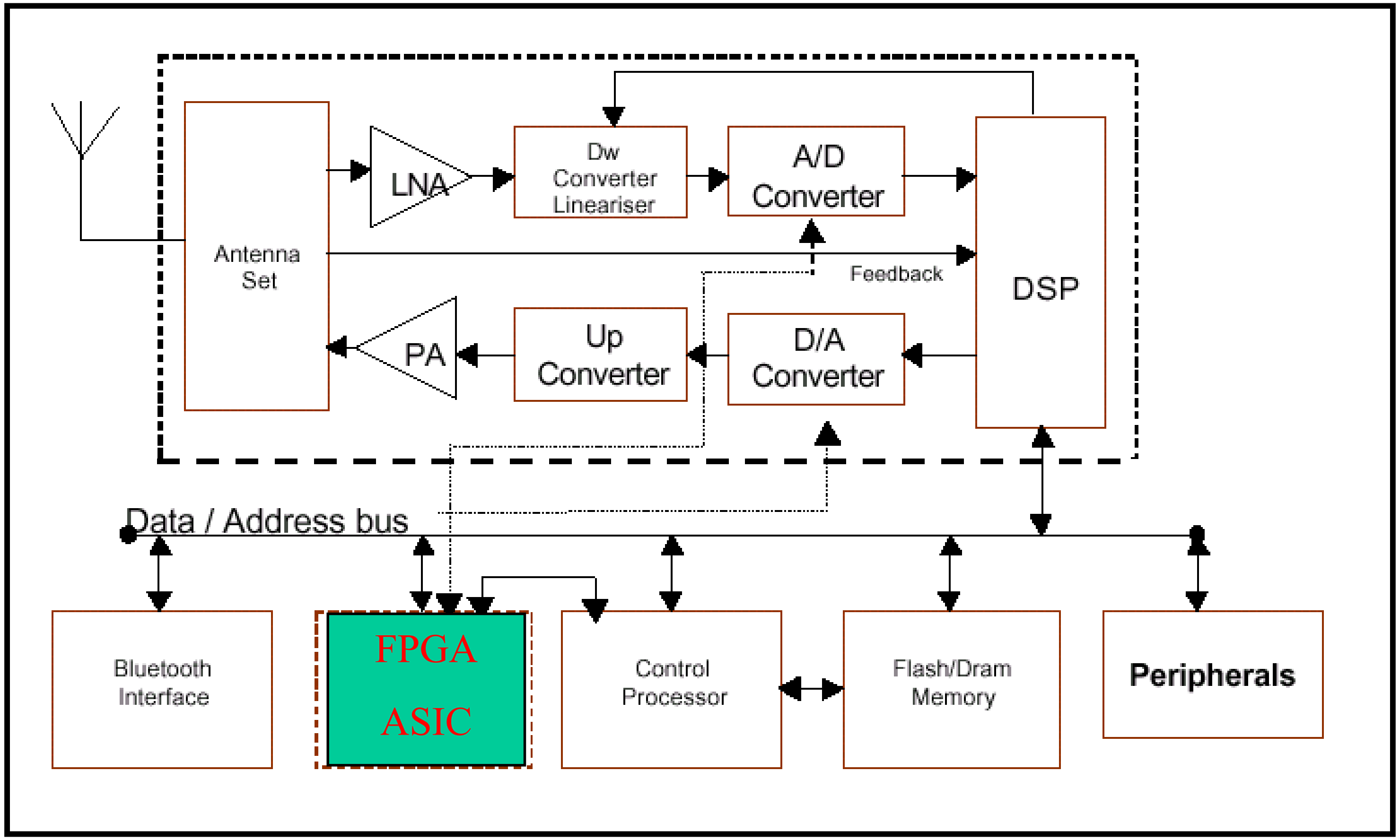


UMTS – Hardware Function Extentions

The asynchronous characteristic in UMTS system needs a more complex synchronization procedure.

The complexity in its realization is due to the big amount of CPU and/or DSP time need to complete the synchronization between the mobile and the antenna. The solutions are the use of a powerful embedded system, but it may cost in power consumption, or the realization of an external, to CPU, hardware accelerator block that realize the desired function only when it is necessary, in real time. In this paper we present a full hardware block done in a FPGA for UMTS-FDD initial synchronization procedure.

UMTS Terminal : envisaged architecture



The **core of the system is the DSP**, responsible of most of the baseband processing; the support of **dedicated FPGAs or ASICs** for particular **heavy computational operations** like rake-decoding/Interference mitigation can be necessary depending on DSP computational power. In this last case, a **dedicated bus between the DSP and the ASIC could also be needed, or the ASIC should directly communicate with the AD/DA converters and then with the DSP**.

The **Control Processor** manages the exchange of data/addressing information between the **DSP and the ASIC**

A **digital predistortion in the TX path** is envisaged, performed by the loop “DSP-Up conversion path-Antenna set-Feedback”. The same feedback line, shown in figure, is used to perform a dinamic adjustment, **to improve the linearity of the receiving section**.