Link Adaptation in Mobile Communication Networks

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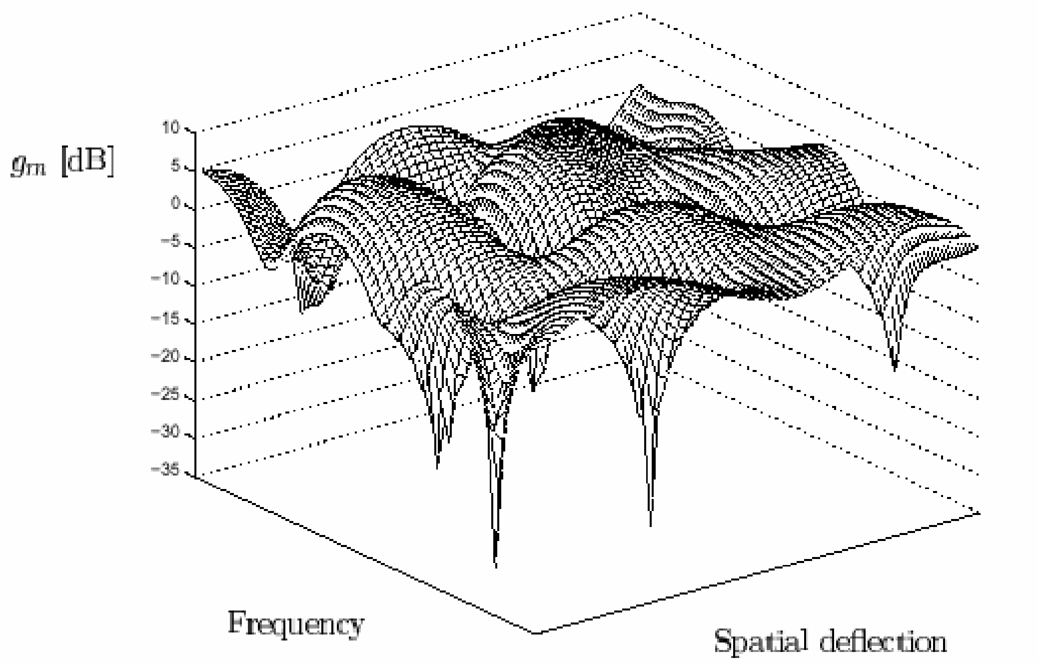
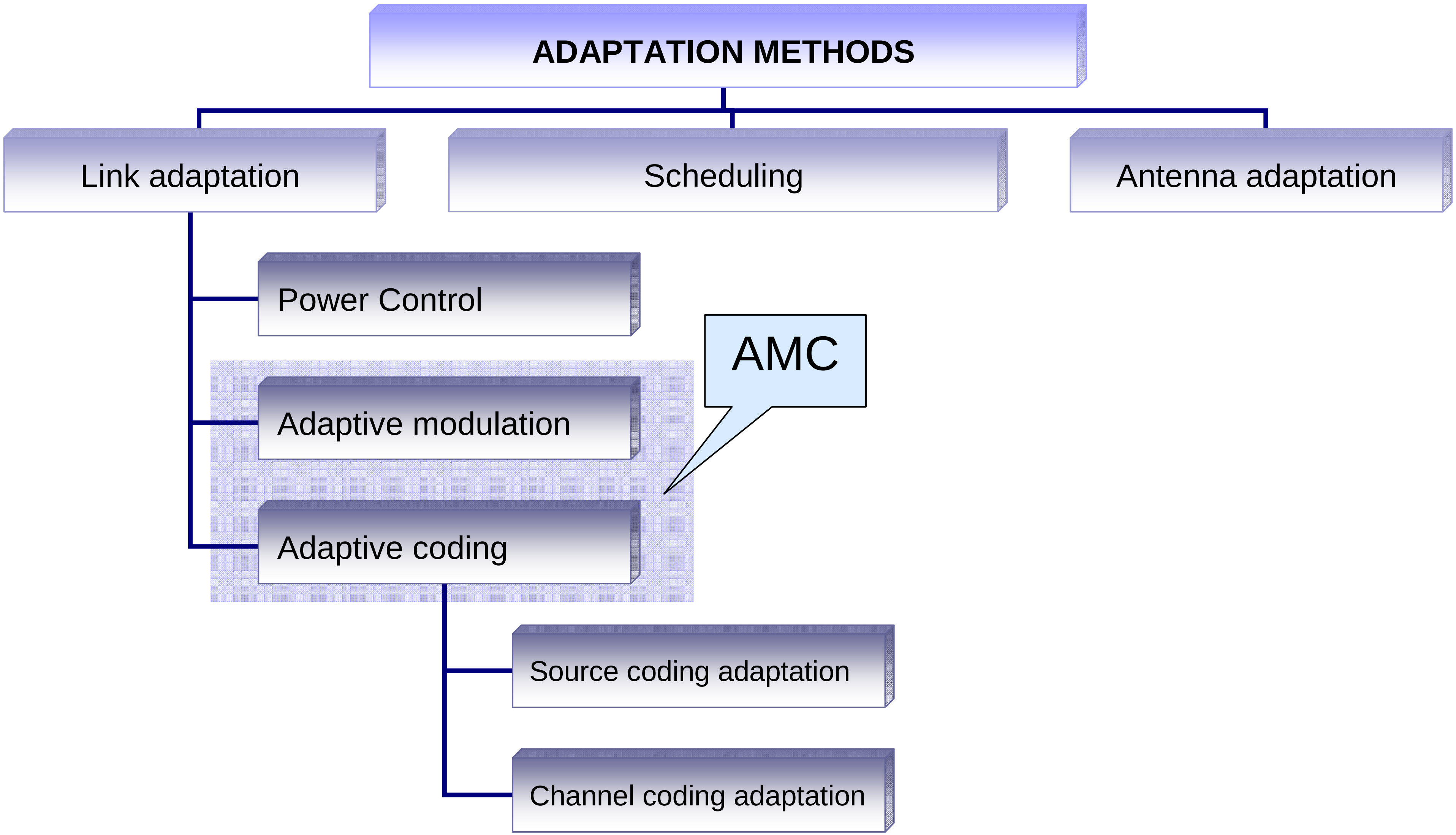
Introduction

Adaptation system uses the actual information about radio channel state to optimize system parameters (SIR, BER, FER) by changing (adaptation) transceiver parameters.

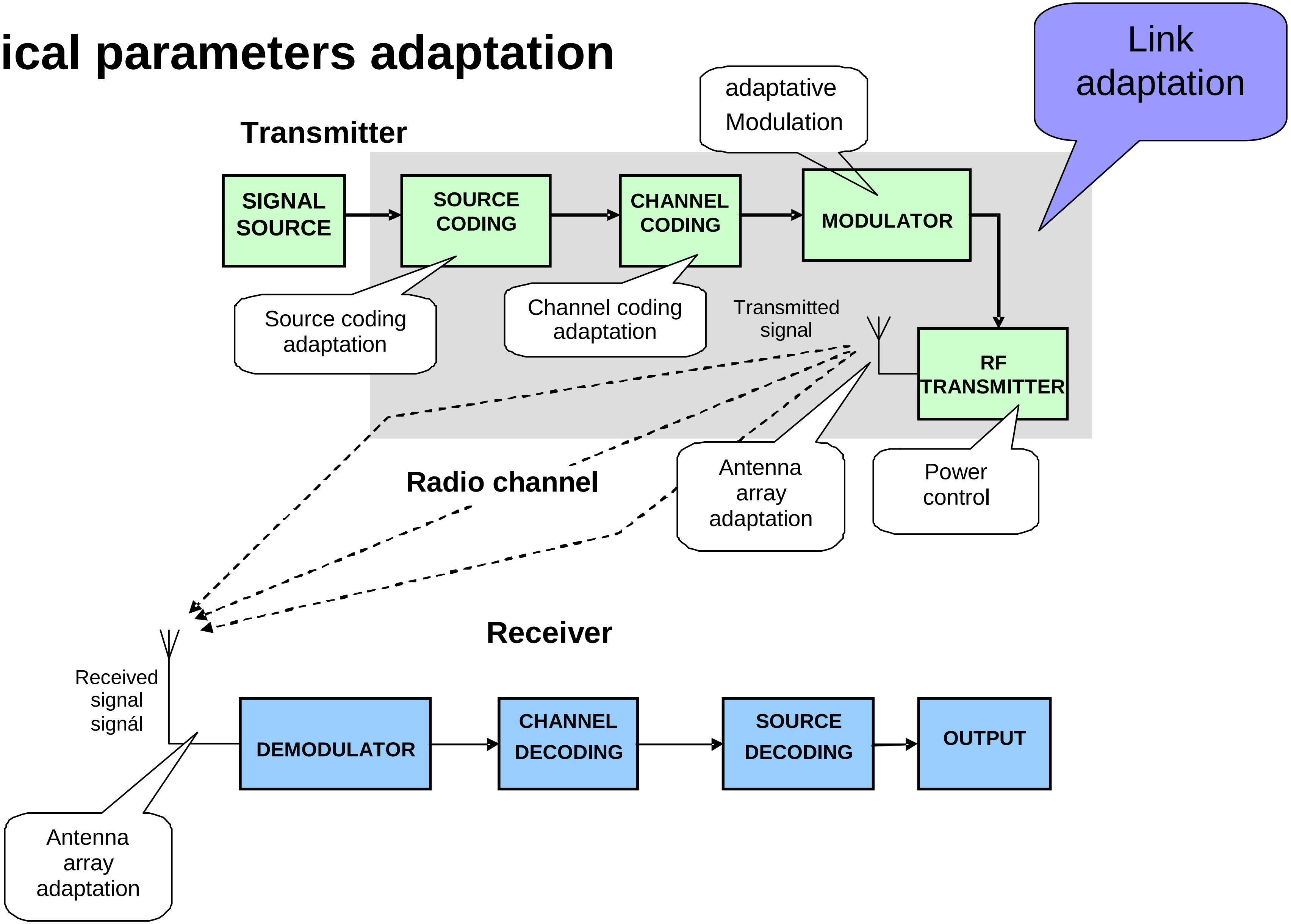


Adaptation – automatic control of requested QoS level during communication by changing of:

- ❑ time and target of transmission (Scheduling)
- ❑ transmitted signal parameters (Link adaptation)
- ❑ antenna system parameters


ADAPTATION METHODS
Link adaptation
Scheduling
Antenna adaptation
Power Control
AMC
Adaptive modulation
Adaptive coding
Source coding adaptation
Channel coding adaptation

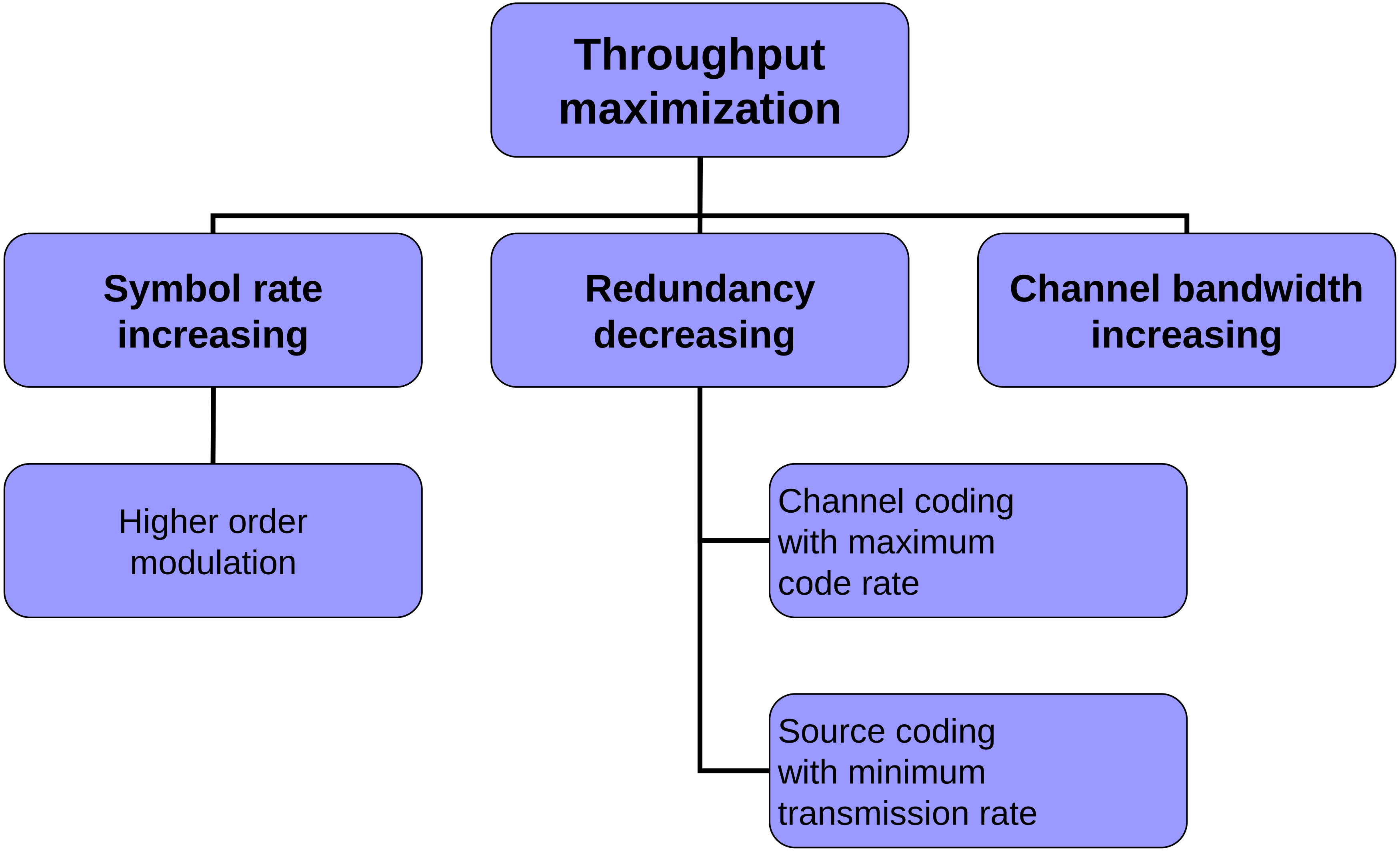
Technical parameters adaptation



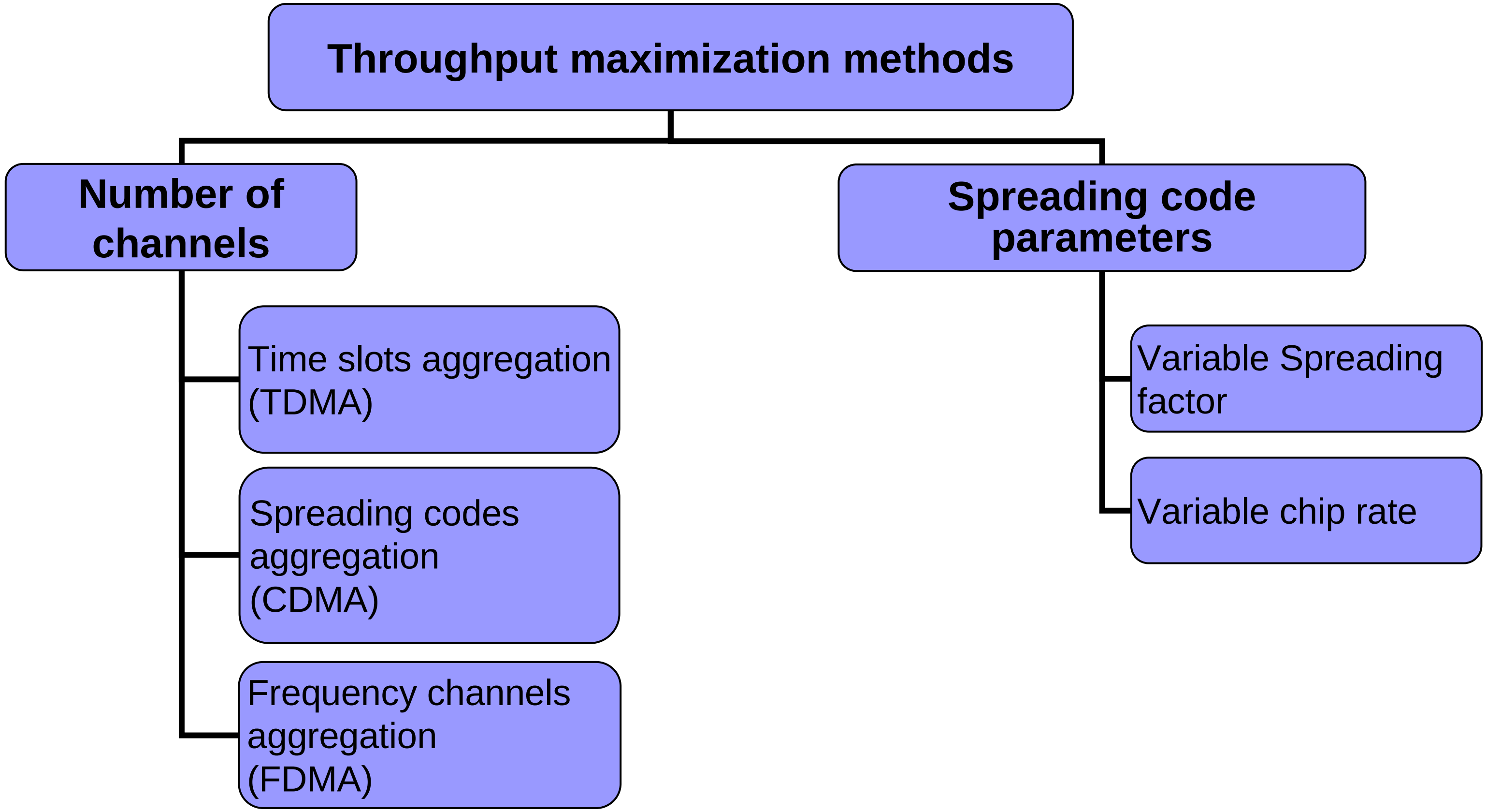
Adaptation criteria

1. Setting of the measurable QoS parameter for specified service (BER, PER, FER, SIR, delay, throughput, jitter)
2. Setting of the parameter threshold level
3. Ensuring the periodical measurement of parameter during communication
4. If the parameter value descends under threshold level during some specified time interval, control system has to change one (or several) parameters

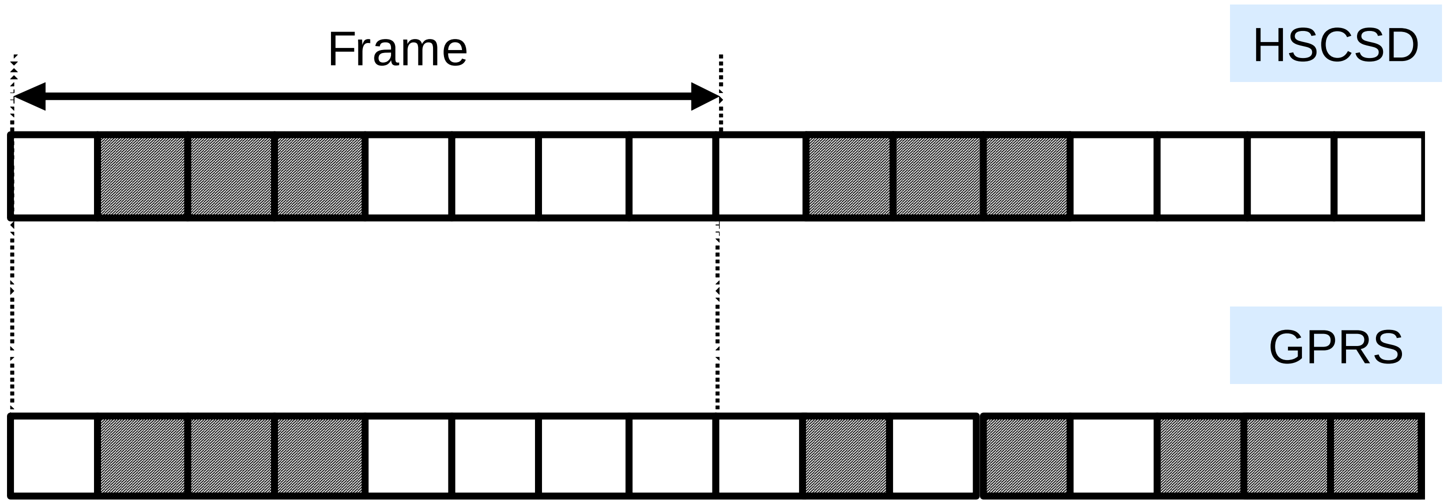
Throughput maximization



Throughput maximization



Time Slots Aggregation



1. Constant number of aggregated slots
2. Variable number of aggregated slots

Number of channels and spreading code parameters

CDMA

$$G_p = \mathrm{SF} = \frac{B_{ss}}{B_s} = \frac{R_{chip}}{R_s} = \frac{T_s}{T_{chip}} = N_{chip}$$

$$\Rightarrow \quad R_s = \frac{R_{chip}}{N_{chip}} = \frac{R_{chip}}{\mathrm{SF}}$$

1. **Variable R_{chip}** – System with several chip rates
2. **Variable SF** – System with variable spreading factor
3. **Variable spreading codes number** – System with several codes

Number of channels and spreading code parameters

System with several codes

$$k\,R_s = k \cdot \left(\frac{R_{chip}}{\mathrm{SF}} \right)$$

Code Aggregation

1 channel

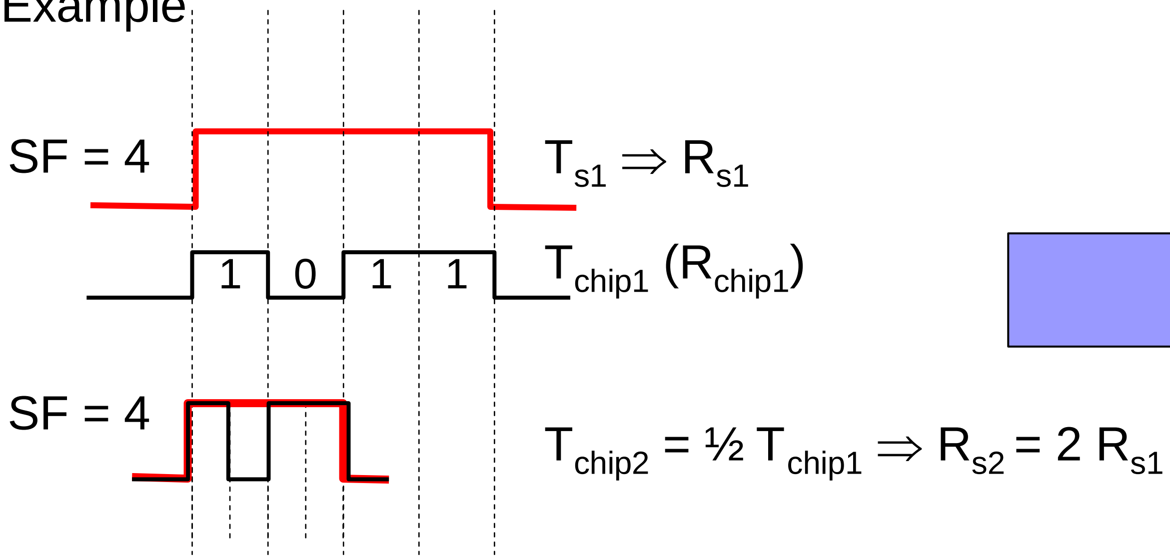
Number of channels and spreading code parameters

System with several chip rates

$SF = N_{chip}$ = const.
T_{chip} = var.
R_{chip} = var.
B_{ss} = var.

$$k\,R_s = \frac{k \cdot R_{chip}}{SF} \quad \text{for} \quad SF = \frac{B_{ss}}{B_s} = \text{const.}$$

Example



Low $R_s \Rightarrow$ Low $R_{chip} \Rightarrow$ wider chips

Number of channels and spreading code parameters

System with several chip rates

Code Aggregation

Several Chip Rates

Standard	Multicarrier – MC			Direct Spread – DS		
	R_{chip} (Mč/s)	B_{ss} (MHz)		R_{chip} (Mchip/s)		B_{ss} (MHz)
cdma2000	1,2288	N x 1,25 MHz (N = 1,3,6,9,12)	1,25 3,75 7,50 11,25 15,00	N x 1,2288 (N = 1,3,6,9,12)	1,2288 3,6864 7,3728 11,0593 14,7456	1,25 3,75 7,50 11,25 15,00
UMTS	Not using			3,84[1] 7,68 15,36		5 10 20

Number of channels and spreading code parameters

System with variable spreading factor

SF = var.
T_{chip} = const.
R_{chip} = const.
B_{ss} = const.

$$R_s = \frac{R_{chip}}{\mathrm{SF}} = \frac{\text{const.}}{\mathrm{SF}}$$

⇒ **OVSF**

Example

$$R_s \Rightarrow N_{chip}$$

$$2 \cdot R_s \Rightarrow \frac{N_{chip}}{2}$$

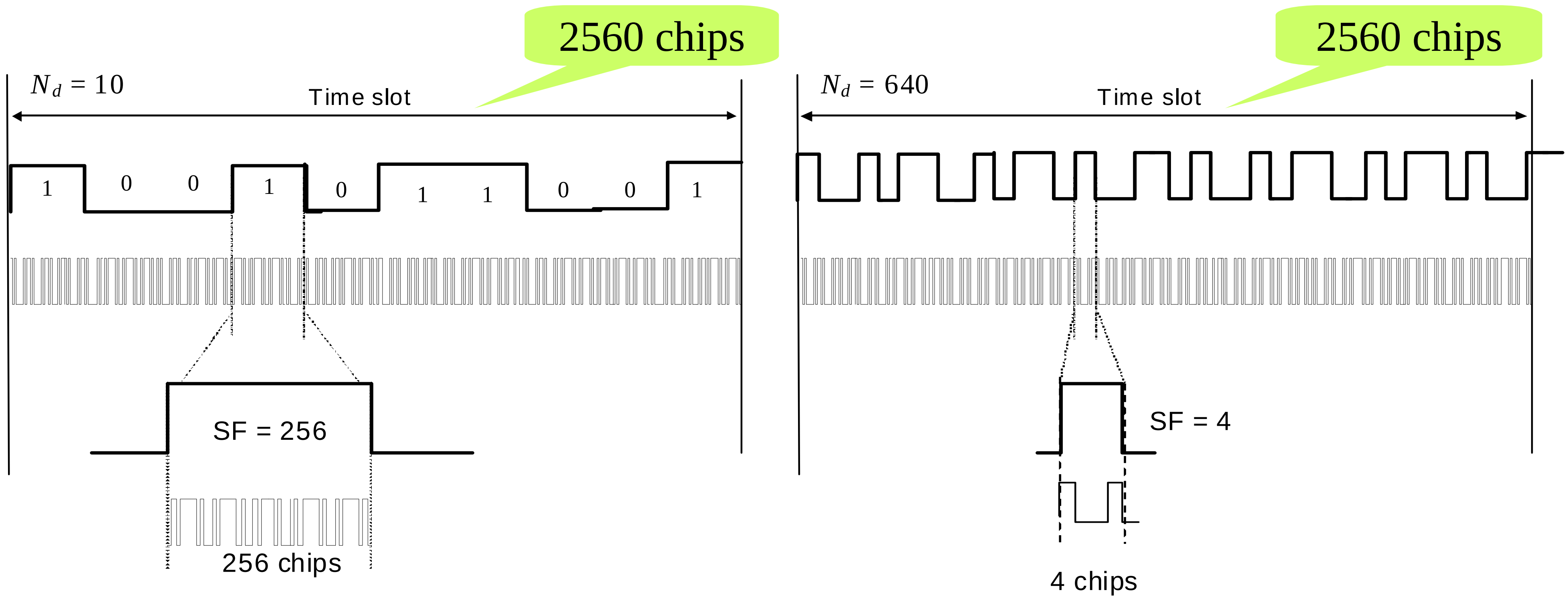
$$k \cdot R_s \Rightarrow \frac{N_{chip}}{k}$$

Problem :

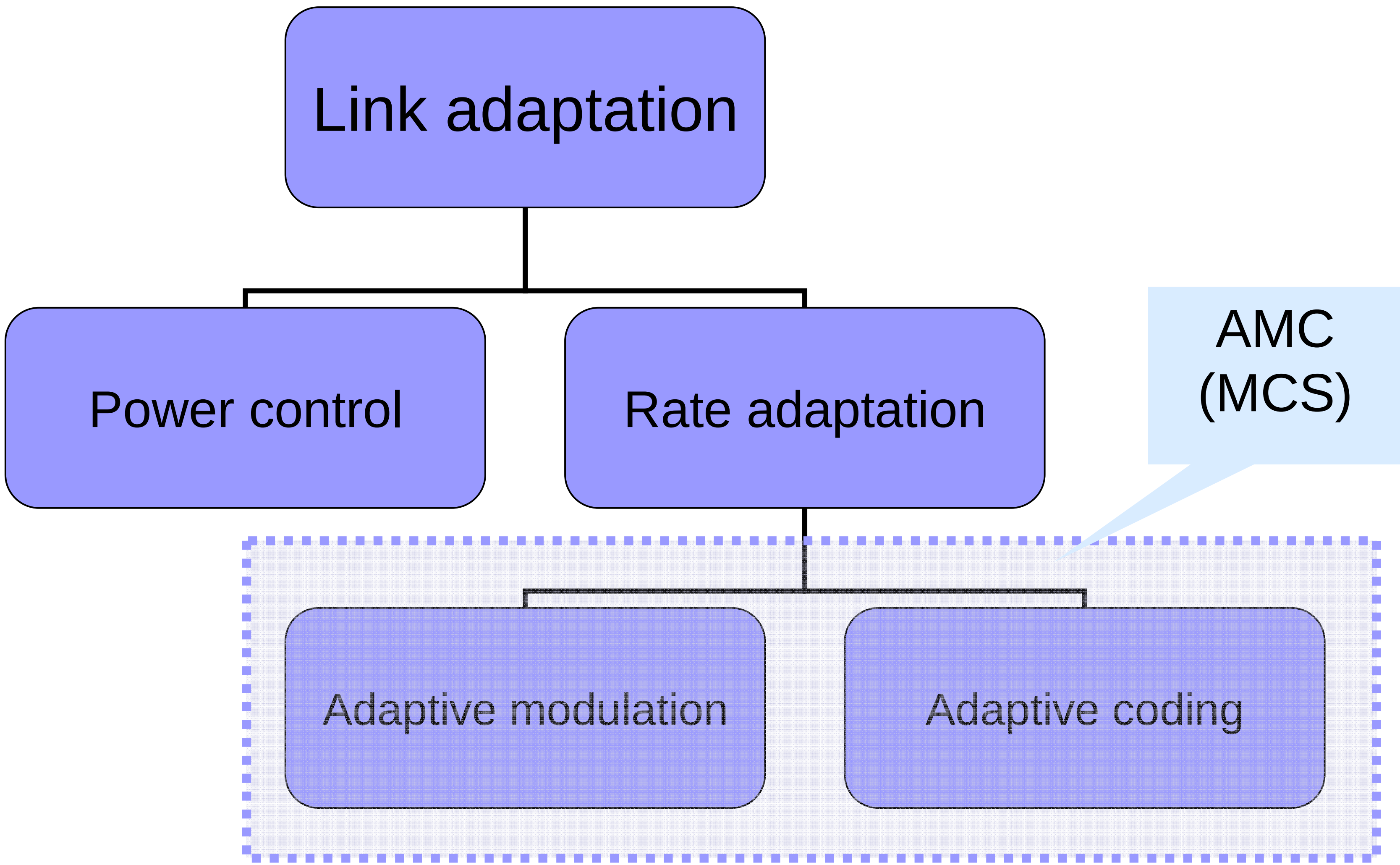
$$\left(\frac{E_b}{I_0}\right)_r = (SIR)_r \cdot \mathrm{SF}$$

1. **Increasing P_r**
   - ❑ Changing position of MS
   - ❑ Changing transmission power of BS
2. **Increasing SF**

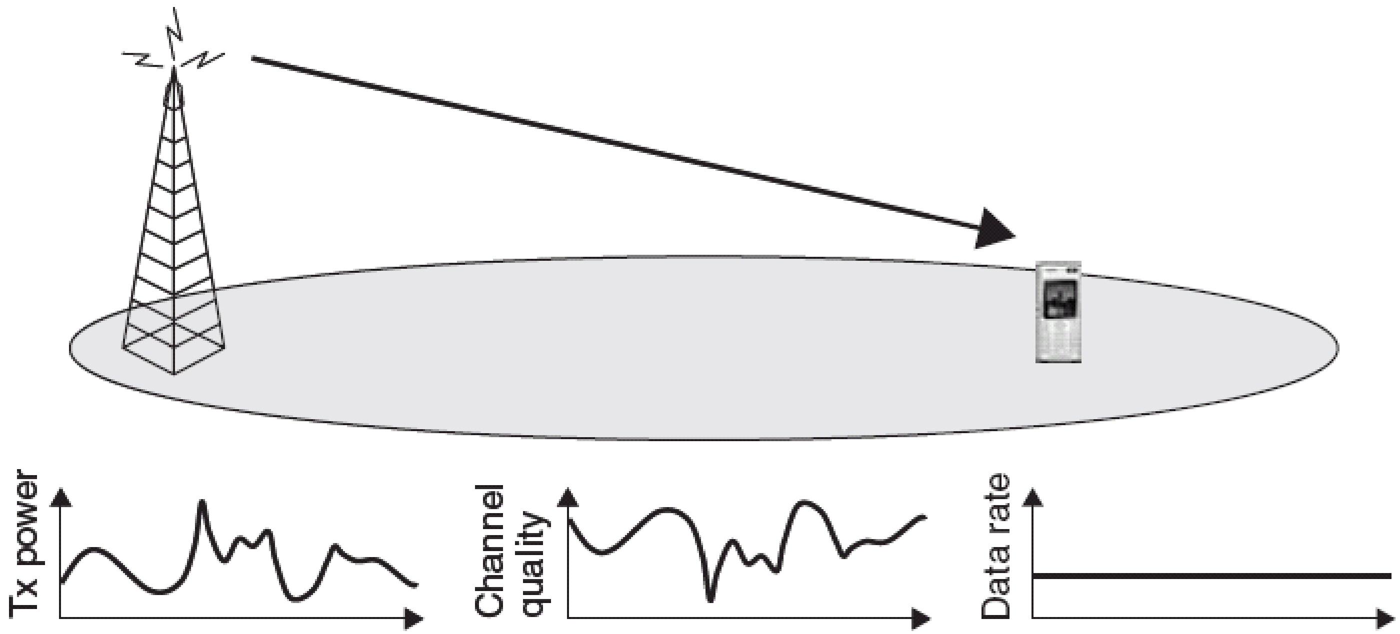
OVSF in UMTS


2560 chips
N_d = 10
Time slot
1 0 0 1 0 1 1 0 0 1
SF = 256
256 chips
2560 chips
N_d = 640
Time slot
SF = 4
4 chips

Link adaptation

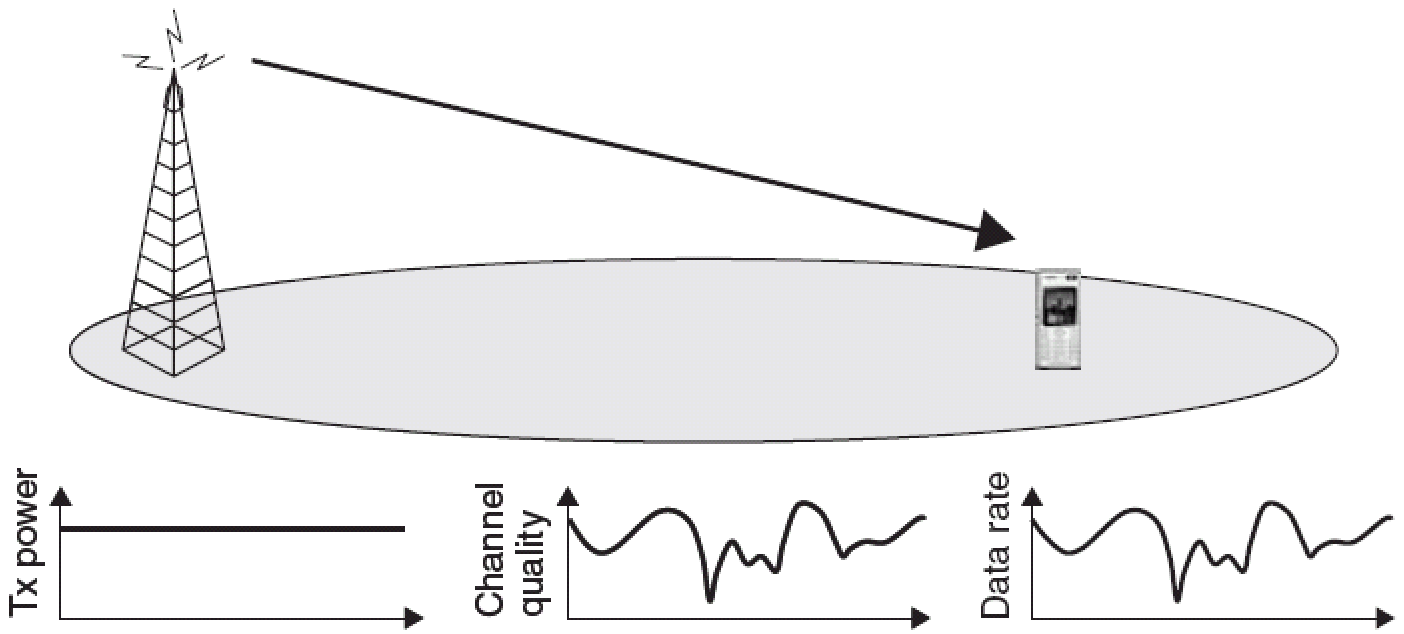


Power control



(a)

Rate adaptation



(b)

Power Control

Power control

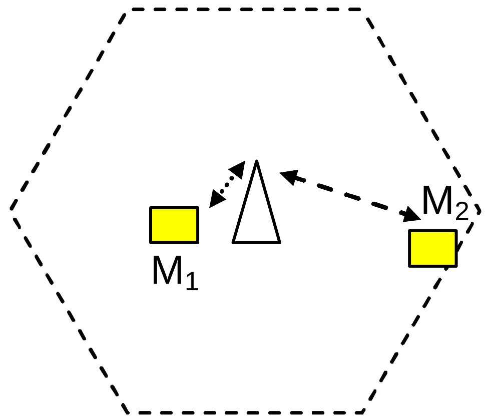
Power control aim:

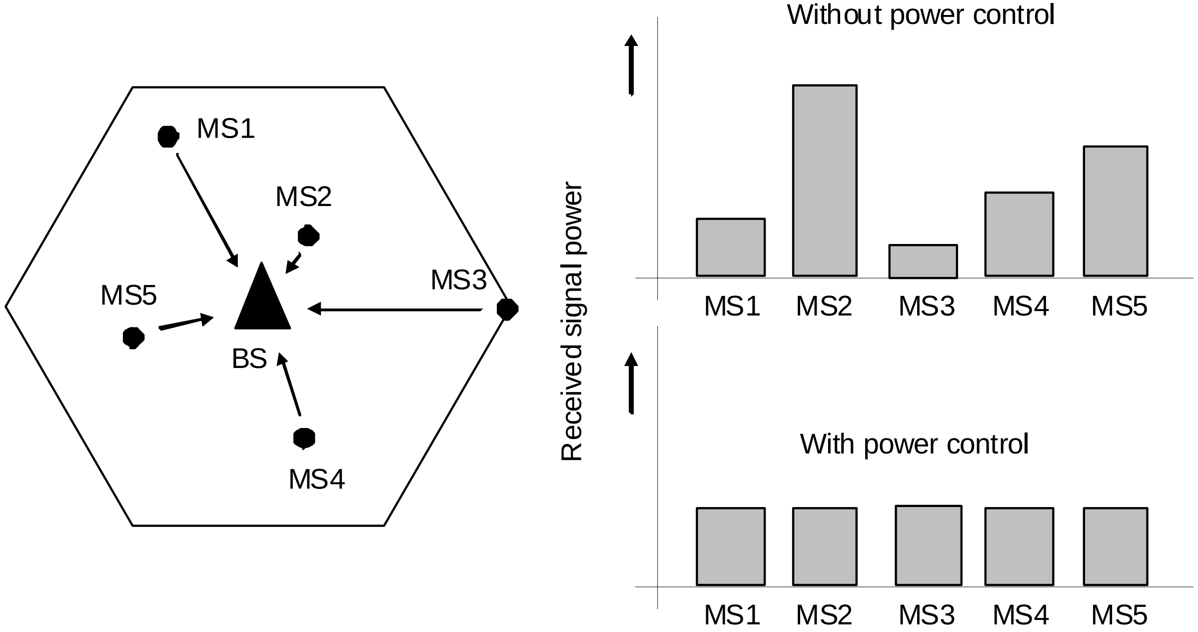
1. **Downlink**:
   - to restrict signal power from BS in cell area (mutual interference decreasing)
2. **Uplink**:
   - to provide the minimum UE transmit power requested for required QoS level
   - interference minimization
   - UE battery power consumption decreasing
   - decreasing of possible health hazard

Power control methods

Near-Far problem

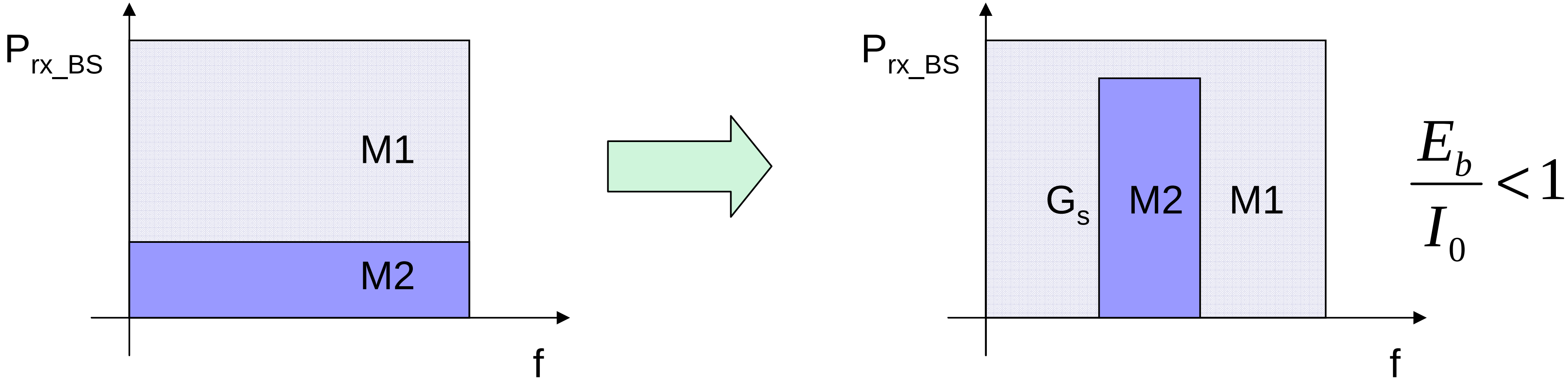
$$\left(\frac{E_b}{I_0}\right)_{M2} = \frac{P_{r2}G_p}{P_{r1}} < 1$$



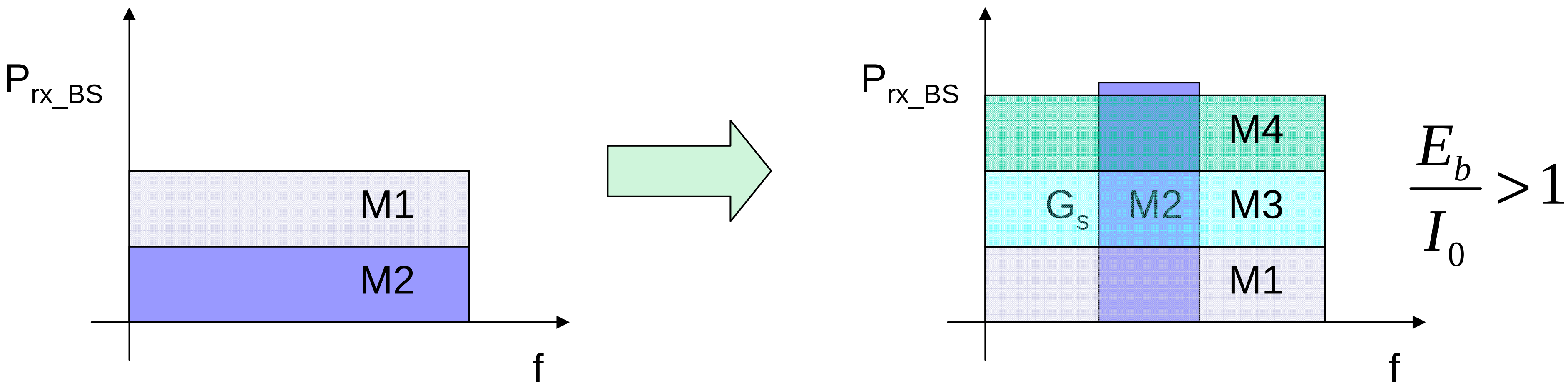


Near-Far problem

Without power control

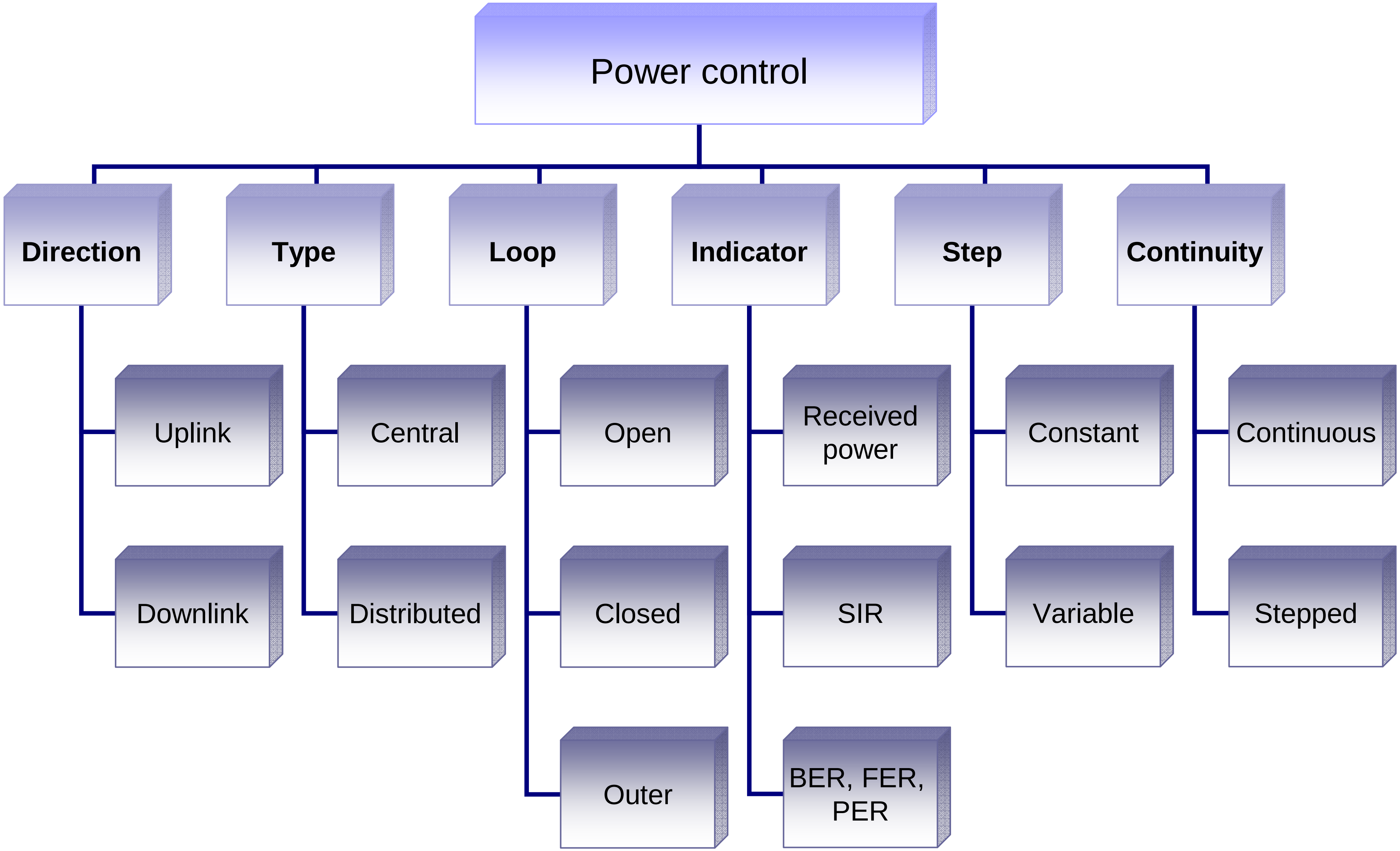


With power control

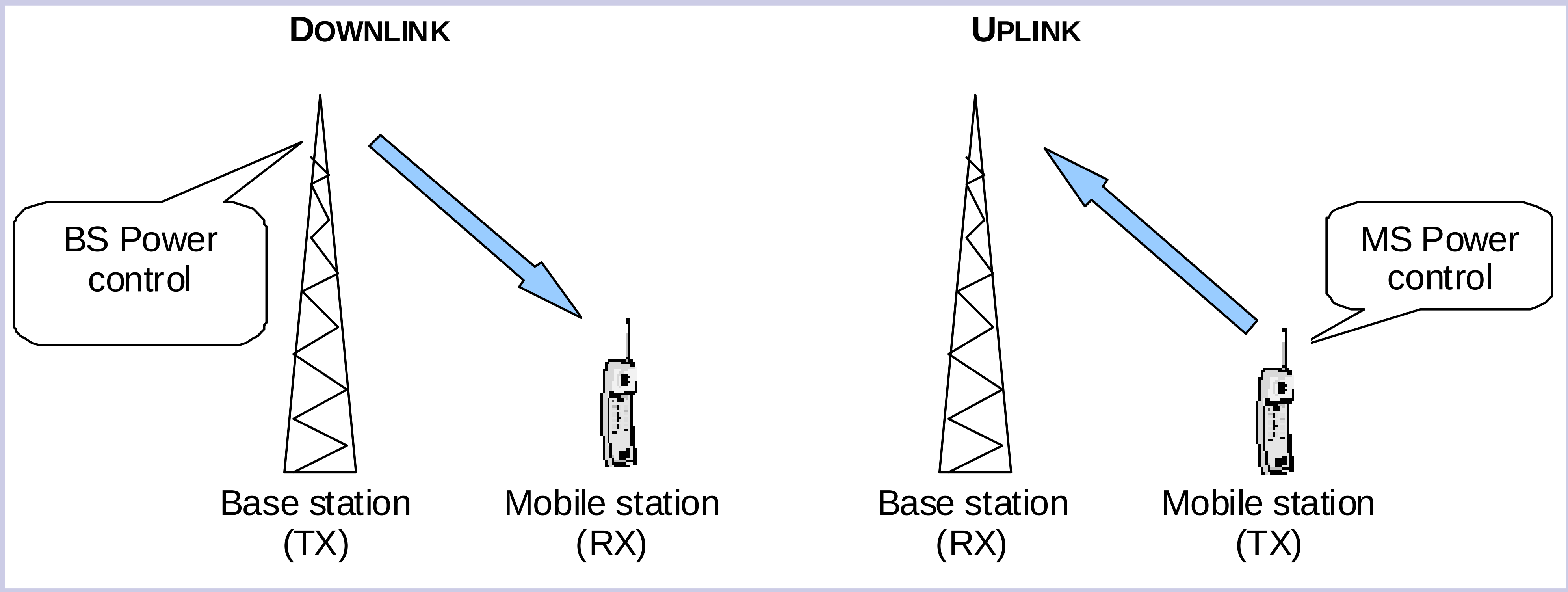


Power control problems

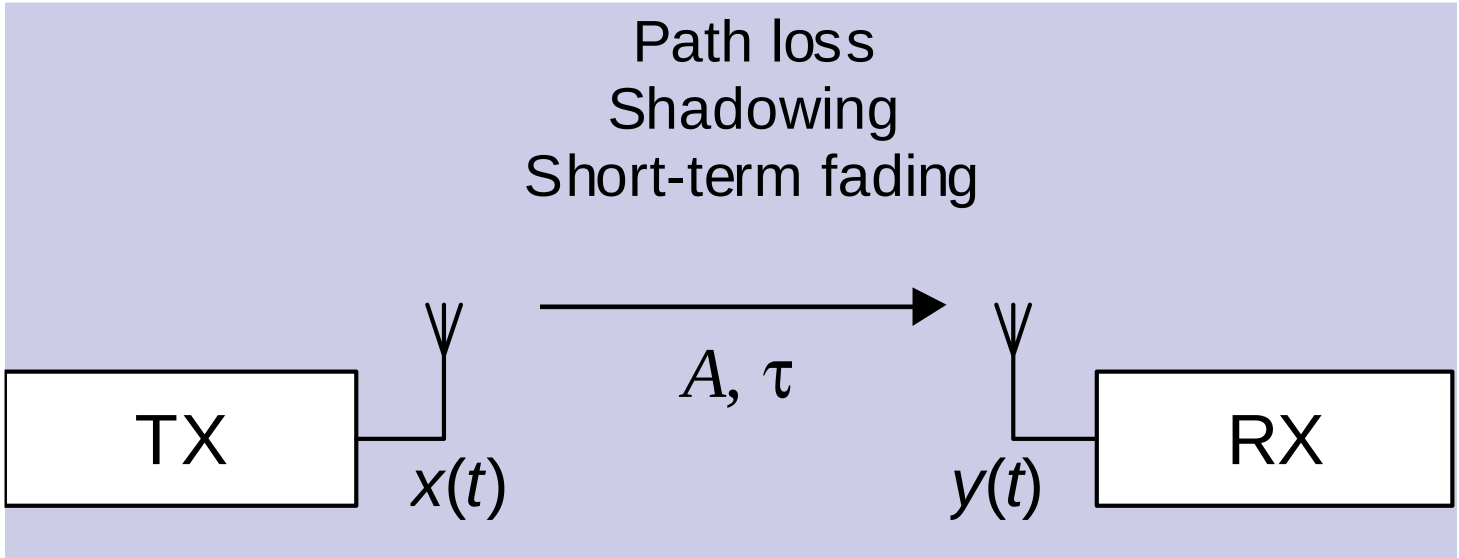
1. *Measurement of communication quality:*
   - Voice (SIR)
   - Data (BER, PER, FER)
     - QI (BER, FER)
     - RSSI (P_{rx})
2. *Restrictions* : power level number
3. *Time delay*


Power control
Direction
Type
Loop
Indicator
Step
Continuity
Uplink
Downlink
Central
Distributed
Open
Closed
Outer
Received power
SIR
BER, FER, PER
Constant
Variable
Continuous
Stepped

Direction


DOWNLINK
UPLINK
BS Power control
MS Power control
Base station (TX)
Mobile station (RX)
Base station (RX)
Mobile station (TX)

PC Loops



$$y(t) = Ax(t-\tau)$$

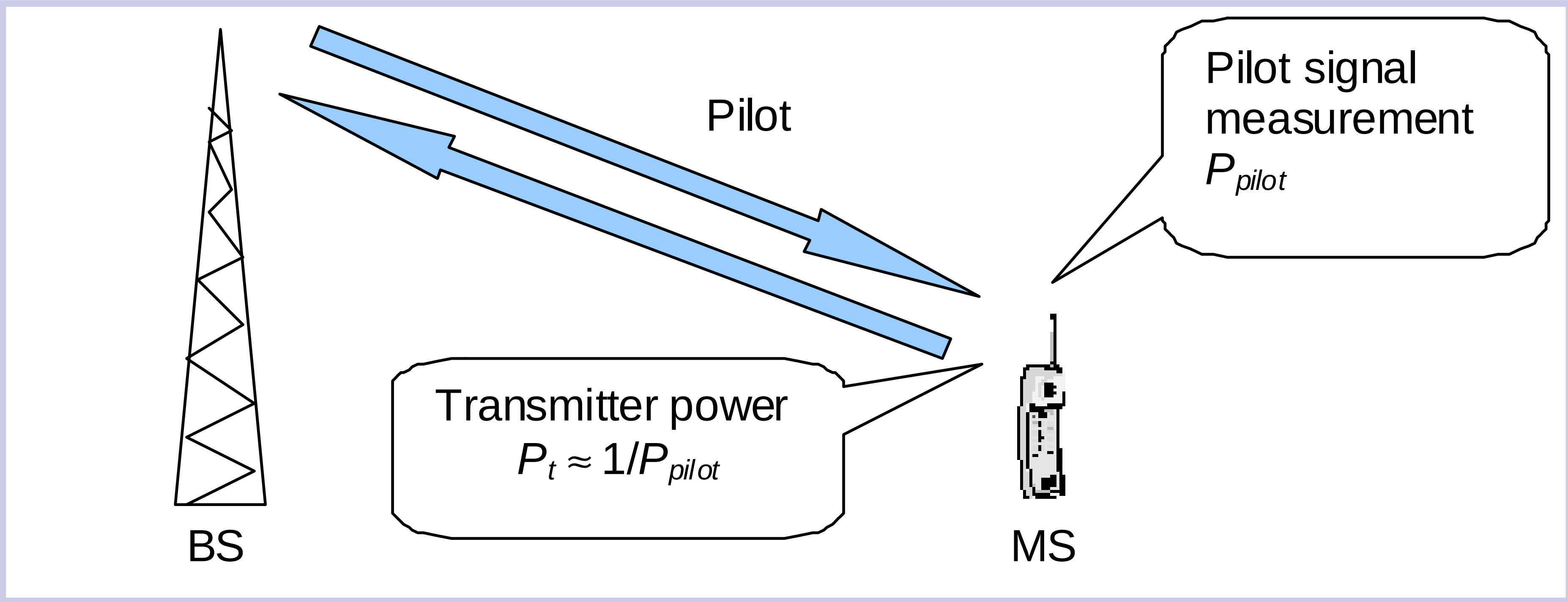
$$A = L_{Path\ Loss} \cdot L_{Shadowing} \cdot L_{ST\ fading} \cdot e^{j\Phi}$$

High correlation in UL a DL (refers to $L_{Path\ Loss}$)

Low correlation in UL a DL (refers to $L_{ST\ fading}$)

Open Loop PC

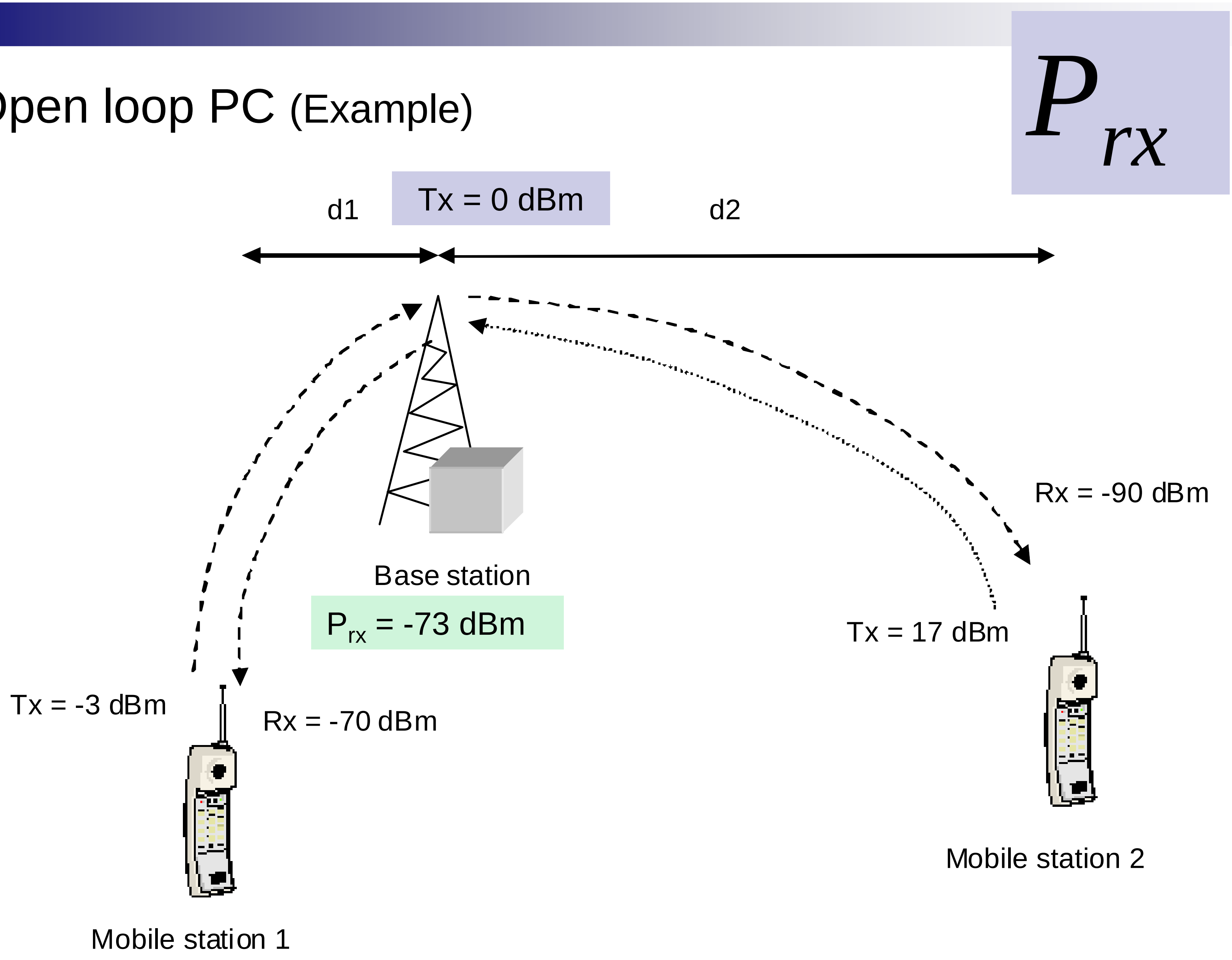
P_{rx}



FDD versus TDD

- quick loop reaction
- high UL and DL correlation
- only UL

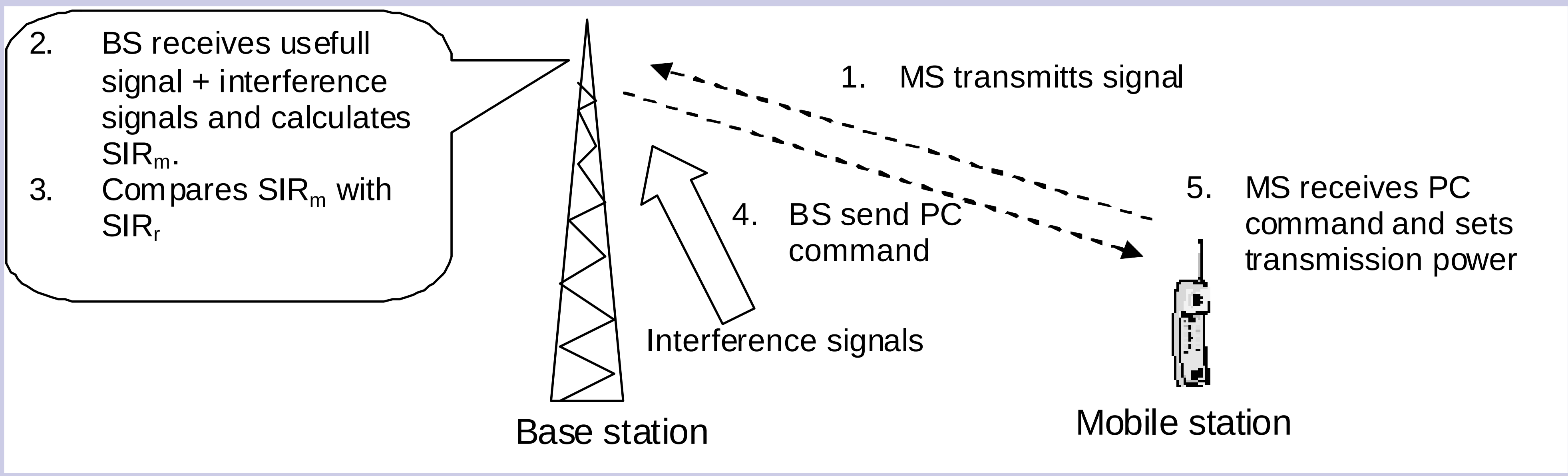
Open loop PC (Example)



Closed Loop PC

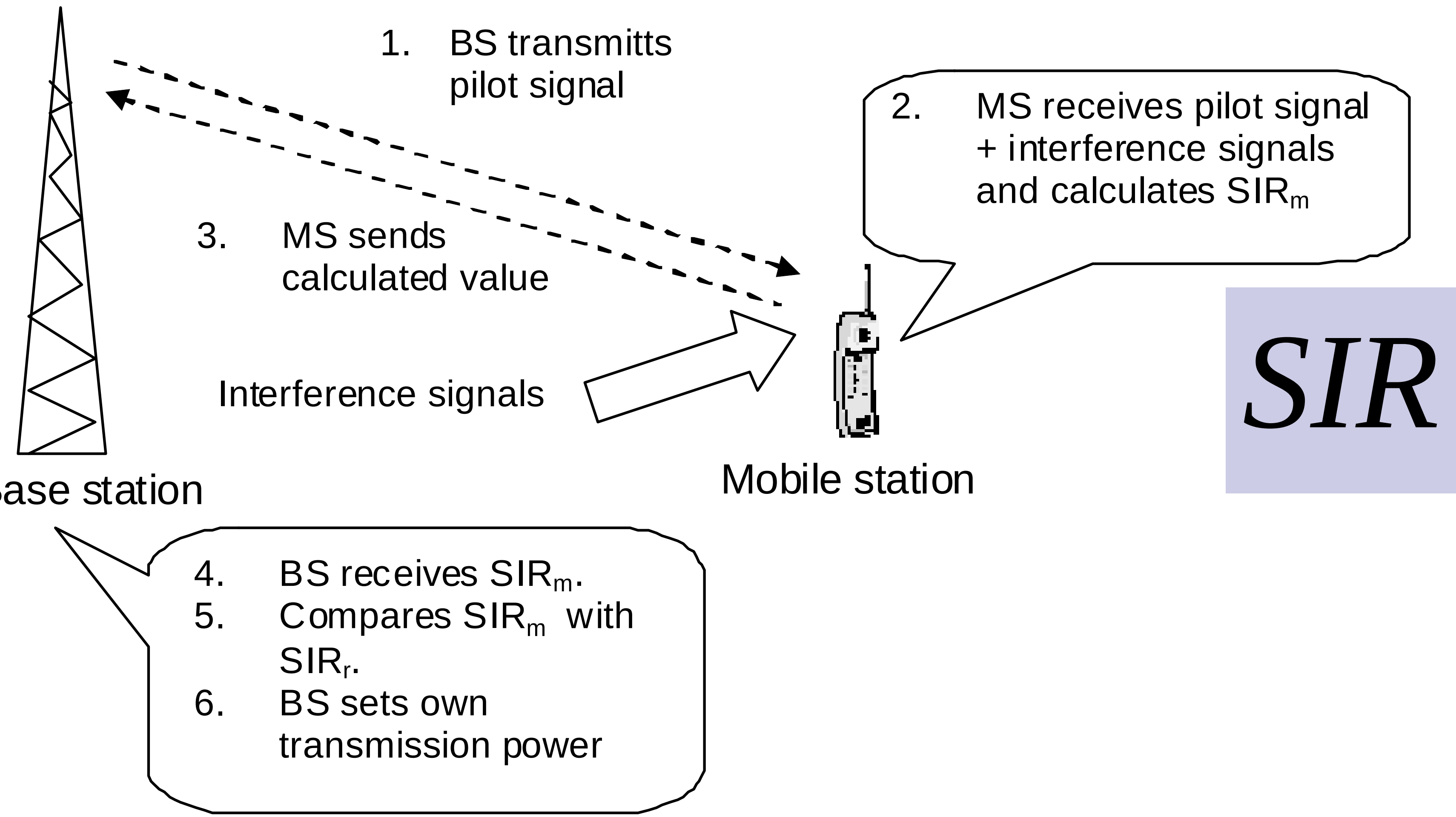
UPLINK

SIR



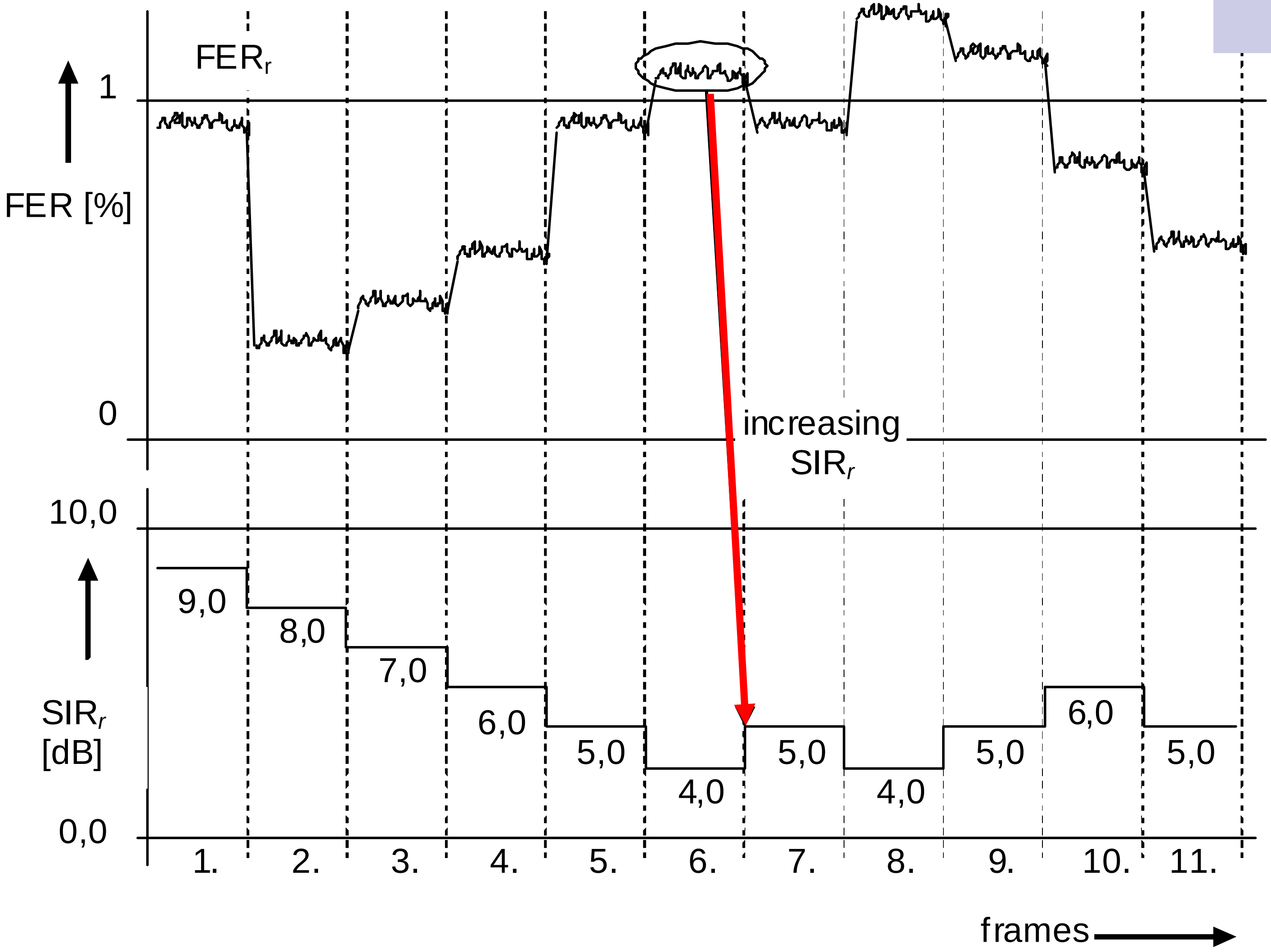
Closed Loop PC

DOWNLINK

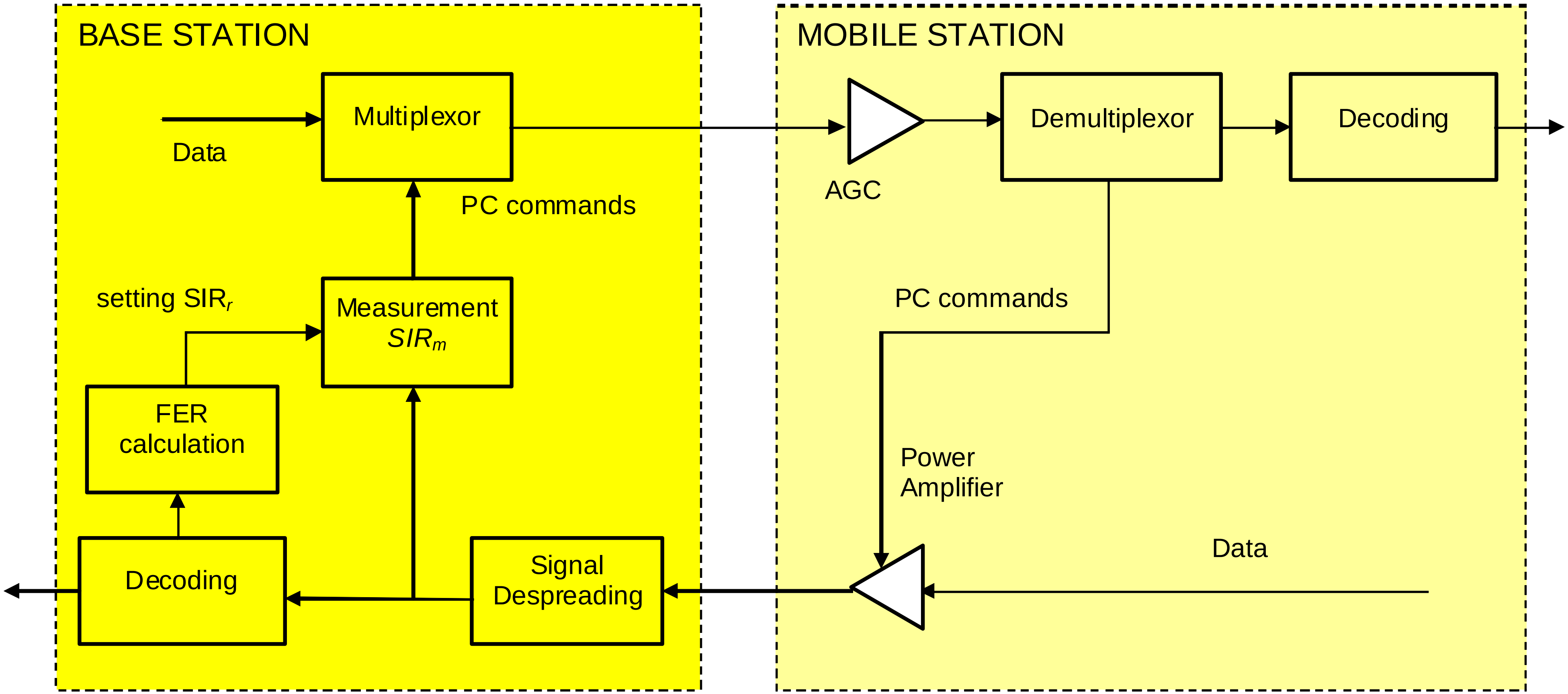


Outer Loop PC

FER



Outer and Closed Loop PC (UL)



Continuity and step PC

1. Continuous PC
2. Stepped PC:
   - Constant step (Up-Down) - Δ algoritmus
   - Variable step (PCM algoritmus)

UP-DOWN

$$P_{tx}(t+1) = P_{tx}(t)\begin{cases} +\Delta & \text{if } (SIR)_m < (SIR)_r \\ -\Delta & \text{if } (SIR)_m \geq (SIR)_r \end{cases}$$

Short-term fading compensation $\Rightarrow t_{loop} < t_{coh}$

Example:

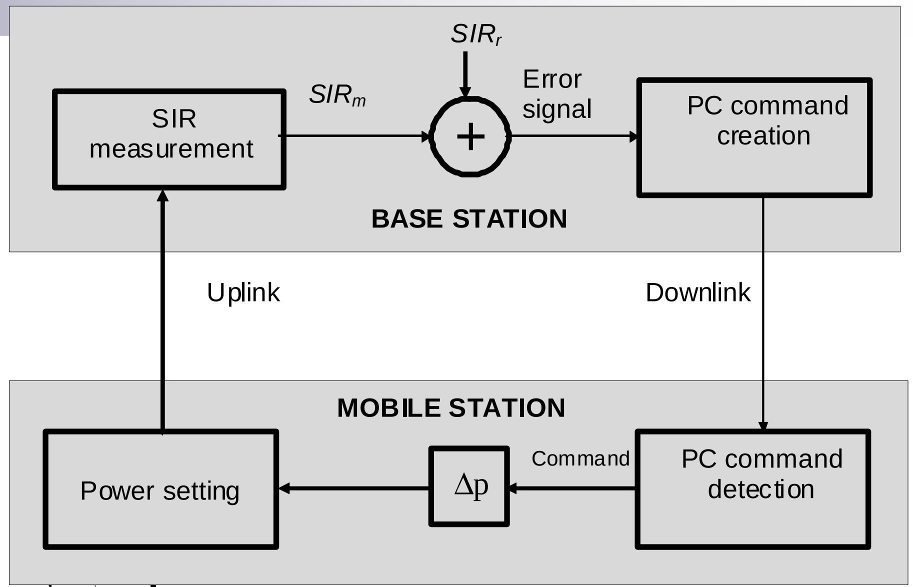
UMTS: v_{max} = 500 kmph, λ = 15 cm $\Rightarrow f_{Dmax}$ = 926 Hz

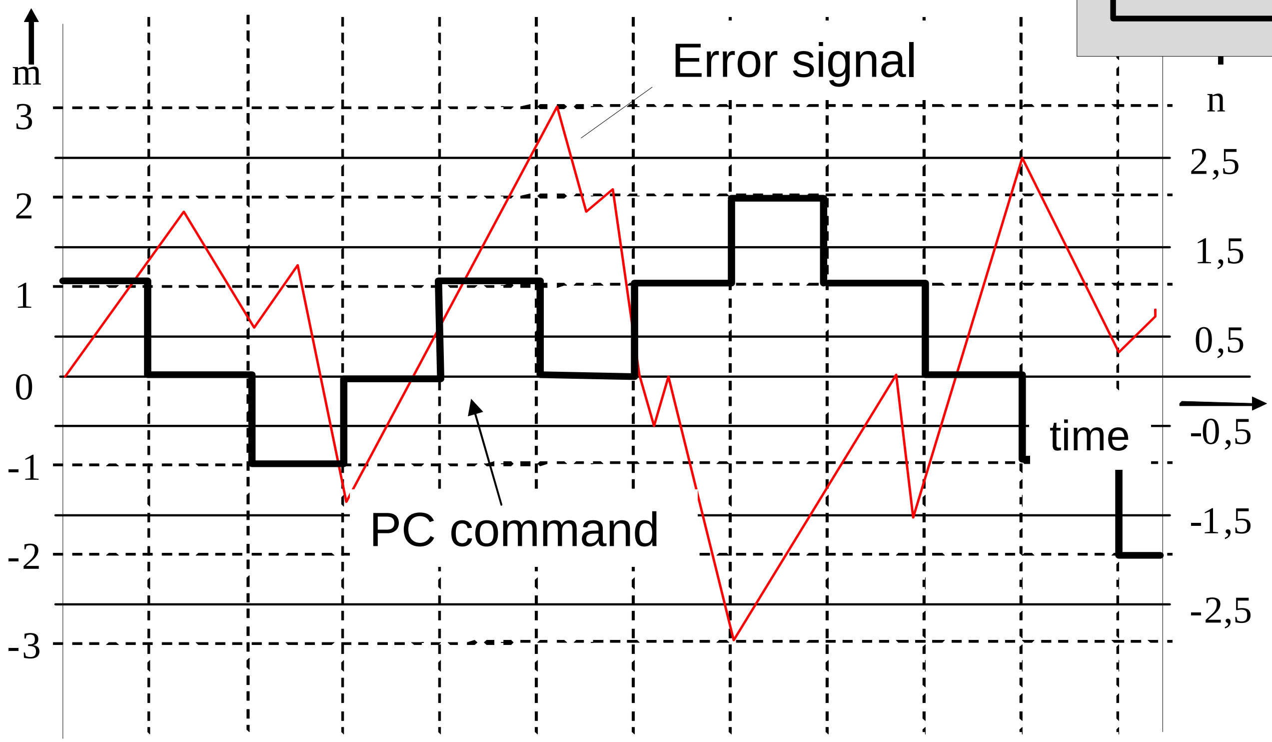
$$t_{coh} = \frac{9}{16 \cdot \pi \cdot f_{D\max}} = 200\ \mu s$$

Constant step PC command

PC with Δ algoritmus

1, 1, -1, 1, 1, -1, -1, -1, 1, 1, 1 [dB]



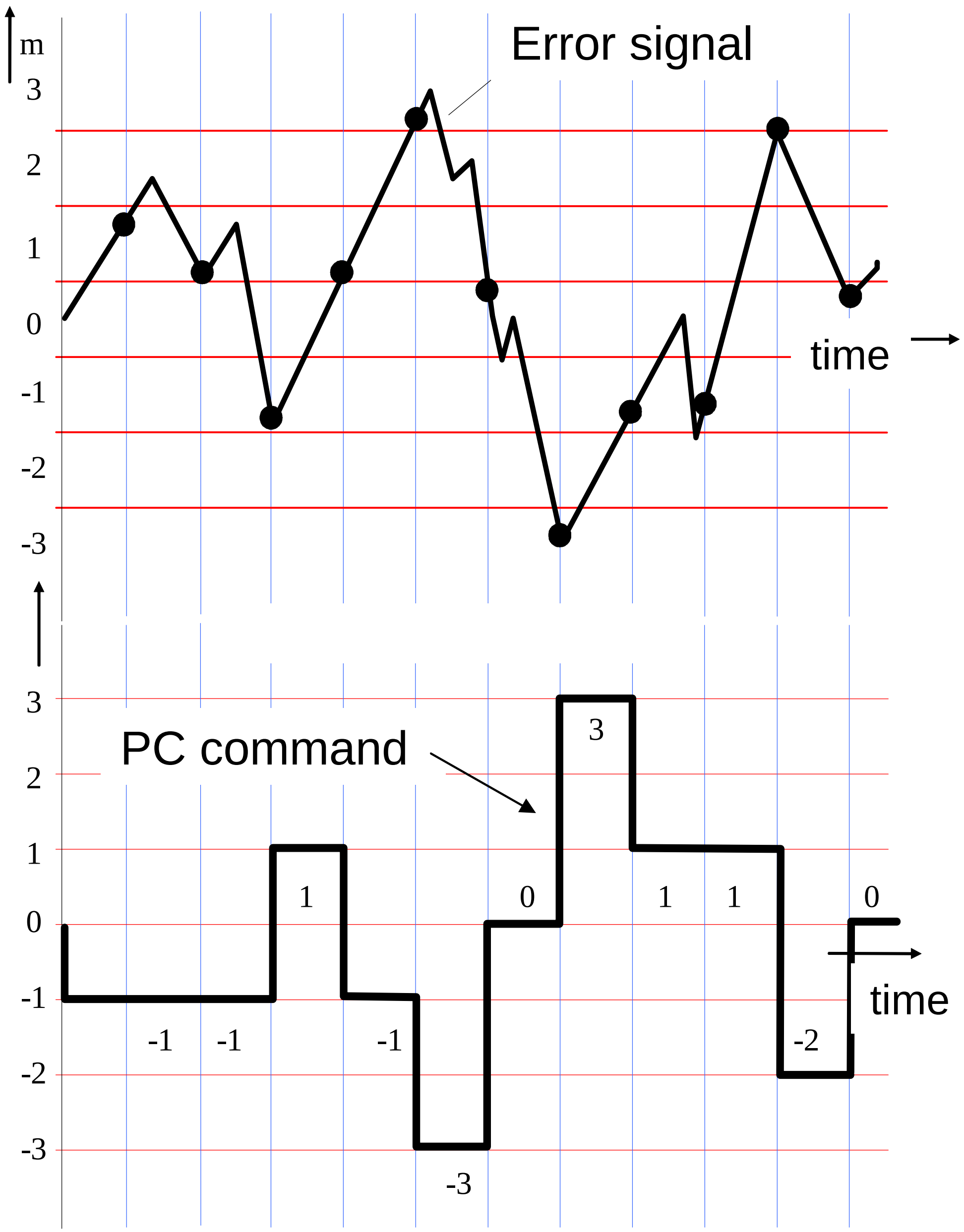


$$Error = SIR_m - SIR_r$$

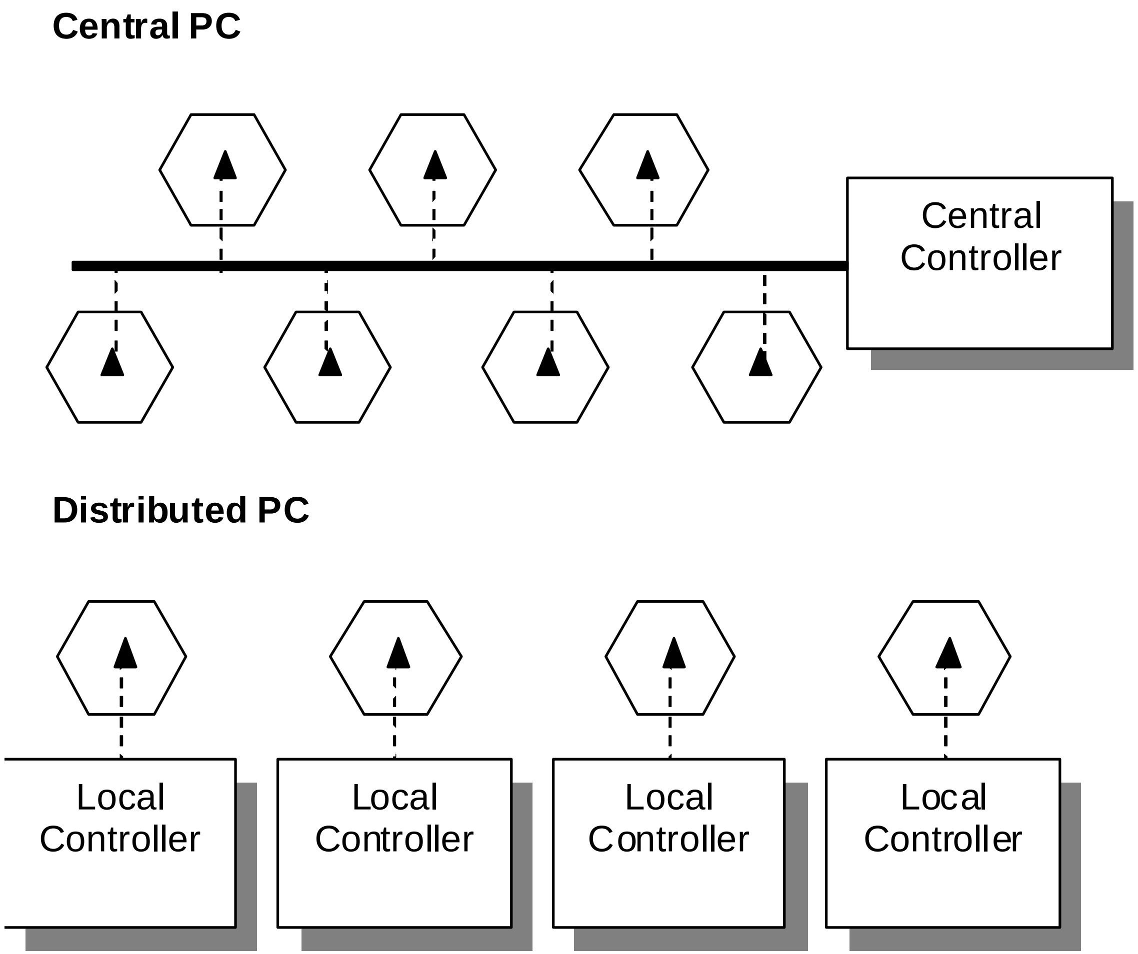
Variable step PC command

PC with PCM algoritmus

-1, -1, 1, -1, -3, 0, 3, 1, 1, 2, 0 [dB]

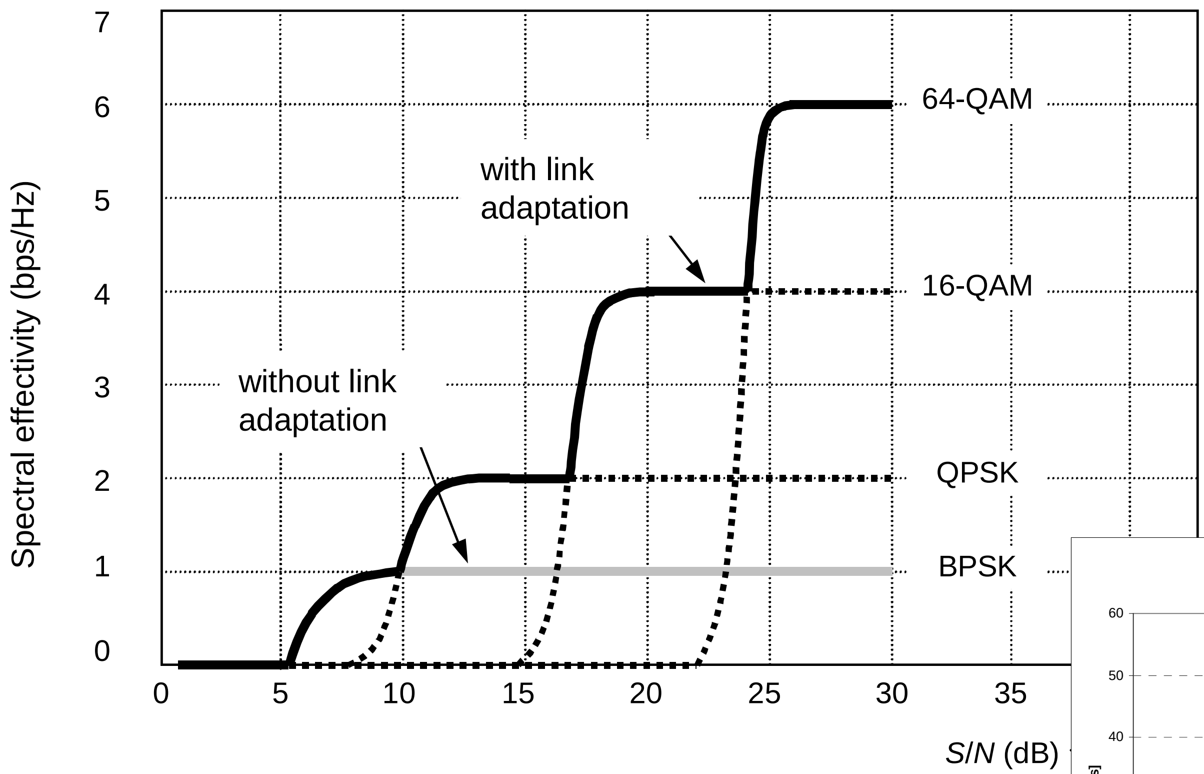


PC type

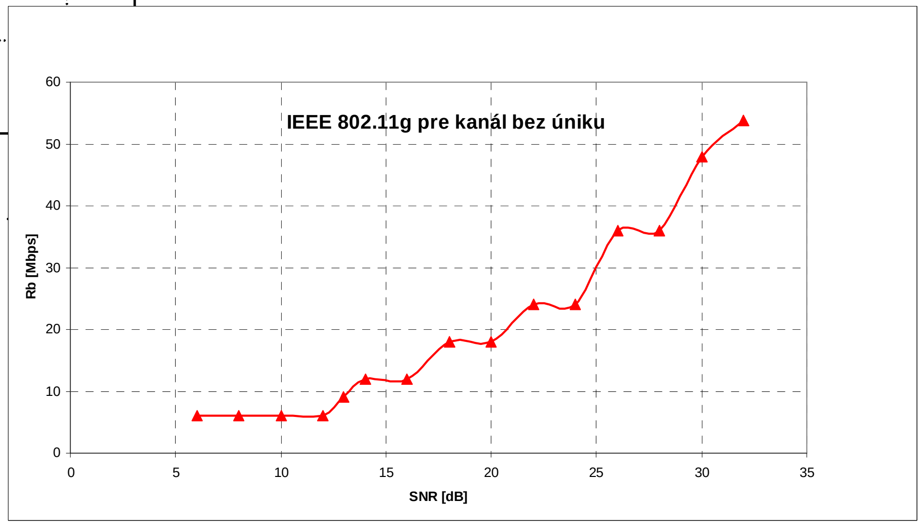

Central PC
Central
Controller
Distributed PC
Local
Controller
Local
Controller
Local
Controller
Local
Controller

Rate Adaptation

Modulation adaptation



BPSK	1\2	<10	6
BPSK	3\4	10	9
QPSK	1\2	11	12
QPSK	3\4	14	18
16QAM	1\2	18	24
16QAM	3\4	22	36
64QAM	2\3	26	48
64QAM	3\4	28	54

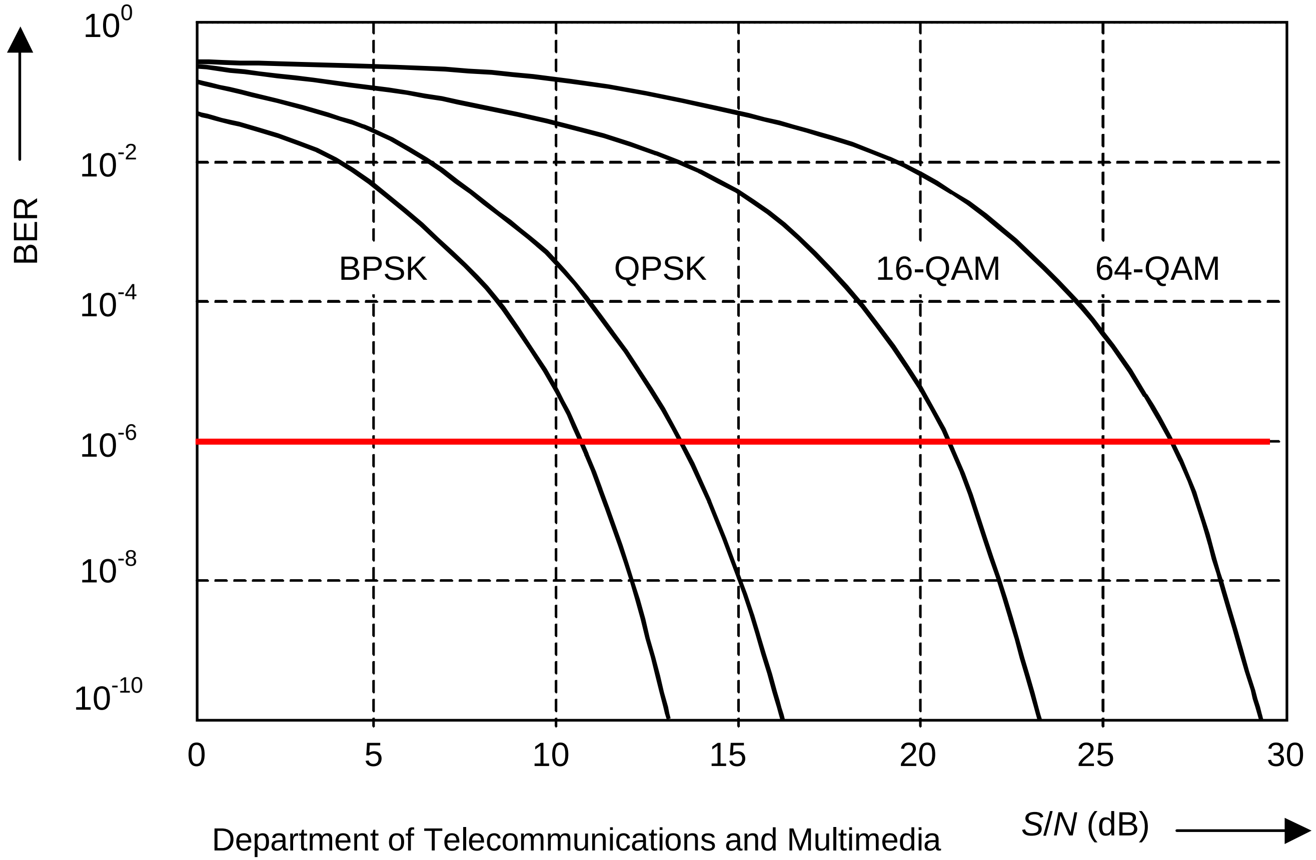


Modulation adaptation

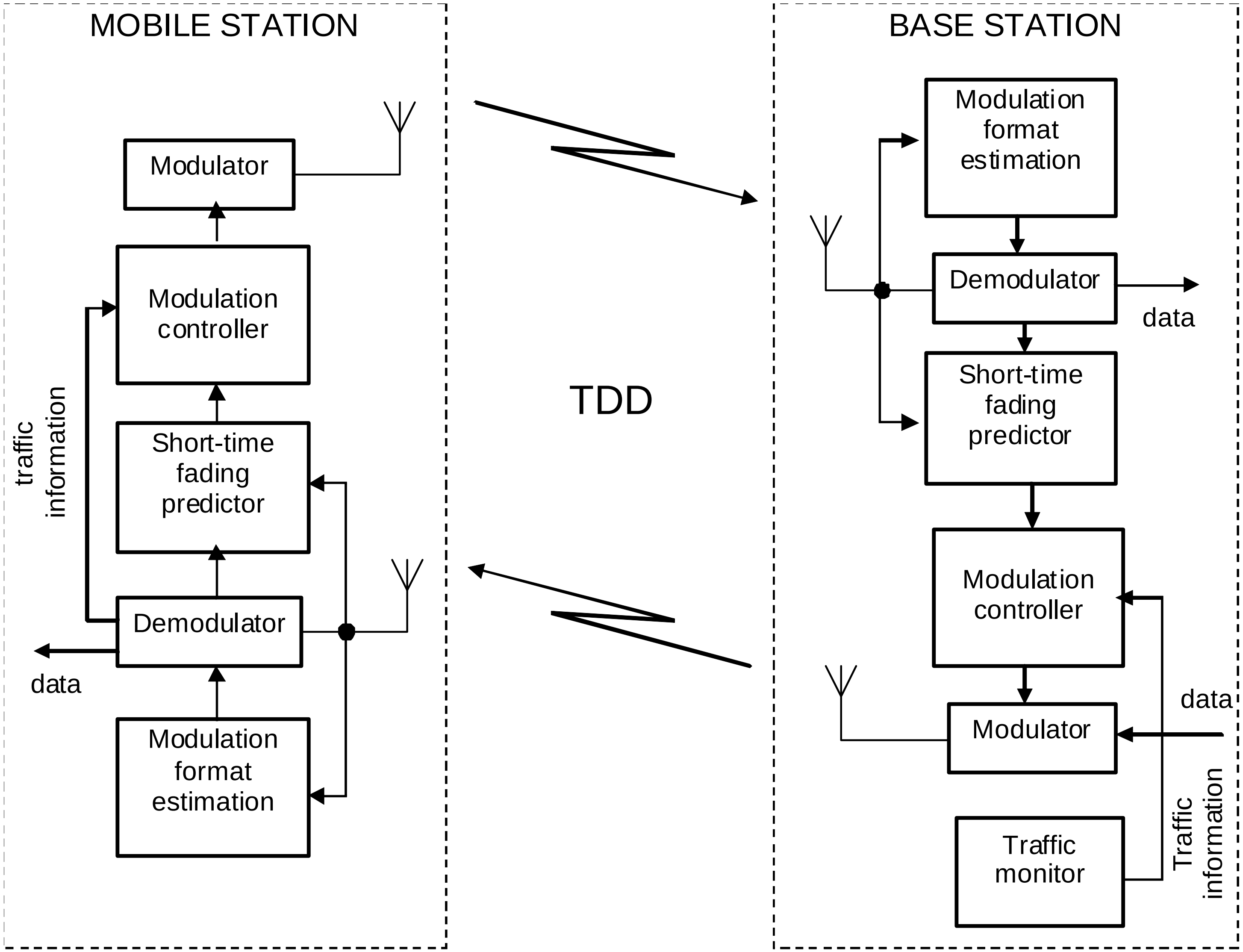
- SNR, SIR (PHY layer)
- BER, PER, FER, BLER (link layer)

Algorithm:

1. Measurement of SNR (BER) in receiver
2. According to BER_{req} to chose MCS scheme for each SNR measurement
3. Information about MCS transmit back to source



Modulation adaptation



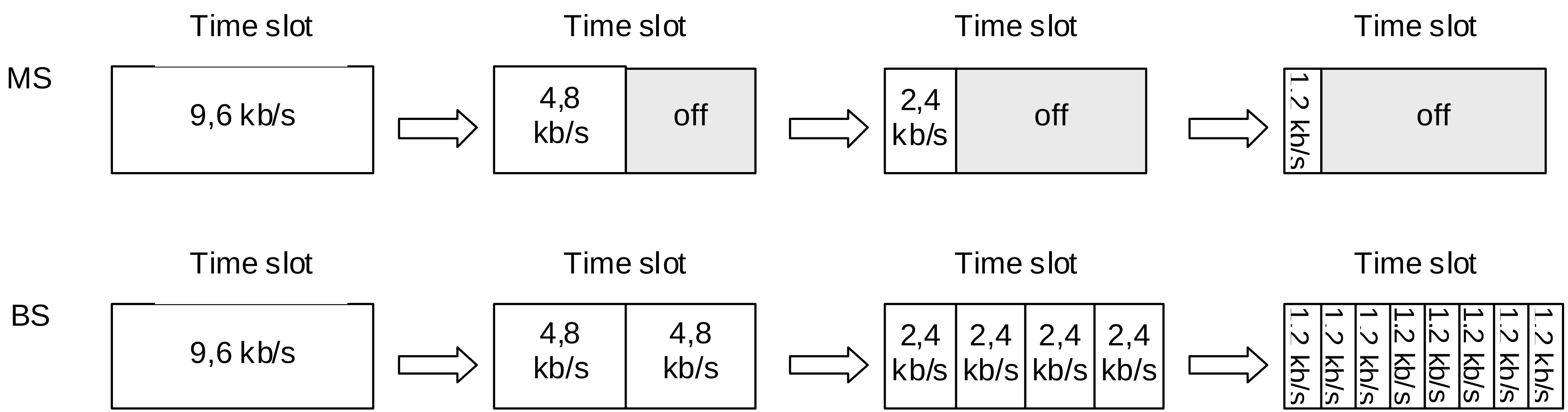
Coding adaptation

Source coding adaptation

$$k_u = \frac{B_{ss}/R}{\left(E_b/N_0\right)_r}$$

Discontinuous transmission (DTX)

cdmaOne (QCELP13)



Coding adaptation

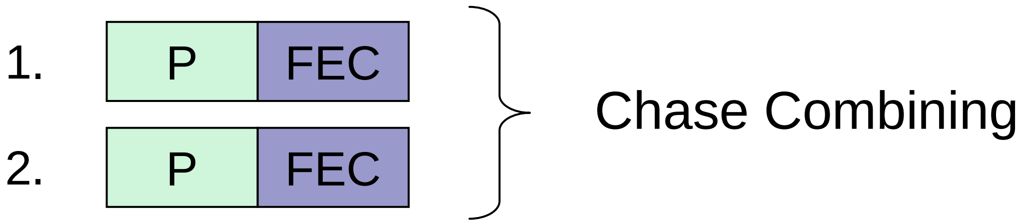
Channel coding adaptation

H-ARQ

1. Without adaptation: FEC is created for the worst channel situation.
2. With adaptation: Code rate changes accordingly channel conditions

H-ARQ = ARQ + FEC $\Rightarrow$ Joint decoding

H-ARQ I.

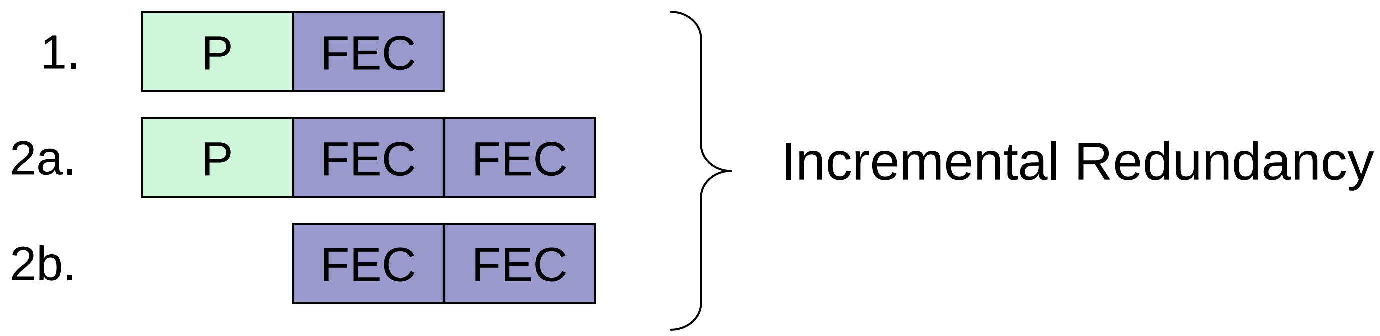


Coding adaptation

H-ARQ

Channel coding adaptation

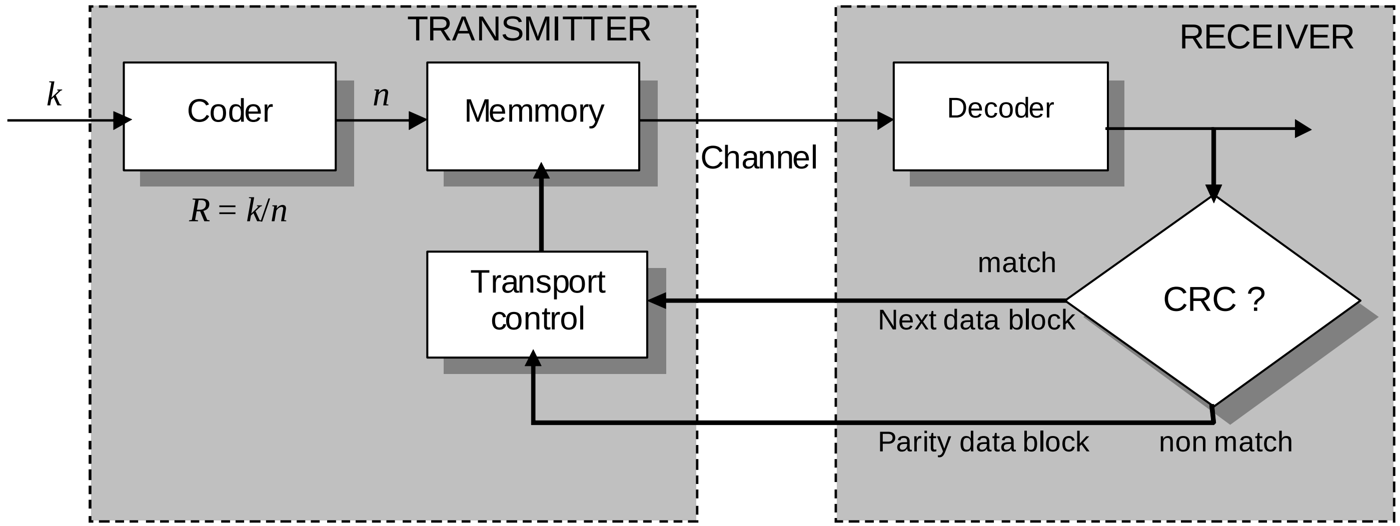
H-ARQ II.



H-ARQ III.

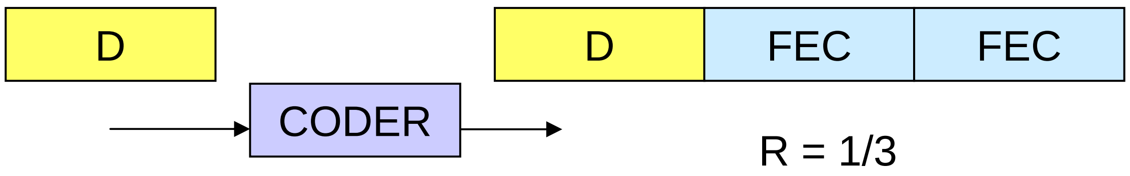
Coding adaptation

H-ARQ II. Incremental redundancy



EGPRS:

FEC = 1/3



1. transmission — D — R = 1

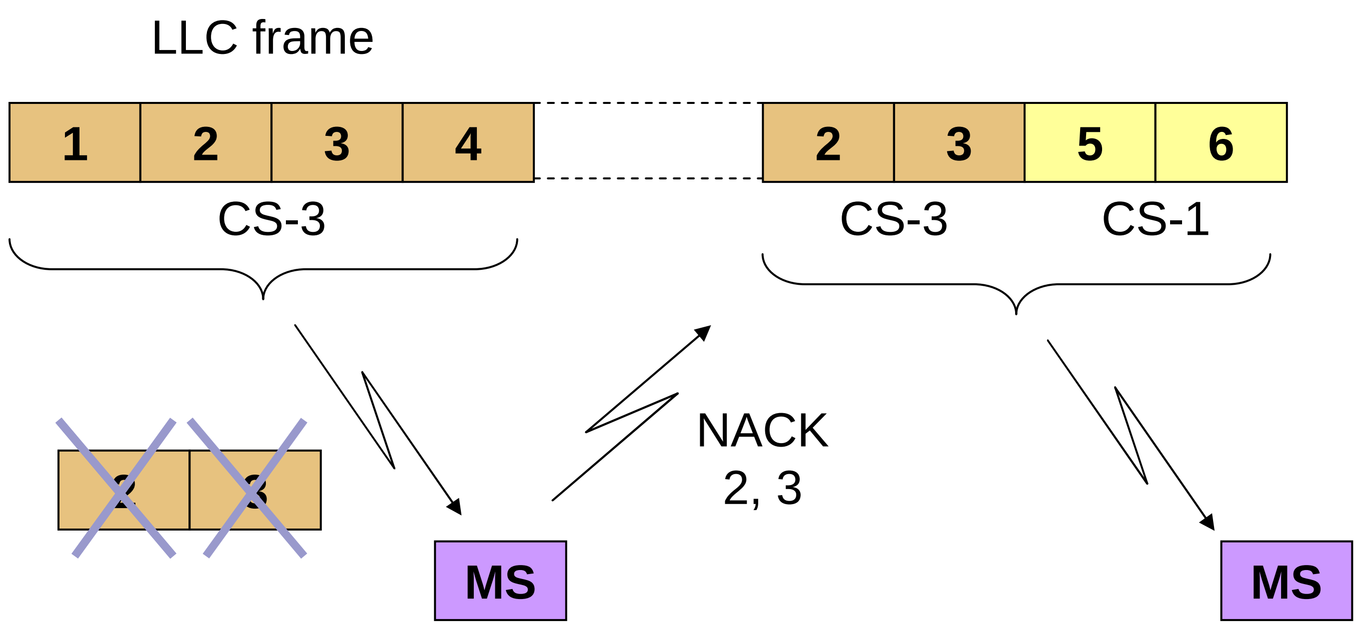
2. transmission — FEC — R = 1/2

3. transmission — FEC FEC — R = 1/3

Packet resegmentation

Coding schemes	Code Rate (FEC)	Real throughput (kb/s)
CS1	1/2	6.7
CS2	2/3	10.0
CS3	3/4	12.0
CS4	1	16.7

GPRS



Packet resegmentation

EDGE

MCS	Modulation	Code Rate	Packet Head Code Rate	Throuhput (kb/s)	Group
MCS-9	8-PSK	1.0	0,35	59,2	A
MCS-8		0.92	0,35	54,5	A
MCS-7		0.76	0,35	44,8	B
MCS-6		0.49	1/3	29,6	A
MCS-5		0.37	1/3	22,4	B
MCS-4	GMSK	1.0	1/2	17,6	C
MCS-3		0.8	1/2	14,8	A
MCS-2		0.66	1/2	11,2	B
MCS-1		0.53	1/2	8,8	C