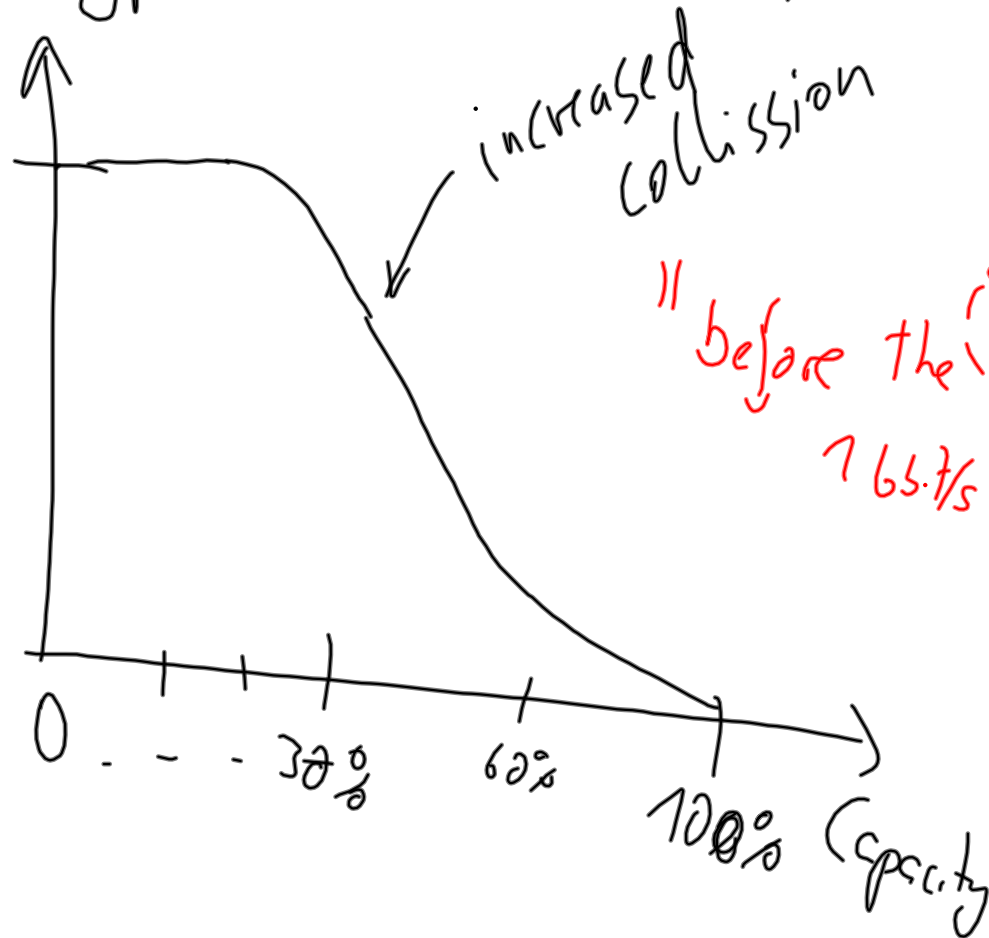


Throughput (Ethernet)



Multiple Access in Mobile Systems

When multiple users share same bandwidth, there are four main techniques:

FDMA (Frequency Division Multiple Access)

- Each user is assigned a separate frequency range

TDMA (Time Division Multiple Access)

- Multiple users share the allocated frequency bands, and each user use an allocated time

CDMA (Code Division Multiple Access)

- The bandwidth used by all users simultaneously, which is separated by means of code

OFDMA (Orthogonal Frequency Division Multiple Access)

- The bandwidth is divided to the different users as needed

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Introduction

Multiple Access is divided in two main types:

- Contentionless: “conflict-free” protocol based on scheduling**
 - Ensuring a transmission, whenever made is a successful one and not interfered by another transmission.
 - Used in Mobile systems such as GSM, UMTS and LTE
- Contention: “Random access” with various means to resolve conflict for simultaneous transmission**
 - In principal, transmission is not guaranteed to be successful
 - Used in WLAN/Wi-Fi systems
 - Also used in mobile system for initial connection set-up

```

graph TD
    Root[Multiple access protocols] --> Contentionless[Contentionless (scheduling)]
    Root --> Contention[Contention (random access)]
    Contentionless --> Fixed[Fixed assigned]
    Contentionless --> Demand[Demand assigned]
    Fixed --> FDMA_TDMA[FDMA TDMA]
    Demand --> Polling[Polling token passing]
    Contention --> CDMA[CDMA]
    Contention --> Repeated[Repeated random access]
    Contention --> Reservation[Random access with reservation]
    CDMA --> Pure[Pure CDMA DS, FH, TH]
    CDMA --> Hybrid[Hybrid CDMA DS/FH TDMA/CDMA]
    Repeated --> ALOHA[ALOHA, s-ALOHA]
    Reservation --> Implicit[Implicit Explicit]
  
```

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Multiple Access in Mobile Systems

When multiple users share same bandwidth, there are four main techniques:

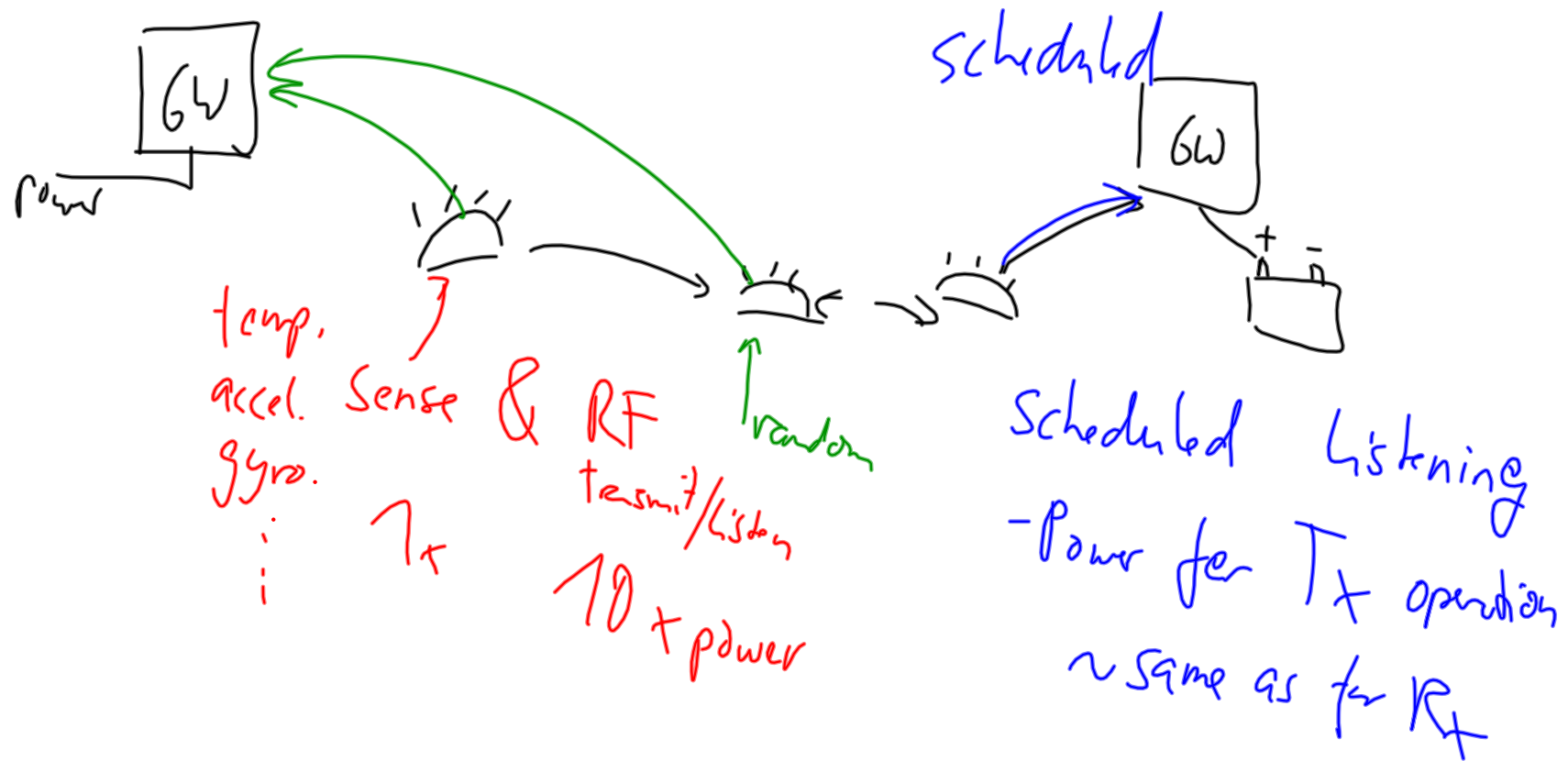
- FDMA (Frequency Division Multiple Access)
 - Each user is assigned a separate frequency range
- TDMA (Time Division Multiple Access)
 - Multiple users share the allocated frequency bands, and each user use an allocated time
- CDMA (Code Division Multiple Access)
 - The bandwidth used by all users simultaneously, which is separated by means of code
- OFDMA (Orthogonal Frequency Division Multiple Access)
 - The bandwidth is divided to the different users as needed

Speech:
Opera ; bat ; languages
One at a time
Code with language

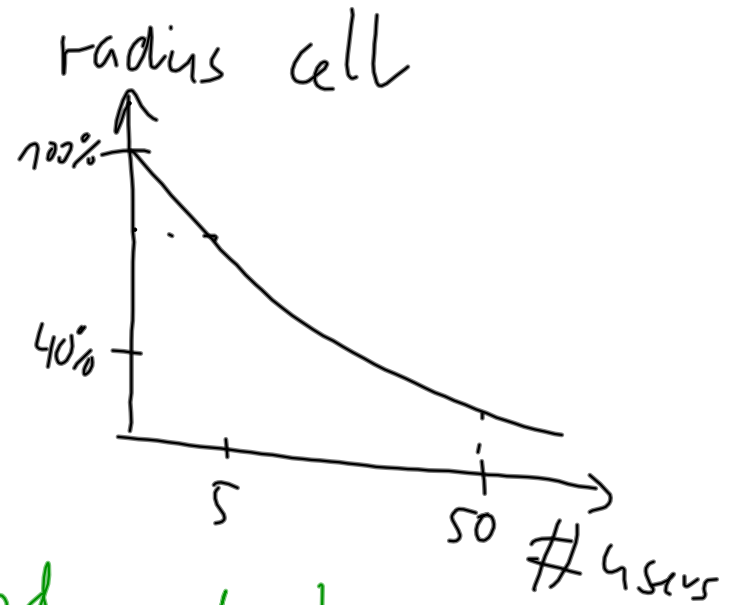
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Sensor network



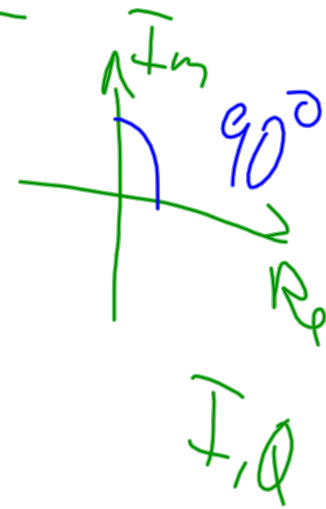
Cell breathing CDMA



codes are not independent
cos, sin

$$j = \sqrt{-1}$$

more codes $\rightarrow$ interference



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(O) FDMA, TDMA and CDMA

FDMA

(a)

TDMA

(b)

CDMA

(c)

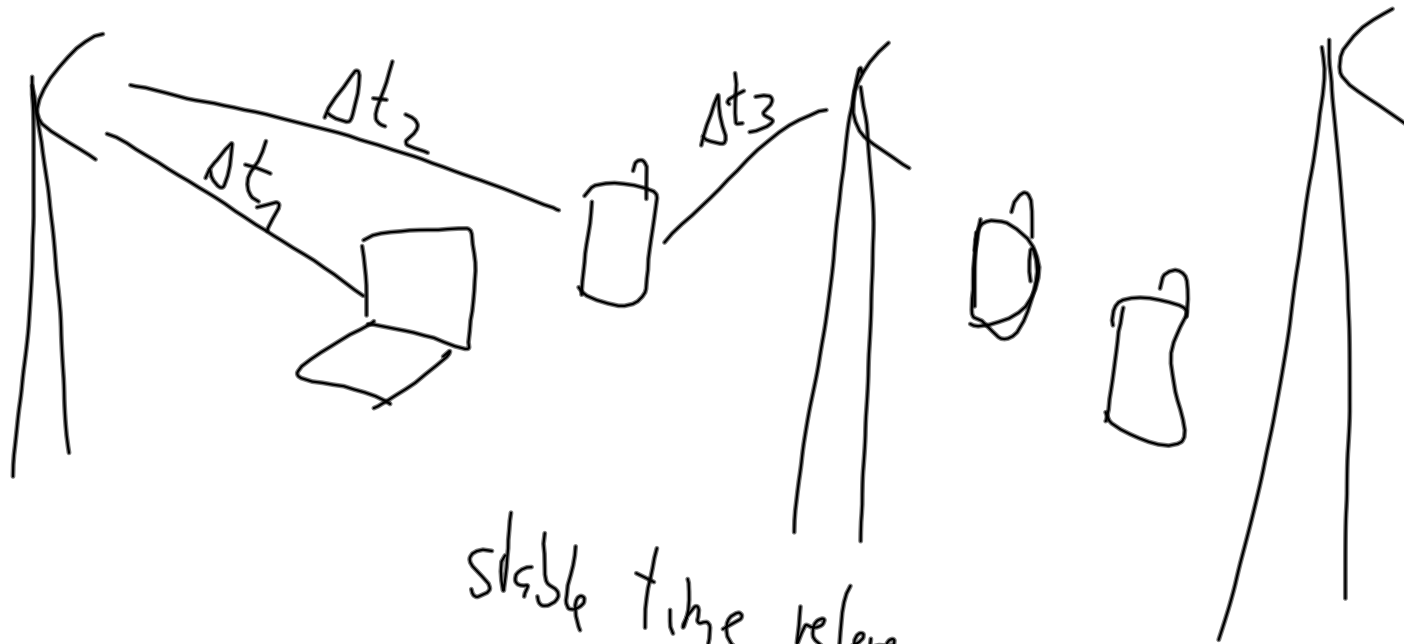
TD-CDMA

UMTS = WCDMA = FD-CDMA (TD-CDMA)

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Synchronisation



stable time reference

100 Mbit/s $\rightarrow$ 50ns ref(?)

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Duplex Transmission

FDD: A duplexer is needed since same antenna is used for both way transmissions

TDD: No duplexer is needed

(a)

(b)

Transmit

Receive

Data in

Modulator

Duplexer

Demodulator

Data out

high data rate

time synchronization

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Duplex Techniques and Systems

Systems are characterized both by its method of multiple access and duplex

For example

- FDMA/FDD (e.g. NMT)
- TDMA/FDD (e.g. GSM)
- TDMA/TDD (e.g. DECT)
- CDMA/TDD (e.g. UMTS TDD)
- CDMA/FDD (e.g. UMTS FDD)
- OFDMA/TDD (e.g. WiMAX)
- OFDMA/FDD (e.g. LTE)

Cell breathing

Frequency reuse

4:1 frequency reuse

1, 5, 10, 20 MHz

cell bandwidth

5 MHz

10 MHz

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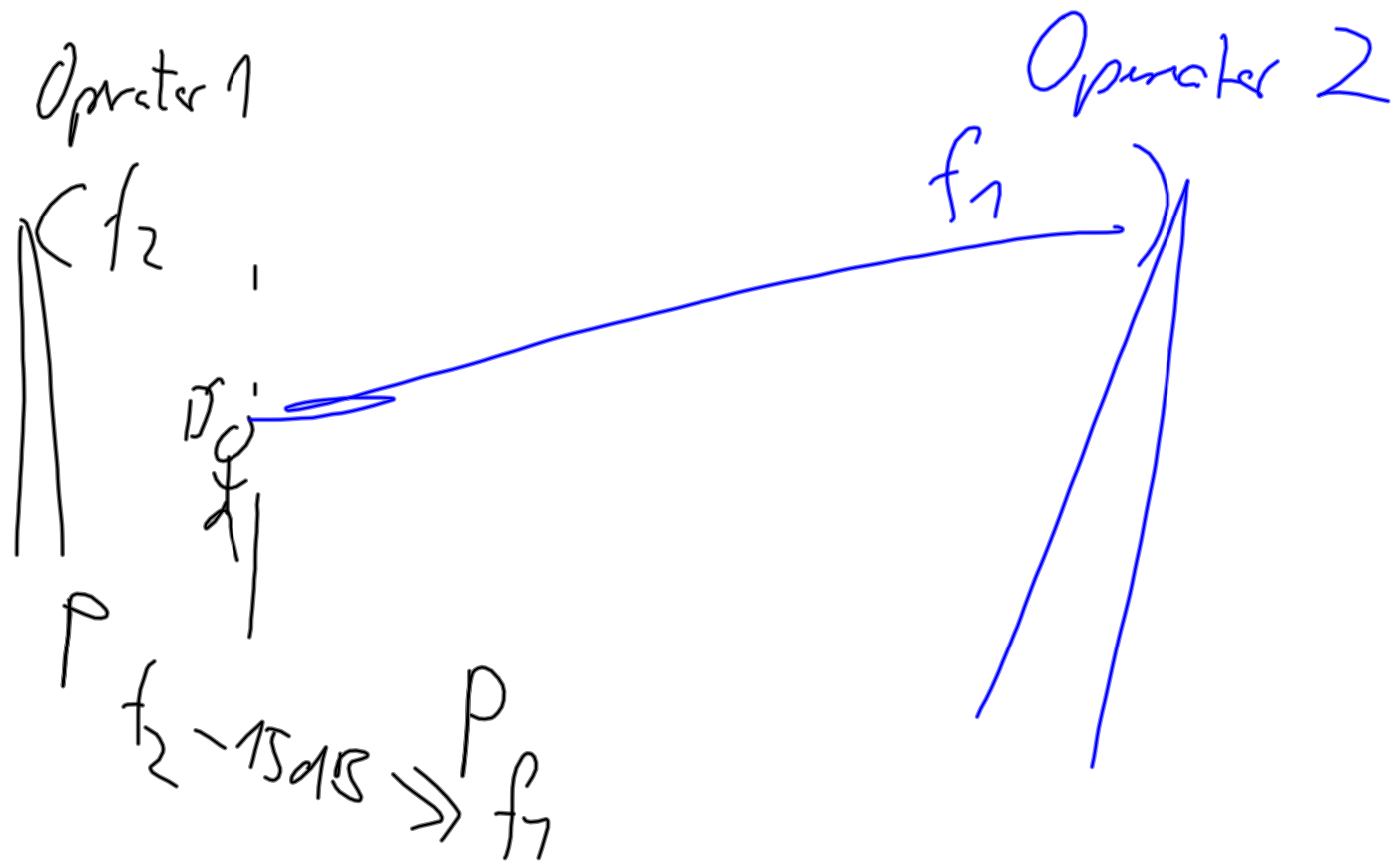
Advantages of FDMA

- The major advantage of FDMA is the “hardware simplicity” since discrimination between users is done by simple bandpass filters.
- No timing information or synchronization is required
- Little problem of frequency-selective fading and Intersymbol Interference (ISI) since bandwidth assigned to each user is relatively small

UMTS: only 15dB filter for adj. channel

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TDMA: Timeslot and Frame

The diagram illustrates the structure of a TDMA frame and its relationship to a superframe and timeslots. At the top, a horizontal bar represents a 'Superframe', divided into 'Frame 1', 'Frame 2', and several empty slots. Below this, a single 'One TDMA frame' is shown, consisting of a 'Preamble', an 'Information message', and 'Trail bits'. This frame is then mapped to a sequence of 'Slot 1', 'Slot 2', and 'Slot N'. A detailed view of a slot shows its internal structure: 'Trail bits', 'Synch. bits', 'Information data', and 'Guard bits'. The 'Guard bits' section is circled in green. Handwritten red lines connect the 'Superframe' to the 'One TDMA frame', and green lines connect the 'One TDMA frame' to the 'Slot' structure. The 'Guard bits' section is also circled in green.

Preamble:

- Address and synchronization information

Guardbits:

- Necessary to allow non-ideal time synchronization between the mobile?

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TDMA in GSM

GSM is a combined FDMA / TDMA system

- The frequency band is divided into the carrier (carriers) of 200 kHz
 - Different carrier used in different cells
 - For larger capacity requirements, multiple carrier used in a cell
- Each carrier is divided into eight TDMA timeslots, which together is called a TDMA frame.

$8 = 1 = \text{signalling} + 7 \text{ data} + 8 f_1 + 8 f_2$
- Each frame is 4.615 ms (= 120/26 ms) and each time slot is 0577 ms (= 15/26 ms). A time slot is the smallest unit in GSM
- Each channel uses one time slot per TDMA frame
- Bit-rate on the physical layer in GSM is 270.833 kHz $\sim 270 \text{ kb/s}$

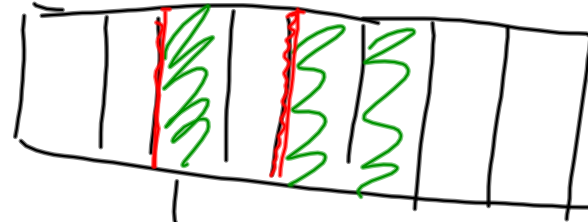
$BW_{\text{GSM}} = 5 \text{ MHz} / (3.84 \text{ MHz})$

$LTE = 1, 2, 5, 7, 9, 20 \text{ MHz}$

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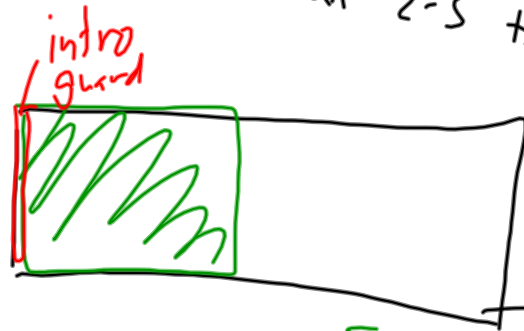
GPRS



max 270 kbit/s / 8
~ 30 kbit/s per slot
time slots

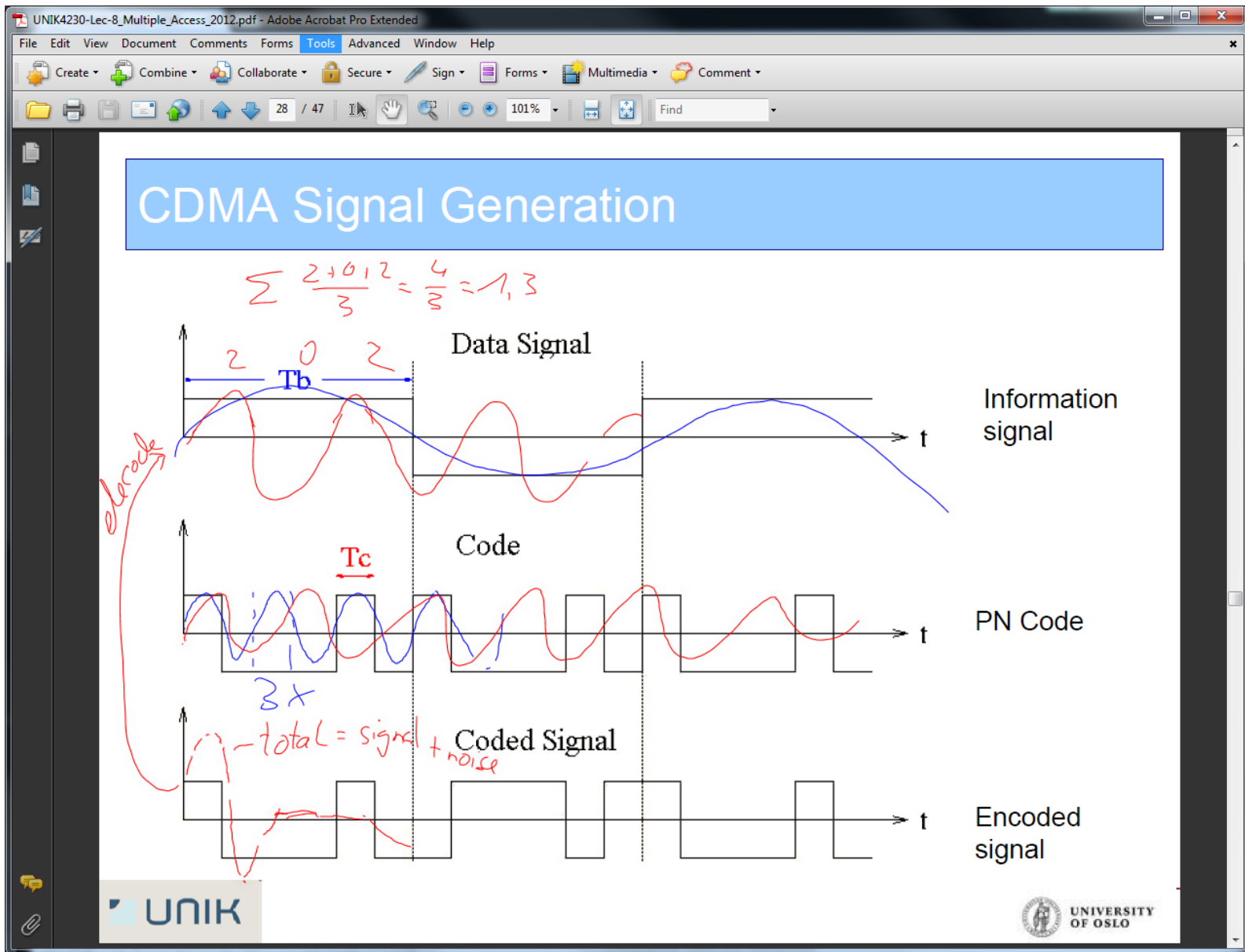
typical 8-12 kbit/s / time slot
max 2-3 time slots

EDGE



GPRS < 30 kbit/s

EDGE < 128 kbit/s 8 slots

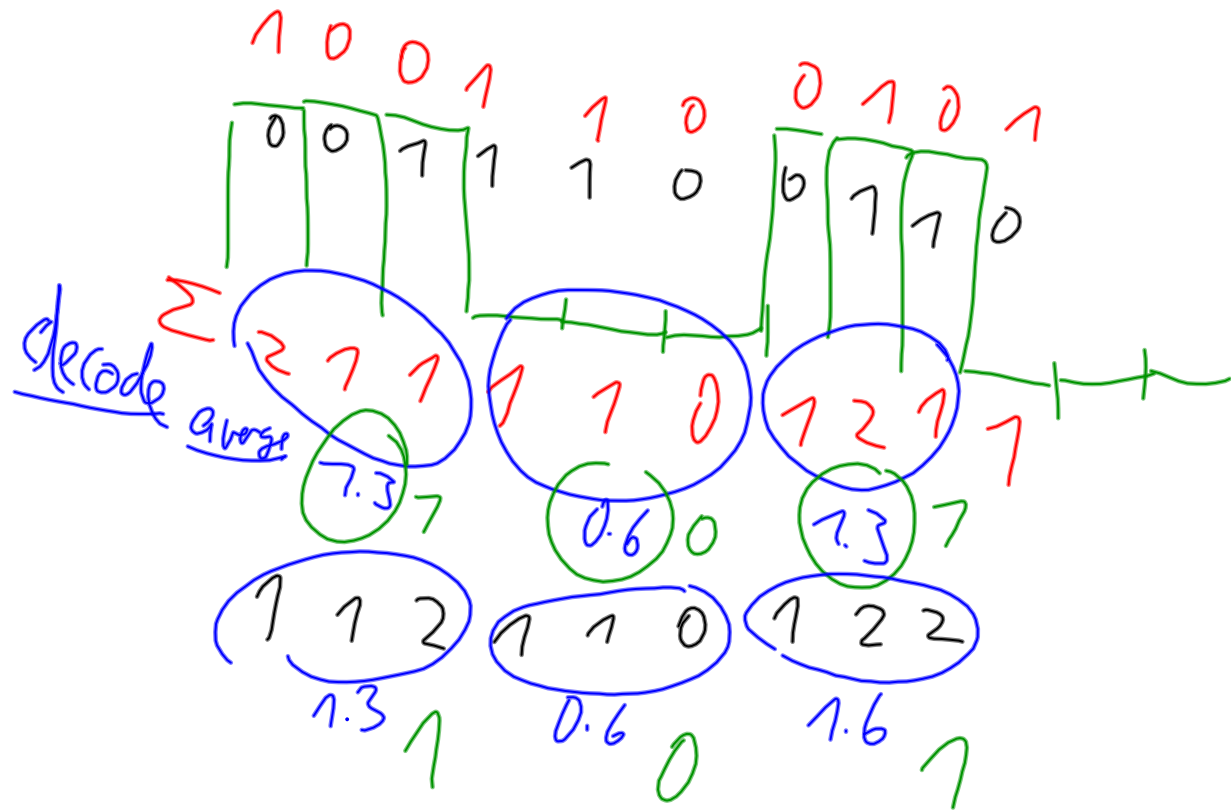


Example of noise reduction



code
3x repeat

50.5 noise
10011001
00111001



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Interference in CDMA

- Different users have different spreading-code, which is almost orthogonal
- If orthogonality between the codes is perfect then no interference at the receiver.
- Cross correlation between two spreading sequences s_n and s_m is:

sin, cos

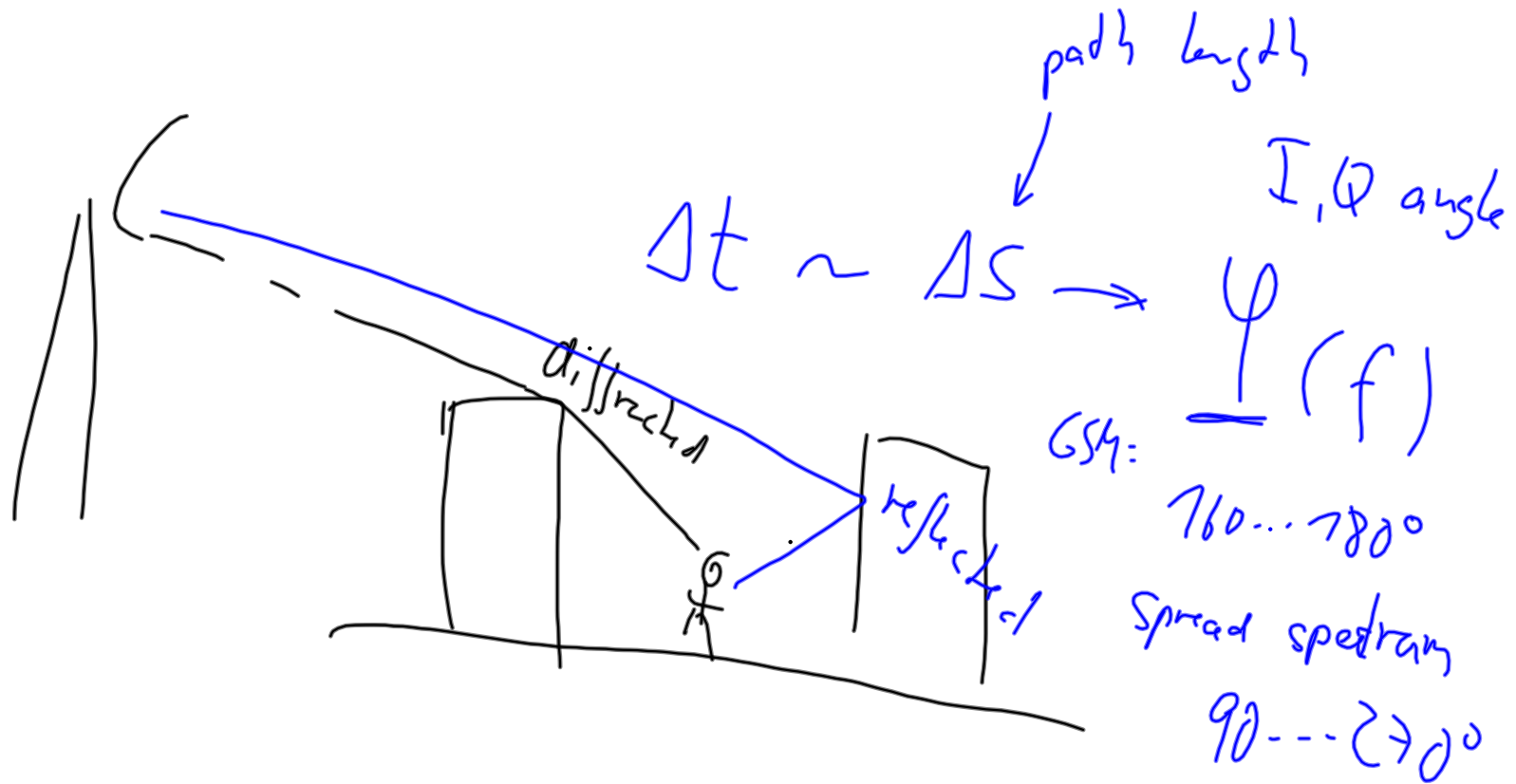
$$R_{nm}(\tau) = \frac{1}{T_b} \int_0^{T_b} s_n(t) \cdot s_m(t - \tau) dt$$

- Perfect orthogonality means that cross-correlation function is zero for all (τ)
- In practice orthogonality is not perfect, thus there is some interference
- In CDMA, there is a soft capacity limit, new users degrades signal quality a little bit for everyone, but there is no absolute limit to the many users may be allowed

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Spread Spectrum



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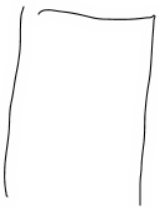
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Spread Spectrum

- Spread spectrum is a generic term for techniques that spread the information over a wide frequency range (broadband)
- ~~Can be~~ various reasons for this, for example:
 - Avoid fast fading
 - Avoid jamming (especially in military applications)
- Available in two main types of spread spectrum:
 - Direct-Sequence
 - Frequency Hopping
- CDMA uses direct sequence spread spectrum to achieve multiple access



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OFDMA-Orthogonal Frequency Division Multiple Access

- OFDMA is based on OFDM, where the carrying waves are distributed on multiple users
- By dividing the data stream many parallel narrowband signals we get long symbols, which reduces inter-symbol interference (ISI)
- Frequency selective fading can be suppressed by the fact that data is spread over several sub-carriers
- Interference from other users is suppressed due to the orthogonality between the carrying waves
- There is a fixed relationship between symbol length and separation between the carrying waves: $T \cdot \Delta f = 1$

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Advantages

- LTE downlink
OFDMA

Handwritten notes on the right side of the page:

- OFDMA
- uplink
- SC-FDMA

- MA Singb Carrier
"Cheap handsets"

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Summary

- Multiple access allows multiple users the opportunity to share the available bandwidth
- FDMA is a simple scheme with each channel is allocated a frequency band. The main advantage is easy implementation, and that there is no need for synchronization and timing information. The main disadvantages are less flexibility in resource allocation and the need for very sharp cut-off filters.
- In TDMA users are separated in time. The main advantage (compared to FDMA) is the flexibility in resource allocation, and the possibility of variable data rate. The biggest drawback is the need for synchronization. TDMA schemes are also susceptible to fading.
- In CDMA each user is assigned a unique PN code. Each code consists of K chips, each with duration of T_c , and $KT_c = T$, the bit duration. Thus, CDMA uses a much larger bandwidth than TDMA or FDMA. All user share the same bandwidth all the time
- In CDMA, PN sequences are almost orthogonal to each other

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Summary

- Spread spectrum is a generic term for techniques that spread the information over a wide frequency range. There are two main types of spread spectrum:
 - Direct Sequence (used in CDMA)
 - Frequency Hopping
- In OFDMA orthogonal carrying waves are distributed on multiple users
 - This technique provides high robustness against frequency selective fading
 - Scalable OFDMA, which is used in LTE, provides the opportunity for flexible bandwidth utilization

Questions? Josef 90838066

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