CDMA UMTS radio

CDMA basics

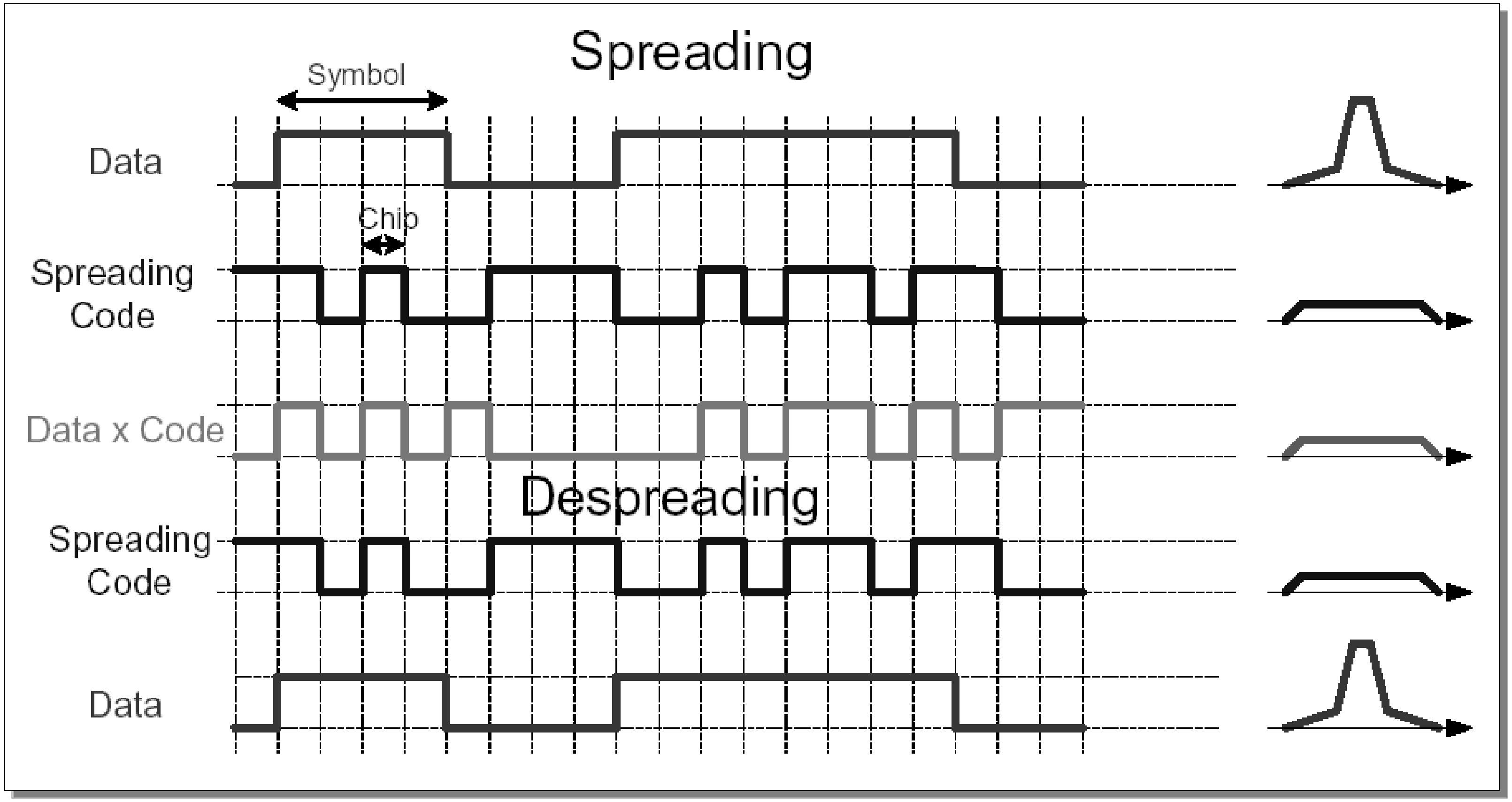
CDMA basics

- instead of a single bit (or symbol) a sequence (code) is transmitted
- code rate is faster than the bitrate
  - hence the signal's spectrum is wider
  - therefore it is a spread spectrum technique

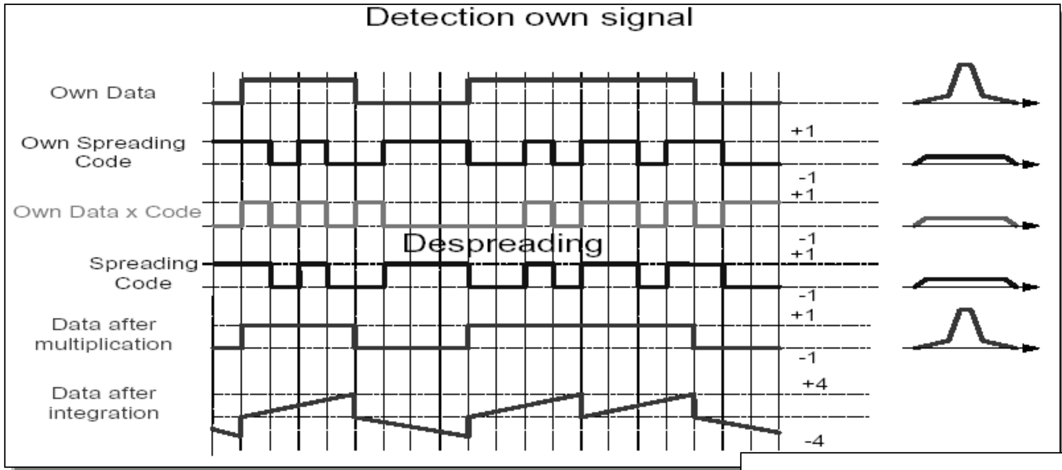
CDMA basics

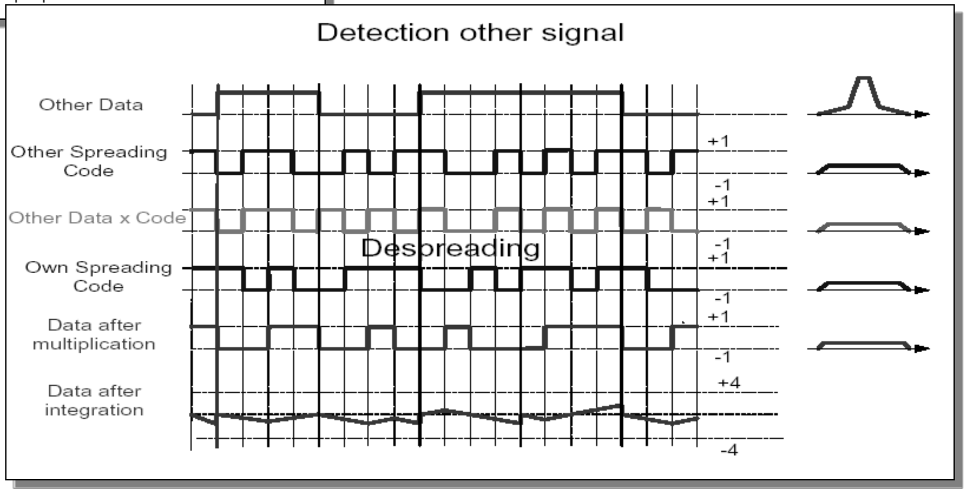
- users use the same frequency baqnd, in the same time
- codes are used to distinguish the information of the users
- the channel carries the sum of all users' codes
- the receiver can extract the given user's information from this sum, knowing the code
- it can work if the codes are orthogonal to each other

CDMA basics



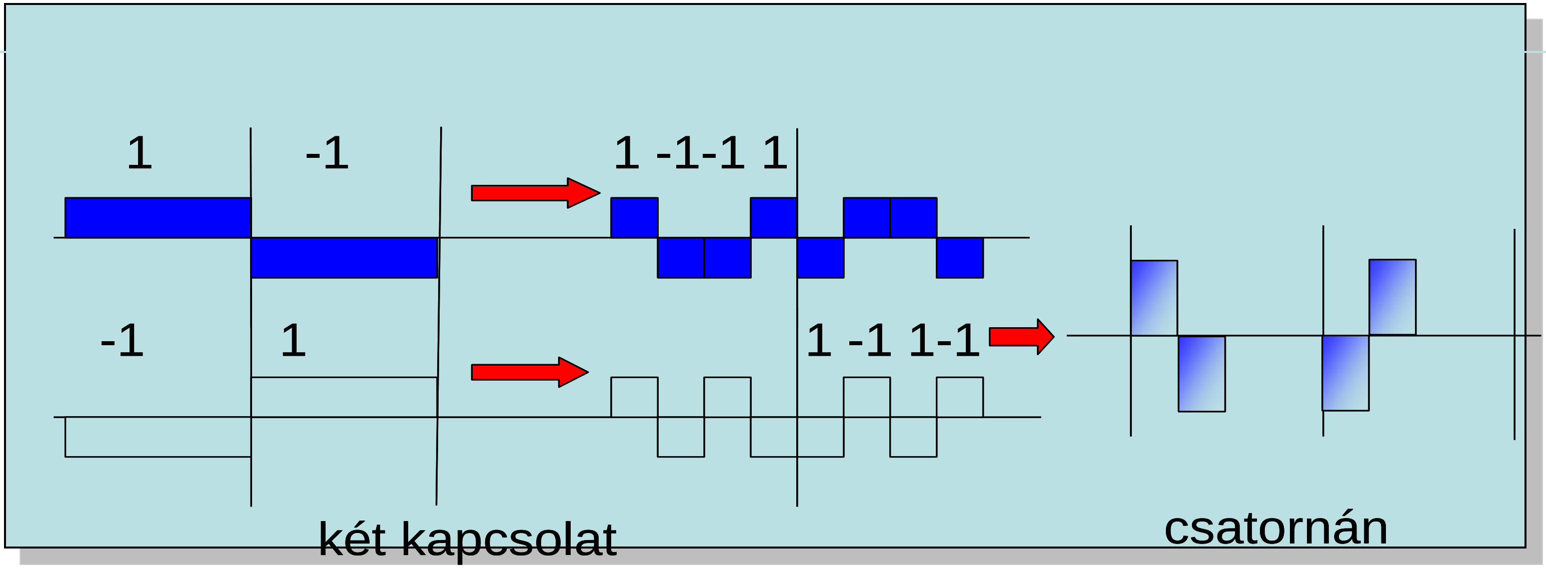
Spreading
Symbol
Data
Chip
Spreading Code
Data x Code
Despreading
Spreading Code
Data


Detection own signal
Own Data
Own Spreading Code
Own Data x Code
Despreading
Spreading Code
Data after multiplication
Data after integration
+1
-1
+1
-1
+1
-1
+1
-1
+4
-4


Detection other signal
Other Data
Other Spreading Code
Other Data x Code
Despreading
Own Spreading Code
Data after multiplication
Data after integration
+1
-1
+1
-1
+1
-1
+1
-1
+4
-4

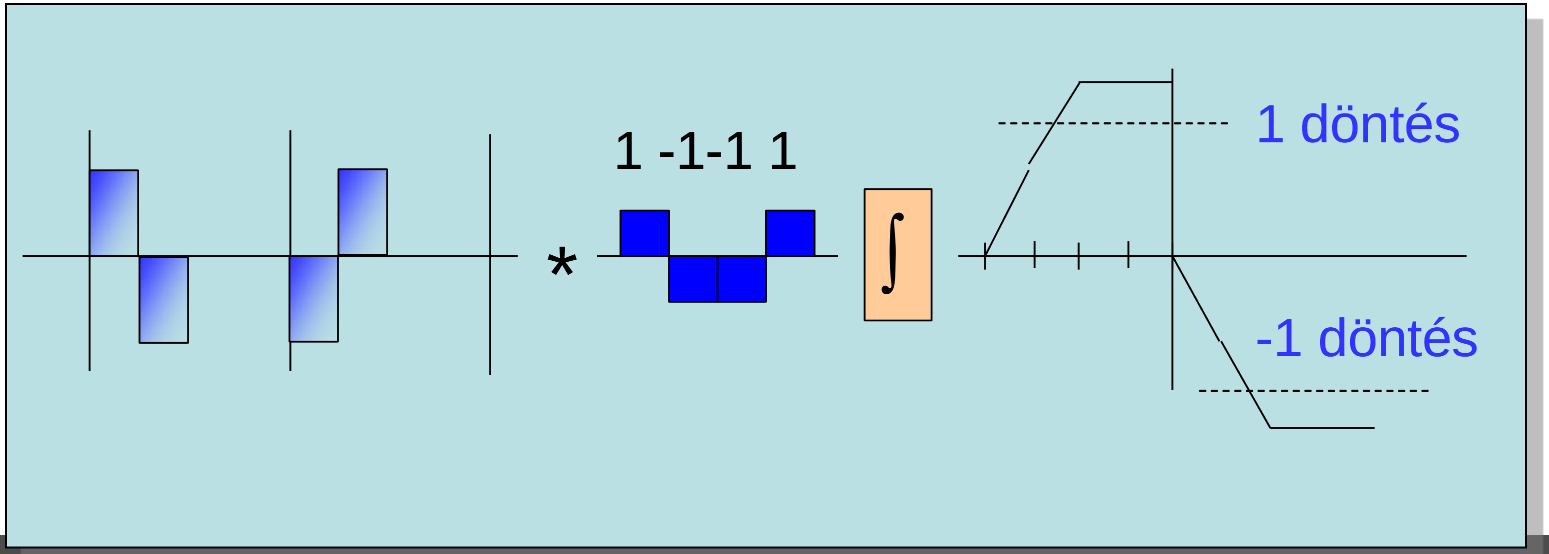
CDMA basics

- example:



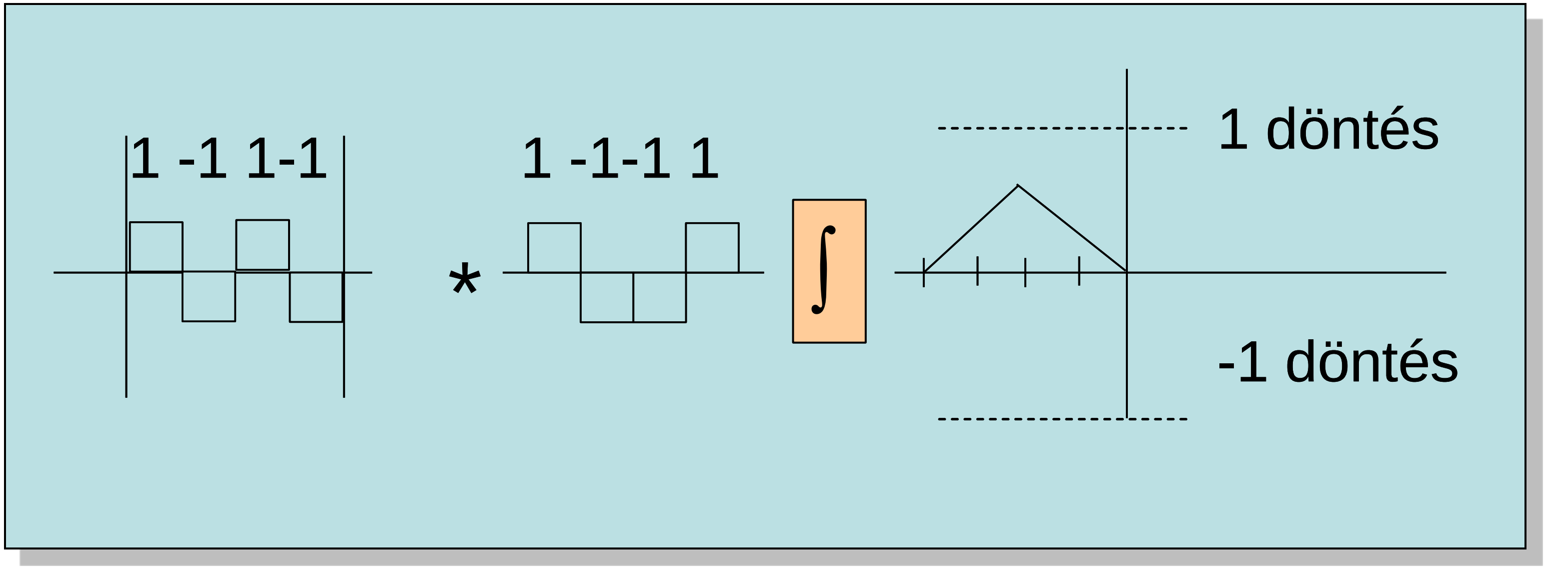
CDMA basics

- receiver side: the receiver correlates the signal with the known code (in other terms: calculates the scalar product of the code and the received signal)
  - meaning: chip-wise multiply the received signal by the code and sum up (or integrate)
- if the sum (or the result of the integration) higher, or lower than a threshold, the bit is decided to be 1 or -1



CDMA basics

- different codes are orthogonal
- correlation (or scalar product) of two codes is zero
- in practice: so called quasi-orthogonal codes are also used -> not perfectly orthogonal -> users’ cause interference to each other



W-H codes, codetree, orthogonality

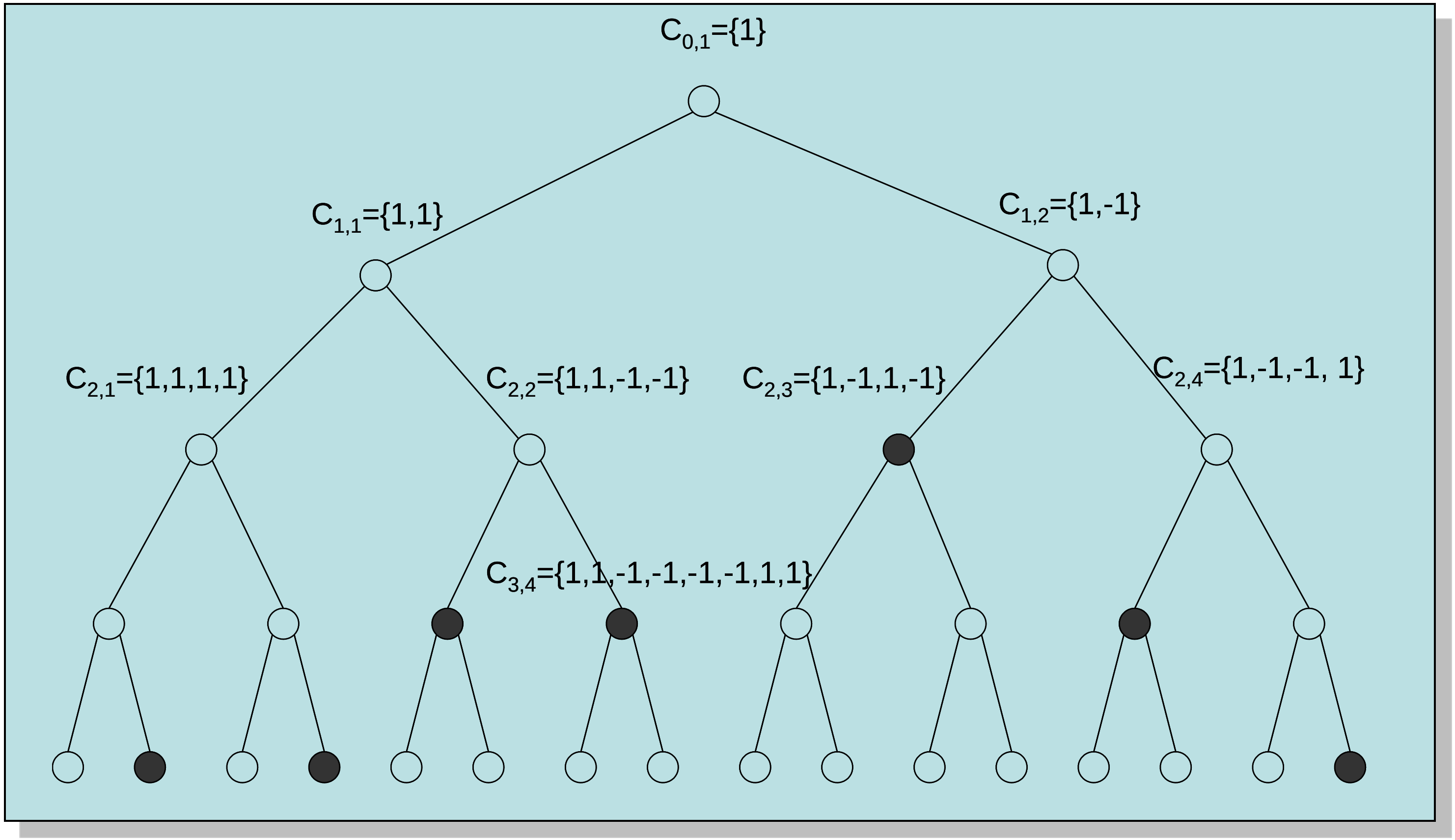
- so-called Walsh-Hadamard (W-H) codes, also called OVSF (Orthogonal Variable Spreading Factor) in UMTS
- generating these codes: code length is 2^n

$$\mathbf{H}_0 = 1\ ;\ \mathbf{H}_1 = \begin{bmatrix} 1 & -1 \\ -1 & -1 \end{bmatrix}\ ;\ \mathbf{H}_n = \begin{bmatrix} \mathbf{H}_{n-1} & -\mathbf{H}_{n-1} \\ -\mathbf{H}_{n-1} & -\mathbf{H}_{n-1} \end{bmatrix}$$

- rows or columns, or -1 times of any of above H matrices are orthogonal W-H codewords of length 2^n
- length of code -> number of orthogonal codewords -> number of channels using these codes
- these are the channelization codes in UMTS

W-H codes, codetree, orthogonality

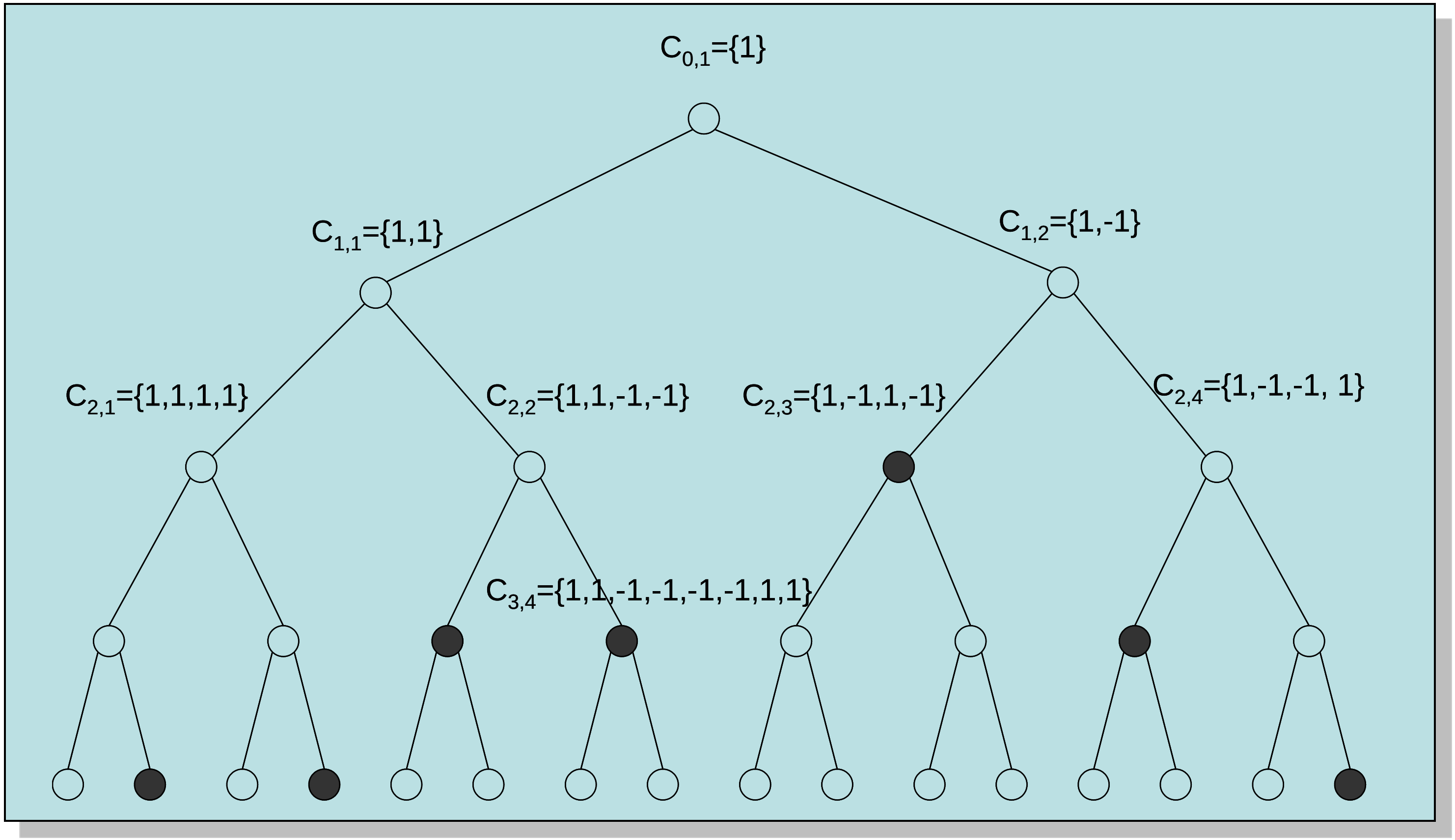
- other representation: codetree



- a node in the graph representation: a codeword
- generation: describe

W-H codes, codetree, orthogonality

- other representation: codetree



- codes at the same level are orthogonal
- codes NOT in ancestor-predecessor relation: orthogonal

W-H codes, codetree, orthogonality

- providing different bitrates to different users:
  - there's a fix coderate (chiprate)
  - users use codes of different length
  - e.g. a user with codelength 8 can deliver 2 bits, while another with codelength 1 can only deliver 1 bit
  - doubling codelength (going down one level in the tree) means halving the bitrate
  - can only work if the codes are orthogonal
  - chosen from different levels in the tree in a way that NO codes in child-parent relation can be allocated at once

Basics of UMTS radio interface

- Main properties
  - frame structure
    - 10 msec frame length containing, 15 timeslots (0,667 msec each)
    - modulation: QPSK (Quaternary Phase Shift Keying): 4 state phase modulation
    - chiprate: 3.84 Mcps (megachip per second)
      - spreading factor (code length)
        - » min 4 max 12 in downlink
        - » min 4 max 2 in uplink
    - codes
      - Channelization codes: Walsh-Hadamard codes, also called OVSF (Orthogonal Variable Spreading Factor) codes
      - Scrambling codes: quasi-orthogonal codes, pieces of very long pseudorandom codes

Basics of UMTS radio interface

- codes
  - Channelization codes: Walsh-Hadamard codes, also called OVSF (Orthogonal Variable Spreading Factor) codes
    - » channelization code: defines a channel (can be data or control channel), hence the notion
  - Walsh-Hadamard codes are orthogonal if they are chip-synchronized
    - » hard to achieve in uplink
  - limited number of channels per Walsh-Hadamard codetree
  - cells may use the same frequency channel even if they are neighboring cells
  - there should be another way to distinguis among:
    - » signals of different cells in downlink
    - » signals of different UEs in uplink

Basics of UMTS radio interface

- codes
  - so scrambling codes are also used
  - scrambling codes in upling distinguish the information of different users
    - » W-H codes are used to separate channels of a single user, e.g. control and data channels, or multiple data channels
  - scrambling codes in downlink distinguish the signal of different cells
    - » W-H codes are used to separate transmission to different users
    - » control and data of a single user in this case is separated in time

Basics of UMTS radio interface

- physical bitrates
  - its gross bitrate, containing control, error correction coding redundancy, protocol overheads, etc.
  - how to calculate?
    -
    - $$\frac{3.84}{codelength} \cdot 2$$
    - Mbps, where the 2 is because of the QPSK, this is valid for the downlink
    - there is no 2 in the uplink expression: here the control and data is transmitted in two different branches of the modulaton
    - so max in downlink: in case of shortest code (4): 1.92 Mbps

Basics of UMTS radio interface

- typical implemented bitrates
  - 384 kbps (using length 8 code, gross bitrate of 920 kbps)
  - 144 kbps
  - 64 kbps
  - 12.2 kbps for voice

  - these are net useful bitrates

Consequences of CDMA in UMTS

- consequences of CDMA
  - scrambling codes quasi orthogonal -> UEs cause interference to each other in upling, cells interfere each other in downlink
  - but communications is still enabled, due to the interference supression capability (low correlation) of the scrambling codes
  - hence:
    - fast and accurate power control needed, every connection should use a power just enough for achieving a signal to interference ratio
    - not more, as this would cause too much interference to others
    - higher traffic means higher interference

Consequences of CDMA in UMTS

- higher traffic means higher interference
- if traffic increases: remote (far from base station) UEs migh not receive satisfactory signal quality
  - it may get out of coverage, without even moving
  - handover might be necessary, despite being stationary
- traffic increases -> interference increases ->coverage shrinks
  - this is breathing cells
- there is no hard limit of the capacity: one more connection just means a tiny increase in interference
  - UMTS has soft capacity
- capacity, coverage and traffic are coupled
- soft handover: a connection is maintained through two or more cells. This is possible, because communicating with another cell or user simply means multiplication my another scrambling code -> can be done in software, numerically, no other hardware needed
  - soft handover is also one consequence of using CDMA

HSDPA

- High Speed Downlink Packet Access (HSDPA)
  - this enabled the mobile internet
  - goal was to increase bitrate and reduce latency
  - there are several novelties compared to UMTS
  - HSDPA uses 2ms long frames (3 timeslots)
    - these are sent together with UMTS frames, using different channelization codes
  - HSDPA uses adaptive modulation and coding (AMC): transport format (modulation + error correction code used) is adapted to channel quality
    - a new modulation, 16 QAM (16 state) was introduced besides QPSK
    - 16QAM can be used if the channel quality is good
    - AMC: good channel: 16QAM+weak coding. Bad channel: QPSK+robust coding

HSDPA

- HSDPA channel: a number (maximum 15) of fixed, length 16 W-H codes are alocated together to form the high-speed channel (unlike UMTS, HSDPA uses fixed length 16 codes)
  - this is a shared channel: a scheduler decides to which UE does it send over this high-speed channel
    - a separate control channel is used to signal which user will get the data from the high-speed channel
  - scheduler also decides on the transport format
    - based on CQI (Channel Quality Indicator), reported by UEs, based on their measurements
    - CQI: a number between 0 (worst channel) and 30 (best channel)
      - there's a mapping table, mapping between the CQI and the transport format to be used
    - UE must report a CQI value that will cause maximum packet loss of 10%

HSDPA

- retransmission
  - if a packet is corrupted, there's retransmission
  - HARQ (Hybrid Automatic Repeat ReQuest), hybrid because of methods used
    - incremental redundancy: retransmissionuses a more robust error correction coding, hence the retransmission will not likely be corrupted
    - chase combining: corrupted packet is not dropped, but combined with the retransmitted one, thus allowing higher chance of proper decoding
- scheduing, AMC and HARQ is done at the NodeB
  - first time in mobile standards when intelligence is moved to the base station
- scheduling
  - can be arbitrar, may or may not taking into account CQI. examples:
    - round robin: send to each UE one after the other (this is fair in time)
    - best CQI: send to the UE who has the best channel (this maximises cell throughput)
    - fair throughput: balance the bitrate aqchieved by all UEs
    - etc.

HSDPA

- device categories
  - depending on the capabilities of devices, e.g. does it implement 16QAM, how many spreading codes can it handle maximum, can it receive in every 2ms, or does it need some processing time between receptions?
  - device category is taken into account in scheduling decisions as well
- bitrates
  - length 16 code: 460 kbps with QPSK, 920 kbps with 16QAM. 15 codes: 14.4 Mbps

HSDPA

- HSPA+
  - further developments
  - 64QAM: 1.5 times bitrate if channel is very good
  - MIMO: 2x2 antennas, enabling doubling the bitrate
  - dual carrier HSPA (dual cell): two UMTS channels (5MHz each) are used together: doubling the bitrate
  - theoretical maximum is around 82 Mbps then
  - HSPA+ is widely deployed over the world