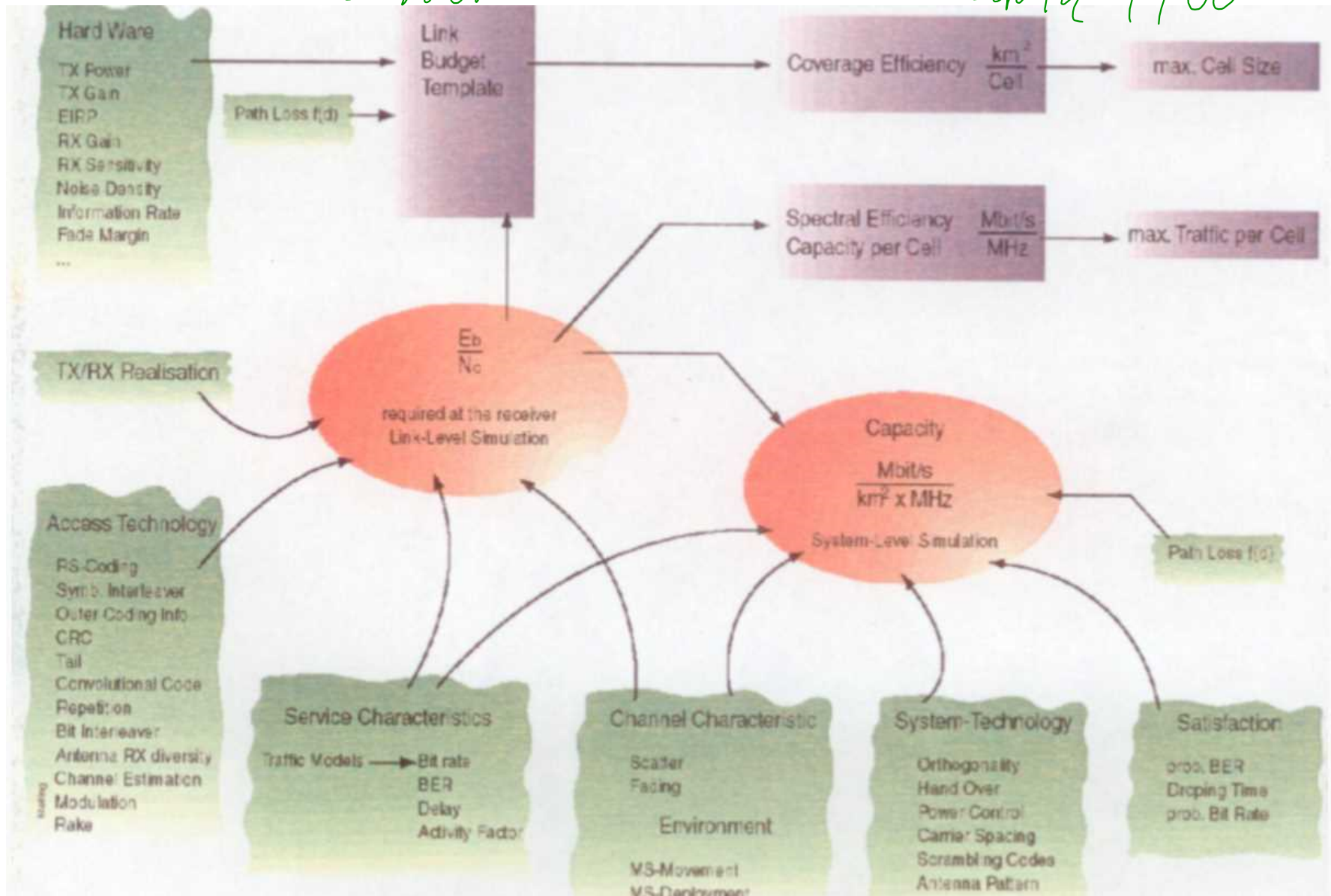
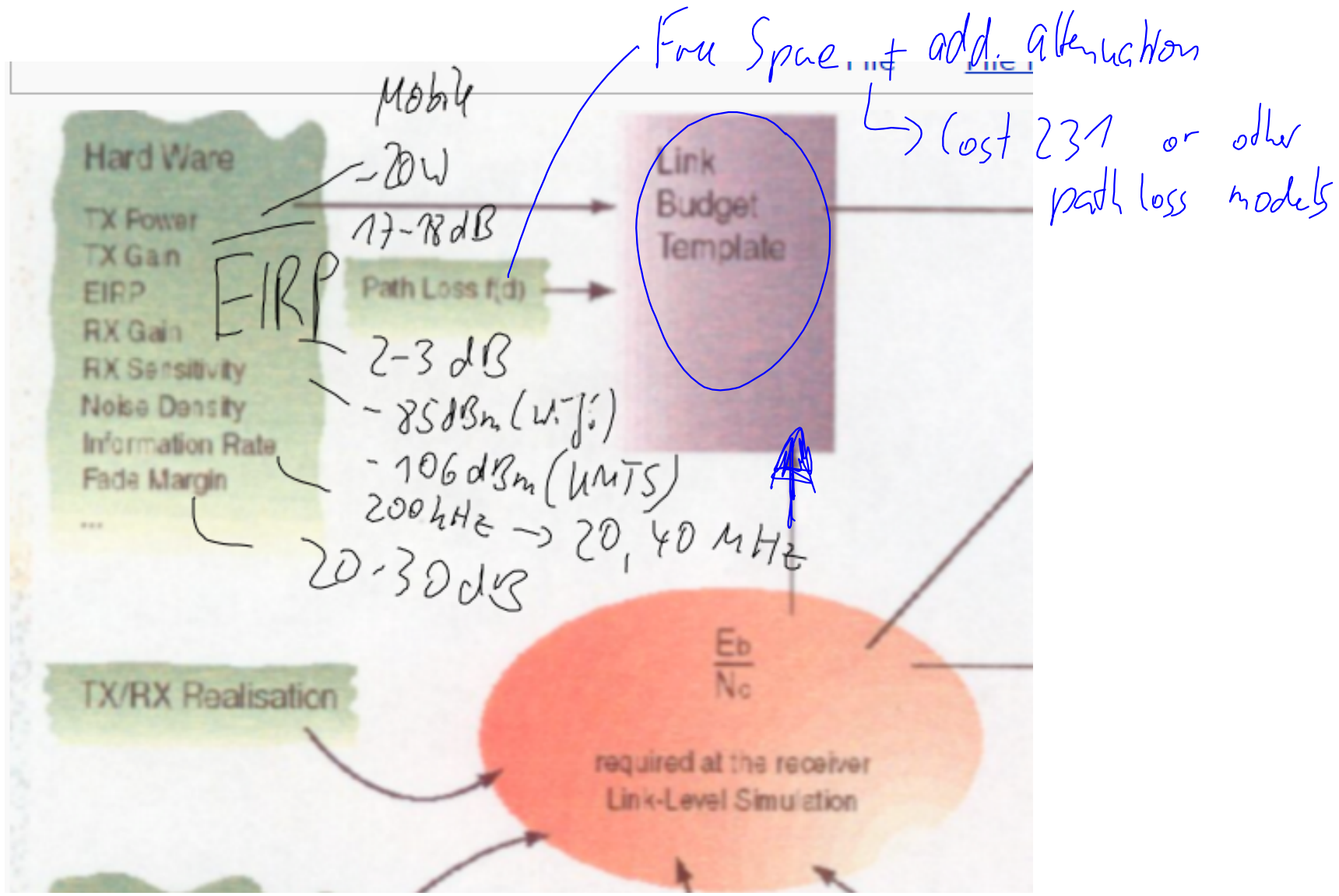
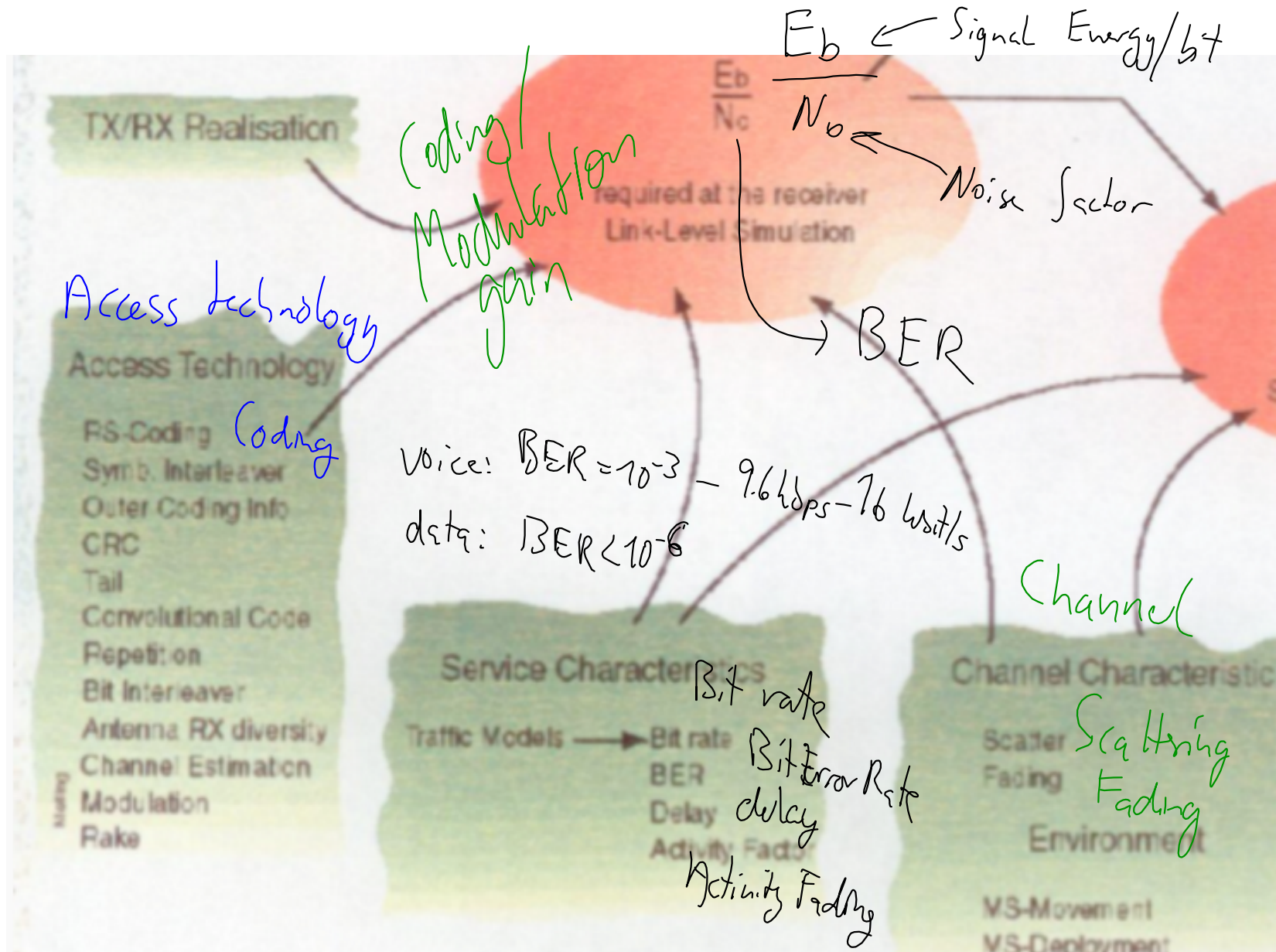


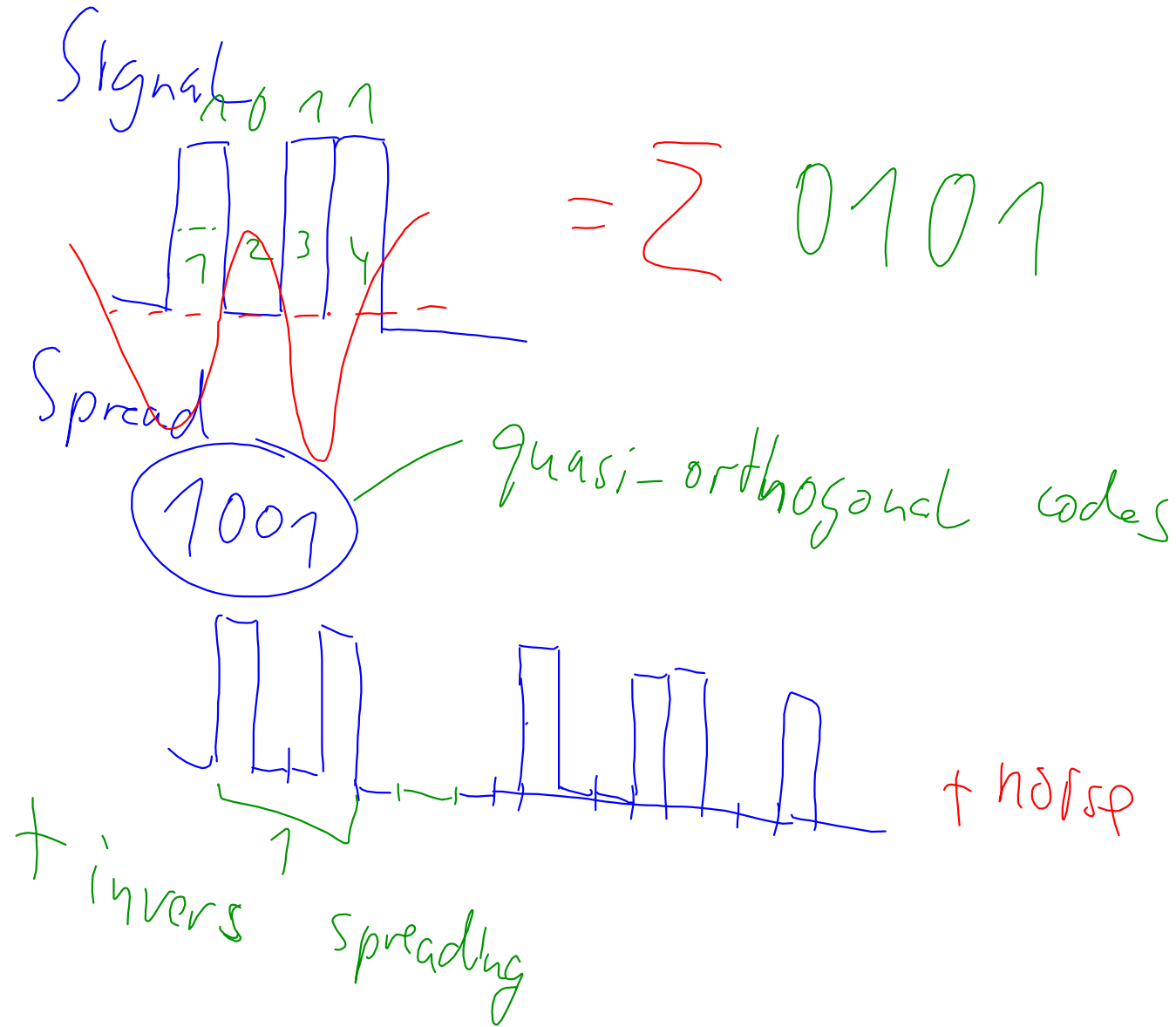
22 Nov

UNIK 4700

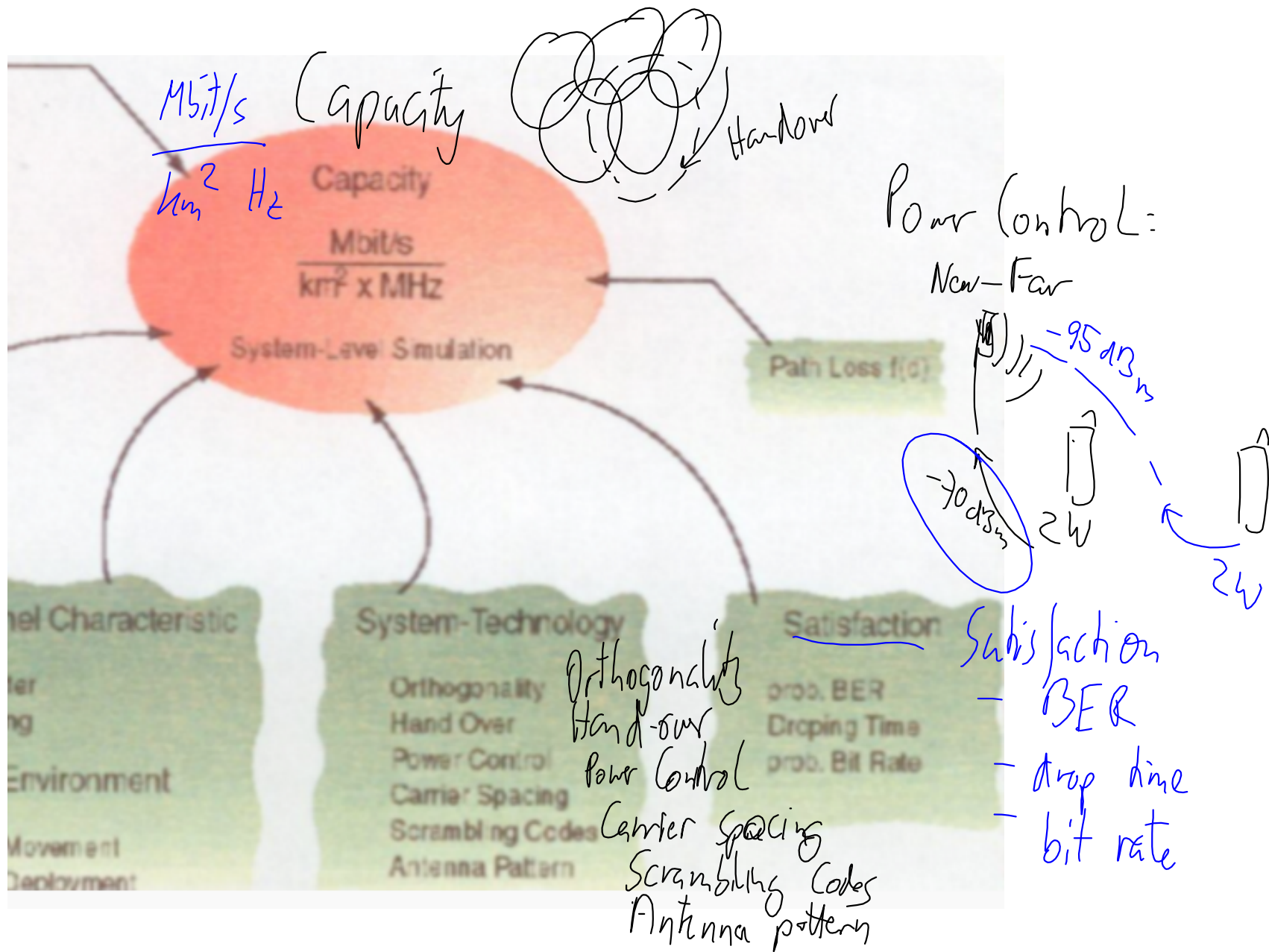


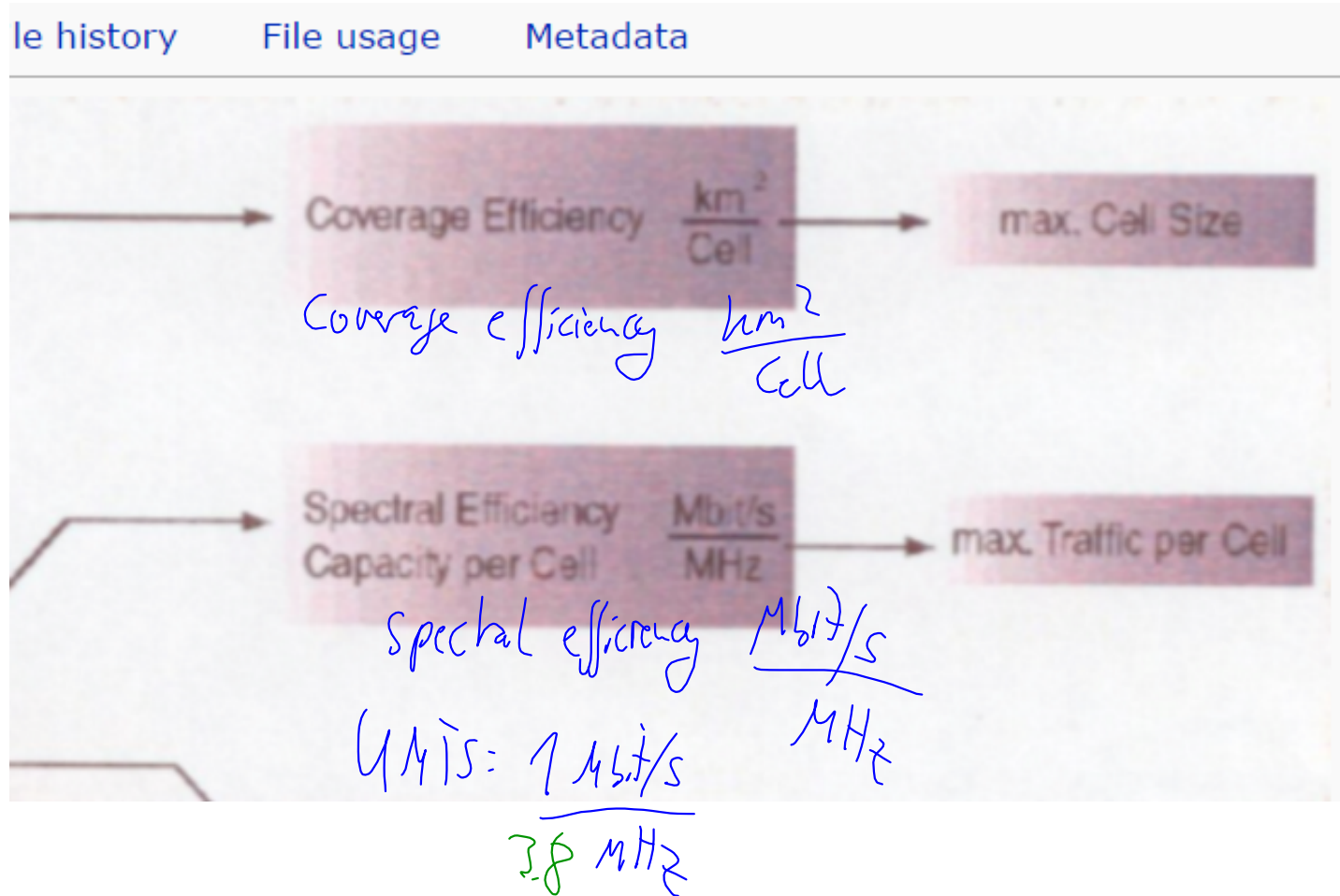












rescue team

VIP service

typical UMTS cell

cell capacity of 1 Mbit/s

rescue team

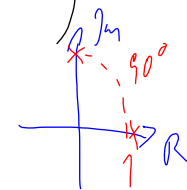
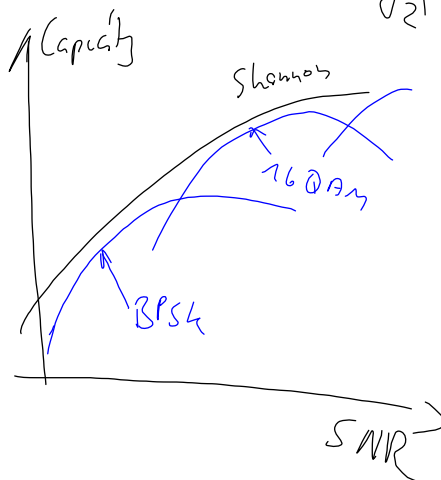
16 Mbit/s high speed access  
HSPA

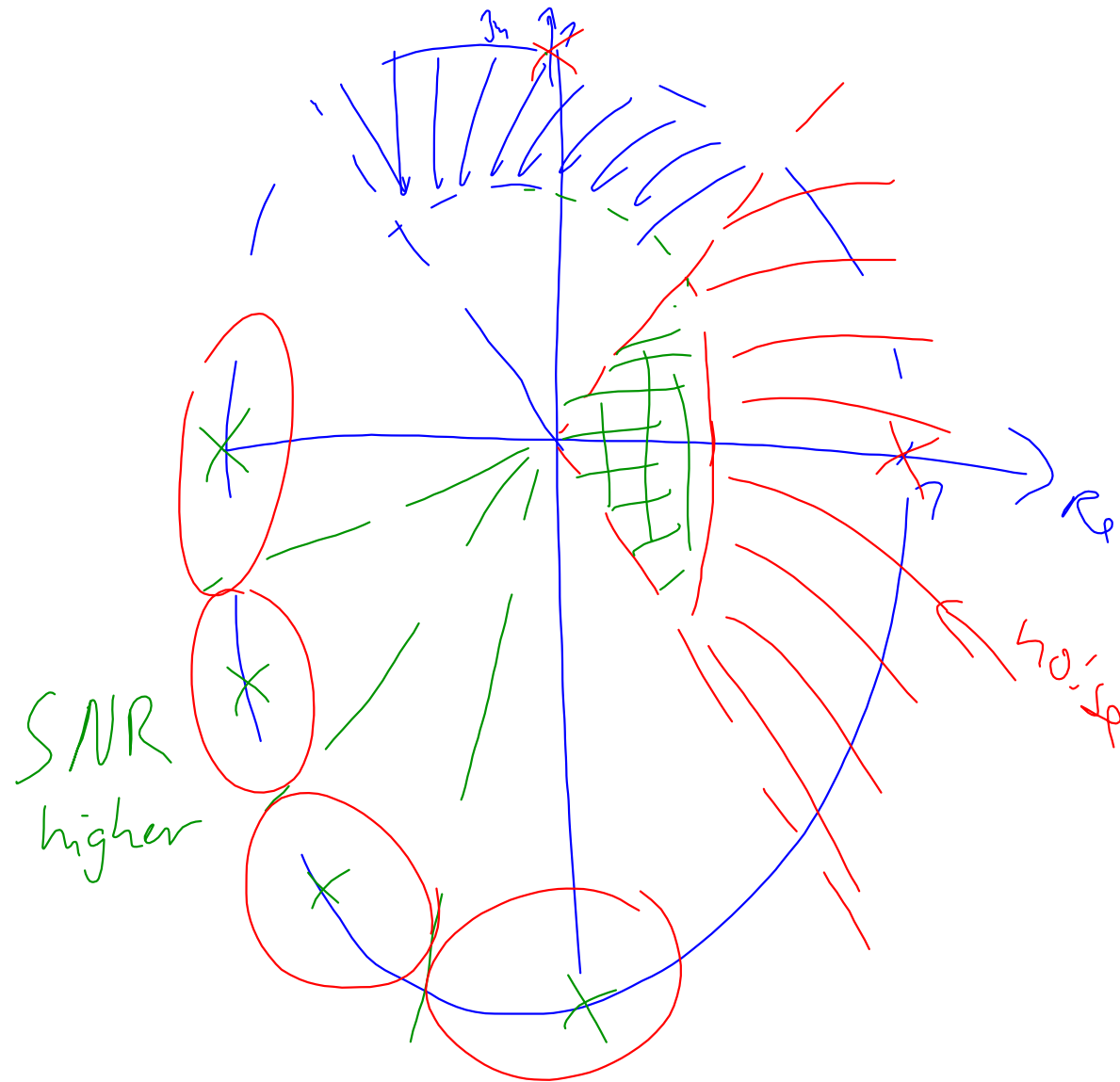
effect of coding/modulation:

$$\frac{P_R}{P_{sens}} = P_T + G_T + G_R - L_{path} - L_{Fading} + G_{Modulation Coding}$$

Capacity

Shannon:  $C = W \log_2(1 + SNR)$





Modulation  
gain  
& noise

SNR  
higher

noise



Currently Available Cellular bands:

- GSM 900: 35 (uplink) + 35 (downlink) = 70 MHz
- GSM 1800: 75 (uplink) + 75 (downlink) = 150 MHz
- Cellular 850: 25 (uplink) + 25 (downlink) = 50 MHz
- UMTS: 60 (uplink) + 60 (downlink) = 120 MHz
- PCS 1900: 60 (uplink) + 60 (downlink) = 120 MHz
- AWS: 45 (uplink) + 45 (downlink) = 90 MHz

3 operators  $\Rightarrow$  25 MHz/operator

35 MHz

75 MHz - LTE<sub>1800</sub> = 55 MHz



LTE: 70 MHz  
2600

"Spectrum Analysis for Future LTE Deployments" (white paper) by Motorola Inc., 2007.

TV band  
~ 270 MHz

Band	Uplink (MHz)	Downlink (MHz)	Carrier Bandwidth (MHz)	Comments
700 MHz	746-763	776-793	1.25 5 10 15 20	Digital Dividend. U.S. commercial spectrum is scheduled to be auctioned in January 2008. Potential future alignment with Europe
AWS	1710-1755	2110-2155	1.25 5 10 15 20	U.S. Auctions completed September 2006
IMT Extension	2500-2570	2620-2690	1.25 5 10 15 20	Initially Western Europe. Offers a unique opportunity for the deployment of LTE in channels of up to 20 MHz.
GSM 900	880-915	925-960	1.25 5 10 15 20	Reallocate this spectrum to advanced networks, such as LTE, from 2009 onwards
UMTS Core	1920-1980	2110-2170	1.25 5 10 15 20	Europe and Asia Pac. Potential for unused WCDMA carriers
GSM 1800	1710-1785	1805-1880	1.25 5 10 15 20	Europe and Asia Pac. Refarm underutilized band along with GSM 900
PCS 1900	1850-1910	1930-1990	1.25 5 10 15 20	U.S. Refarm after new 700 MHz and AWS spectrum is consumed.
Cellular 850	824-849	869-894	1.25 5 10 15 20	U.S. Refarm after new 700 MHz and AWS spectrum is consumed.
Digital Dividend	470-854		1.25 5 10 15 20	Identified at WRC-07.



Source: <http://www.spectrum2020.ca/presentations/Rappaport.pdf>



## Mobile Communication Spectrum

### Spectrum requirements

- increased spectrum need
  - due to mobile broadband
  - indoor coverage, replacement of fixed networks
- low frequencies for increased range, thus coverage

#### Currently Available Cellular bands:

- GSM 900: 35 (uplink) + 35 (downlink) = 70 MHz
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"Spectrum Analysis for Future LTE Deployments" (white paper) by Motorola Inc., 2007.

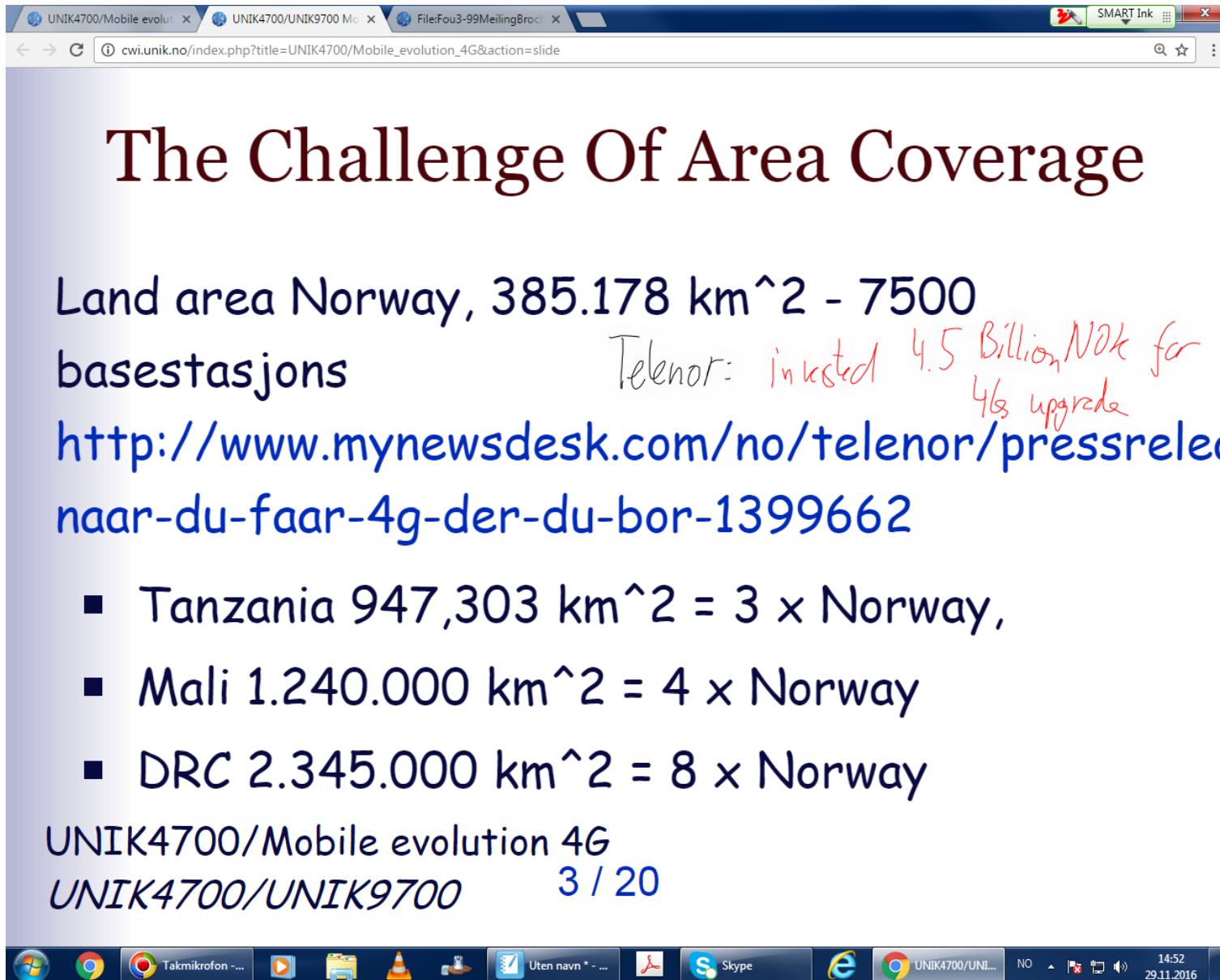
Band	Uplink (MHz)	Downlink (MHz)	Carrier Bandwidth (MHz)	Comments
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Source: <http://www.spectrum2020.ca/presentations/Rappaport.pdf>

overall in cities  
 LTE: 2600 MHz  
 ↳ hot-spots only?  
 Apple: iPhone LTE 1800

UNIK4700/Mobile evolution 4G  
 UNIK4700/UNIK9700 2 / 20





The screenshot shows a presentation slide within a browser window. The browser tabs include 'UNIK4700/Mobile evol...', 'UNIK4700/UNIK9700 M...', and 'File:Fou3-99MeilingBro...'. The address bar shows 'cwi.unik.no/index.php?title=UNIK4700/Mobile\_evolution\_4G&action=slide'. The slide title is 'The Challenge Of Area Coverage'. The main text discusses land area in Norway and the number of base stations. A handwritten note in red ink says 'Telenor: invested 4.5 Billion NOK for 4G upgrade'. A URL is provided: 'http://www.mynewsdesk.com/no/telenor/pressrelec naar-du-faar-4g-der-du-bor-1399662'. A bulleted list compares Norway's land area to Tanzania, Mali, and DRC. The footer of the slide includes 'UNIK4700/Mobile evolution 4G' and 'UNIK4700/UNIK9700 3 / 20'. The Windows taskbar at the bottom shows various icons and the system clock at 14:52 on 29.11.2016.

# The Challenge Of Area Coverage

Land area Norway, 385.178 km<sup>2</sup> - 7500 basestasjons

*Telenor: invested 4.5 Billion NOK for 4G upgrade*

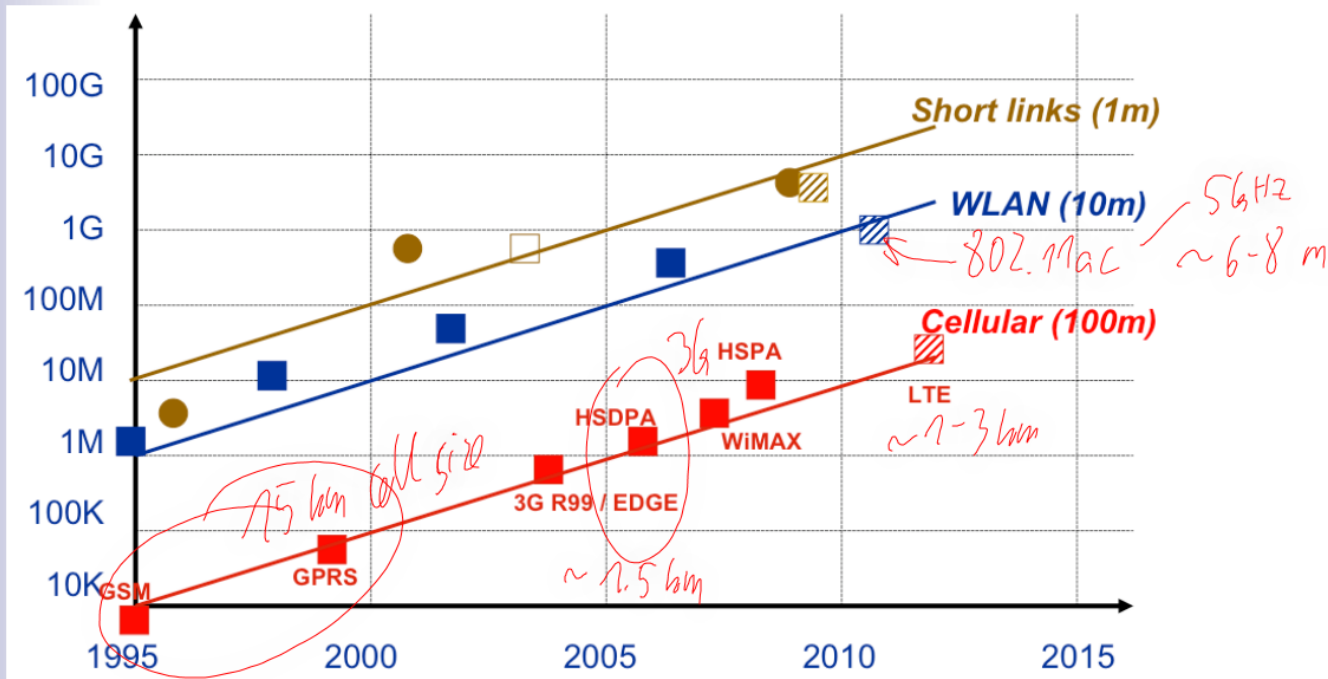
<http://www.mynewsdesk.com/no/telenor/pressrelec naar-du-faar-4g-der-du-bor-1399662>

- Tanzania 947,303 km<sup>2</sup> = 3 x Norway,
- Mali 1.240.000 km<sup>2</sup> = 4 x Norway
- DRC 2.345.000 km<sup>2</sup> = 8 x Norway

UNIK4700/Mobile evolution 4G  
UNIK4700/UNIK9700 3 / 20



### Throughput Increase

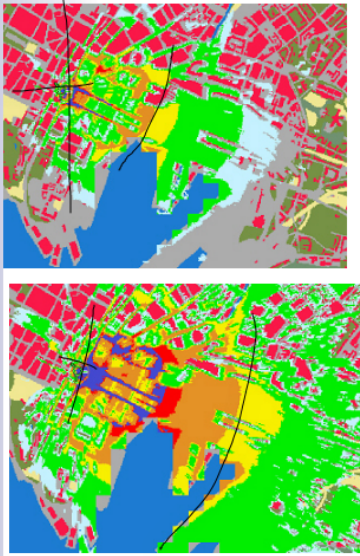


[Presentation G. Fettweis, IEEE VTC forum Baltimore], <http://www.ieeevtc.org/plenaries/vtc2007fall/28.pdf>

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Oslo Simulations, Performed For GSM At 1800 MHz



$T_x = 25 \text{ dB}_m$       10 dB increase  
 $\leadsto 10 \times \text{ power}$

$T_x = 35 \text{ dB}_m$       range  $\leadsto 2 \times$

File:Scaleimage.png

how much does the range decrease when reducing the power by 10 dB?

(Source: Helge Dommarsnes, Telenor Mobil)

UNIK4700/Mobile evolution 4G  
 UNIK4700/UNIK9700      6 / 20



UNIK4700/Mobile evolution 4G x UNIK4700/UNIK9700 Mc x File:Fou3-99MeilingBroc x SMART Ink x

cwi.unik.no/index.php?title=UNIK4700/Mobile\_evolution\_4G&action=slide

## UMTS Cell Planning

UMTS  
60 MHz  $\left\{ \begin{array}{l} 4 \times 15 \text{ MHz} \\ 6 \times 10 \text{ MHz} \end{array} \right.$

Overlay = macro cell + micro cells

Hand-drawn diagram showing macro cell (green) and micro cells (red and blue) overlaid. Frequencies  $f_1$  through  $f_7$  are labeled. A handset is shown receiving signals from  $f_3$  and  $f_4$ .

Filters in handset  
75dB 35dB?

user from operator  $f_3, f_4$

- $f_1$  borderline
- $f_2$  microcell low power
- $f_3$  will jam out  $f_2$

Power vs. frequency graph showing a peak at  $f_3$  and a dip at  $f_4$ . Labels include "Handset filter" and "f3 receive".

UNIK4700/Mobile evolution 4G 9 / 20

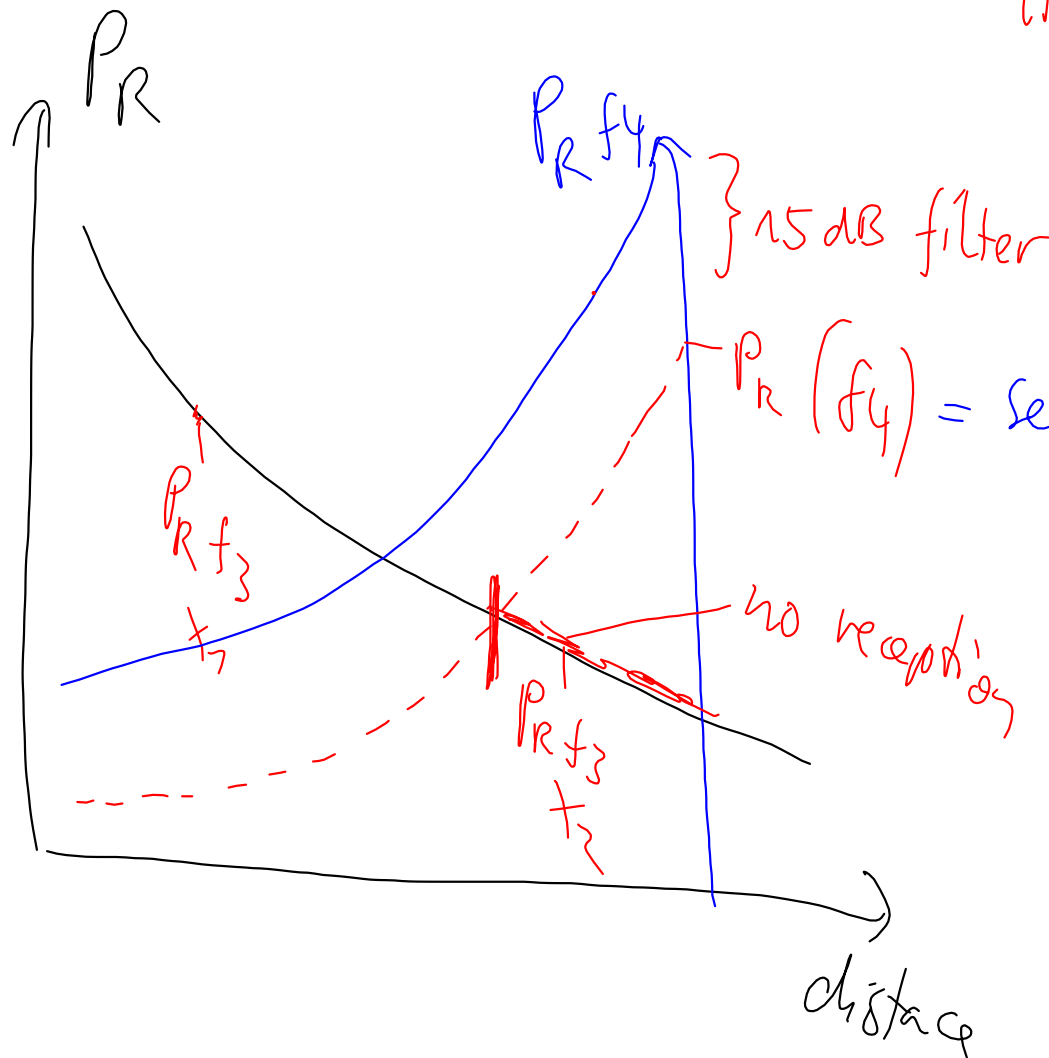
UNIK4700/UNIK9700

9 : UMTS cell planning

Takmikrofon... Uten navn \* - ... Skype UNIK4700/UNI... NO 15:11 29.11.2016



# Handset Separation



} 15 dB filter

$P_R(f_4)$  = seen as noise by  $f_3$

no reception

Reason:  
cheap handsets

UMTS simulator

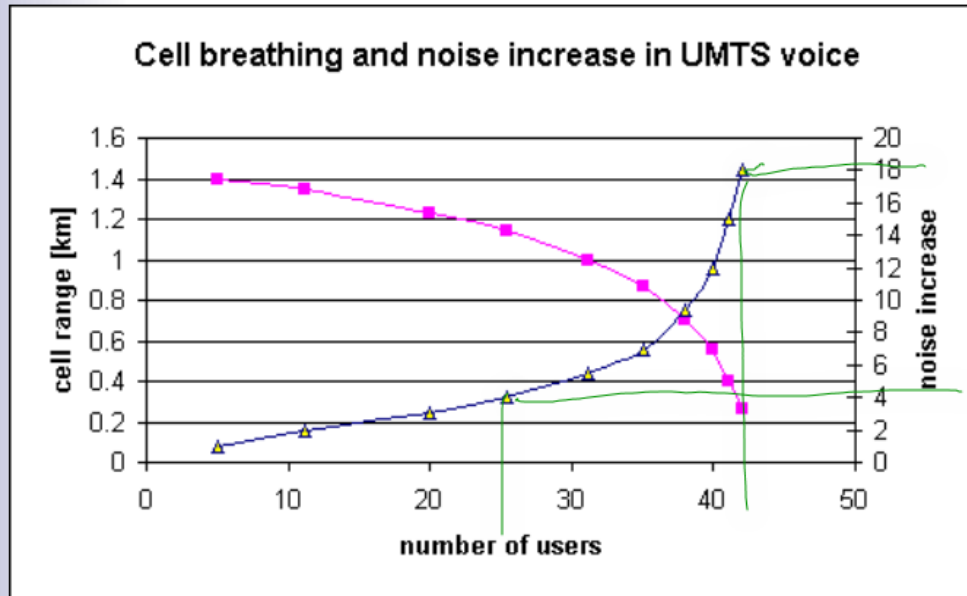
2W

8W

FDD-Results			Pedestrian		Vehicular	
			UL	DL	UL	DL
<b>Speech</b>						
Voice	Bit-Rate	kBit/s	8	8	8	8
	maximum Range	m	1020	910	5900	7350
	Spectrum efficiency	(kBit/s)/MHz/cell	123	125	90	71
	Simultaneous Users	Erlang	154	157	112	89
	Eb/No	dB	3,3	6,1	5,4	7,9
<b>LCD-MM</b>						
Line Low constraint traffic Video	Bit-Rate	kBit/s	384	384	384	384
	maximum Range	m	450	520	2800	3900
	Spectrum efficiency	(kBit/s)/MHz/cell	269	461	192	177
	Simultaneous Users	Erlang	3,5	6	2,5	2,3
	Eb/No	dB	1,3	1,1	2,9	3,2
<b>UDD-HM</b>						
packet switched Web	Bit-Rate	kBit/s	384	384	384	384
	maximum Range	m	500	520	2600	3900
	Spectrum efficiency	(kBit/s)/MHz/cell	449	668	216	
	Simultaneous Users	Erlang	91	135	42	
	Eb/No	dB	0,4	0,1	2,4	2,0

(Source: Telenor FoU report 3-99)

## Cell Breathing Effect In UMTS



noise  
 25 users ~ 4dB noise  
 ↳ 42 users ~ 18dB

View: <http://www.eurescom.de/~public-web-deliverables/P900-series/P921/D2/index.html> for "live simulation" and "Cell Ranges for GSM1800 and UMTS Services"

(Source: Eurescom P921, D2)

UNIK4700/Mobile evolution x UNIK4700/UNIK9700 M... x File:Fou3-99MeilingBroc... x UMTS: The Fundamenta... x SMART Ink

cwi.unik.no/index.php?title=UNIK4700/Mobile\_evolution\_4G&action=slide

## Unstrung.Com - Wireless News, 24 Nov 2009 2600MHz: 40MHz free usage

11:20 AM -- Four Finnish operators got some Long Term Evolution (LTE) and WiMax spectrum for just €3.8 million (US\$5.6 million). (See Finland Awards 4G Spectrum.)

Finland completed its auction of 2.6 GHz spectrum yesterday, which lasted for five days and went 27 rounds. All three main operators and a new entrant acquired licenses for proto-4G mobile broadband services.

For the LTE spectrum (that is, Frequency Division Duplex), Elisa Corp. bid €834,700 (\$1.2 million) for 50 MHz; ~~TeliaSonera AB (Nasdaq: TLSN)~~ bid €819,200 (\$1.2 million) for 50 MHz; and DNA Oy bid €675,700 (\$1 million) for 40 MHz.

For the WiMax spectrum (that is, Time Division Duplex), newcomer Pirkanmaan Verkkö Oy bid €1,468,200 (\$2.2 million) for 50 MHz.

So now Finland, Norway, and Sweden have auctioned 2.6 GHz spectrum. Norway's auction totaled 229 million Norwegian Kronor (\$41 million) in 2007 while Sweden got 2 billion Swedish Kronor (\$304 million) in 2008. LTE deployment plans are well underway in Norway and Sweden. (See Craig Goes to Norway, Sweden Awards 4G Spectrum, Swedish 4G, Telenor to Test Huawei LTE, and TeliaSonera: We'll Do 4G in 2010.)

Meanwhile, the rest of Europe still waits for more spectrum. (See Germany's Monster 4G Auction, Europe Faces 4G Spectrum Delays, French 4G Spectrum Update, and Europe Waits for 4G Spectrum.)

UNIK4700/Mobile evolution 4G / 20

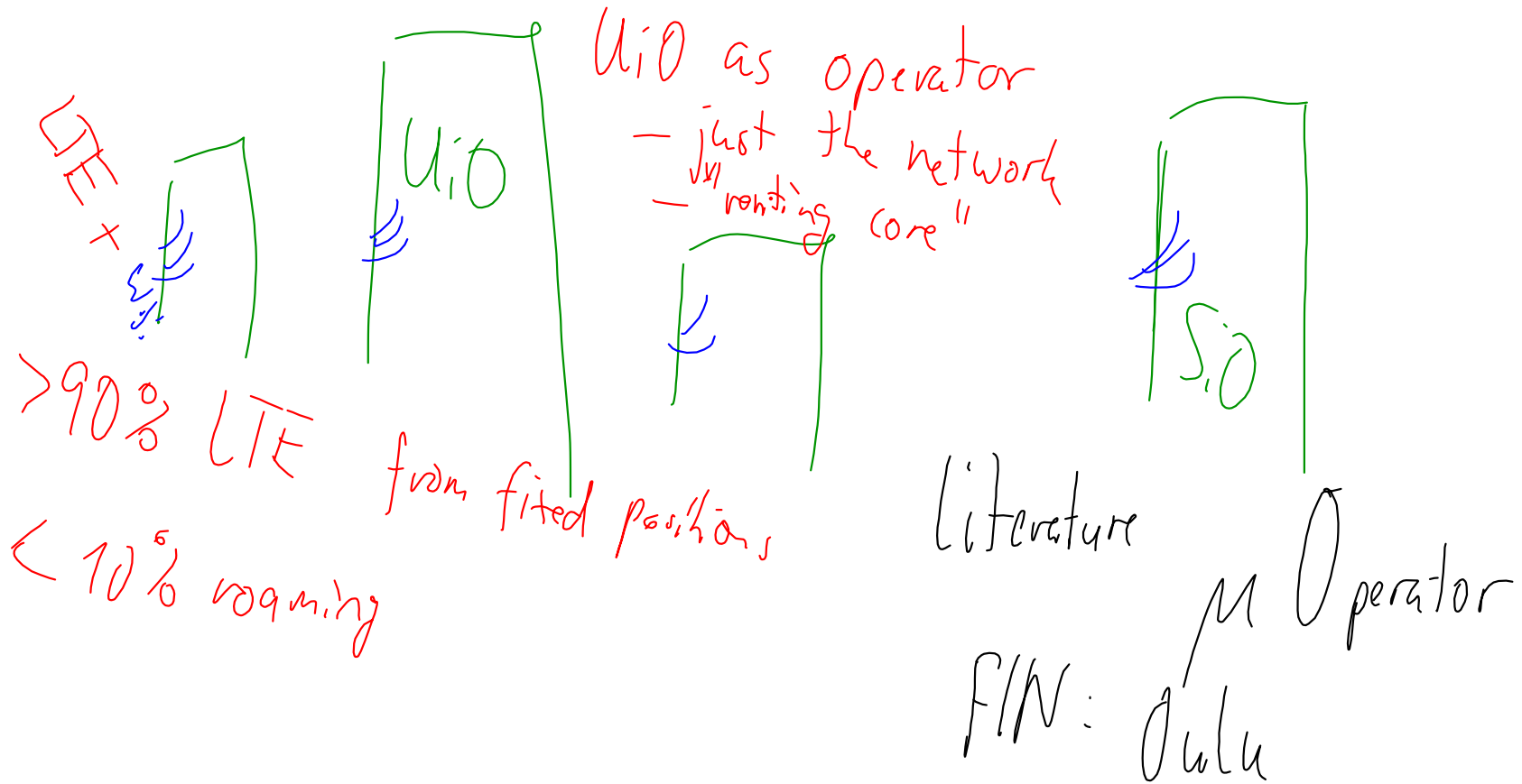
UNIK4700/UNIK9700

18 : Unstrung.com - Wireless News, 24 Nov 2009

Takmikrofon... Uten navn \* - ... Skype UNIK4700/UNI... NO 15:39 29.11.2016

# Free usage of spectrum

LTE<sub>2600</sub> → 20, 40 MHz free usage





## Mobile Communication Spectrum

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  - due to mobile broadband
  - indoor coverage, replacement of fixed networks
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overall in cities  
 LTE: 2600 MHz  
 ↳ hot-spots only?  
 Apple: iPhone LTE 1800

UNIK4700/Mobile evolution 4G  
 UNIK4700/UNIK9700 2 / 20





Way ahead:

5G coverage & capacity

- deal with small groups, e.g. UIC
- authentication, security
- Wifi & (5G) LTE