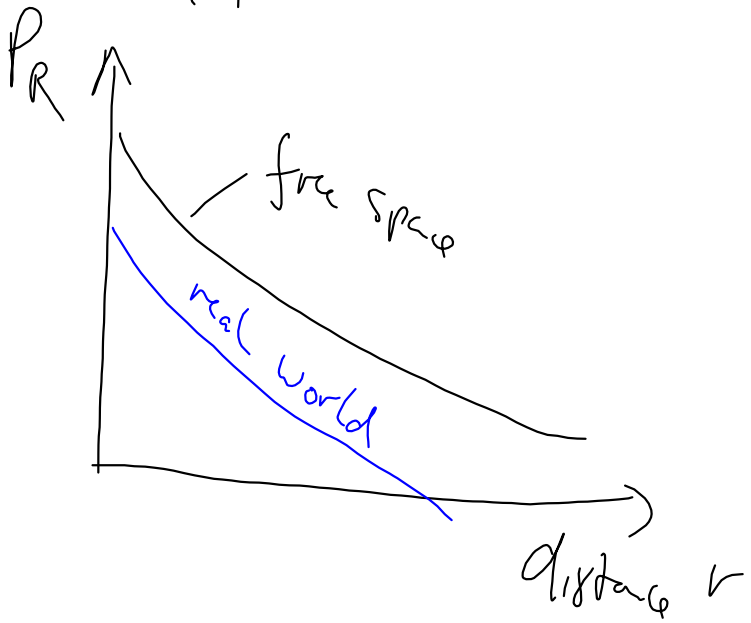
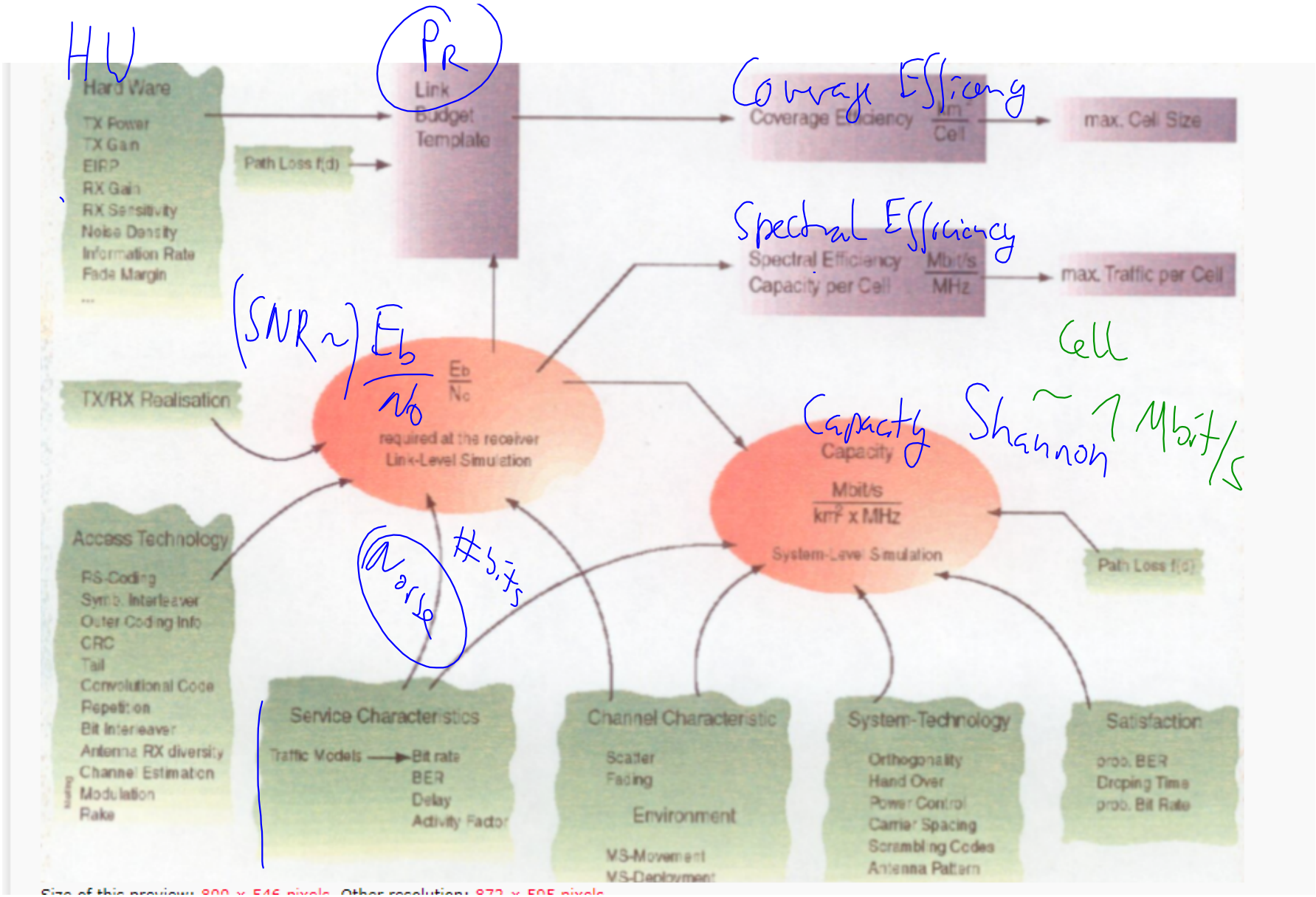
Recall

$L_{Path} \sim \frac{1}{r^2}$ Praxis $\sim \frac{1}{r^{2.x}} - 20\text{-}30\,dB$





Size of this preview: 800 x 546 pixels. Other resolutions: 872 x 595 pixels.

Shared amongst operators

Refarming 26, 36, 46 → ?

1 Operator 12.5 15 + 22 MHz

17.5 + 50 + 120 + 65 MHz

30 operators

Capacity, BW, Int. compatibility

Range, cost of coverage QoS

Latency

Topology

Cost of equipment

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

LTE: 2 x 70 MHz

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

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

http://www.radio-electronics.com/info/cellulartelecomms/lte-long-term-evolution/lte-frequency-spectrum.php

FDD LTE BANDS & FREQUENCIES					
LTE BAND NUMBER	UPLINK (MHZ)	DOWNLINK (MHZ)	WIDTH OF BAND (MHZ)	DUPLEX SPACING (MHZ)	BAND GAP (MHZ)
1	1920 - 1980	2110 - 2170	60	190	130
2	1850 - 1910	1930 - 1990	60	80	20
3	1710 - 1785	1805 -1880	75	95	20
4	1710 - 1755	2110 - 2155	45	400	355
5	824 - 849	869 - 894	25	45	20
6	830 - 840	875 - 885	10	35	25
7	2500 - 2570	2620 - 2690	70	120	50
8	880 - 915	925 - 960	35	45	10
9	1749.9 - 1784.9	1844.9 - 1879.9	35	95	60
10	1710 - 1770	2110 - 2170	60	400	340
11	1427.9 - 1452.9	1475.9 - 1500.9	20	48	28
12	698 - 716	728 - 746	18	30	12
13	777 - 787	746 - 756	10	-31	41
14	788 - 798	758 - 768	10	-30	40
15	1900 - 1920	2600 - 2620	20	700	680
16	2010 - 2025	2585 - 2600	15	575	560
17	704 - 716	734 - 746	12	30	18
18	815 - 830	860 - 875	15	45	30
19	830 - 845	875 - 890	15	45	30
20	832 - 862	791 - 821	30	-41	71
21	1447.9 - 1462.9	1495.5 - 1510.9	15	48	33
22	3410 - 3500	3510 - 3600	90	100	10
23	2000 - 2020	2180 - 2200	20	180	160
24	1625.5 - 1660.5	1525 - 1559	34	-101.5	135.5
25	1850 - 1915	1930 - 1995	65	80	15
26	814 - 849	859 - 894	30 / 40		10
27	807 - 824	852 - 869	17	45	28
28	703 - 748	758 - 803	45	55	10
29	n/a	717 - 728	11		
30	2305 - 2315	2350 - 2360	10	45	35
31	452.5 - 457.5	462.5 - 467.5	5	10	5

TDD LTE BANDS & FREQUENCIES		
LTE BAND NUMBER	ALLOCATION (MHZ)	WIDTH OF BAND (MHZ)
33	1900 - 1920	20
34	2010 - 2025	15
35	1850 - 1910	60
36	1930 - 1990	60
37	1910 - 1930	20
38	2570 - 2620	50
39	1880 - 1920	40
40	2300 - 2400	100
41	2496 - 2690	194
42	3400 - 3600	200
43	3600 - 3800	200
44	703 - 803	100

Example DE

850 50 MHz / 2 = 25 MHz

2 operators : 12.5 MHz

1800 750 MHz / 2 = 75 MHz

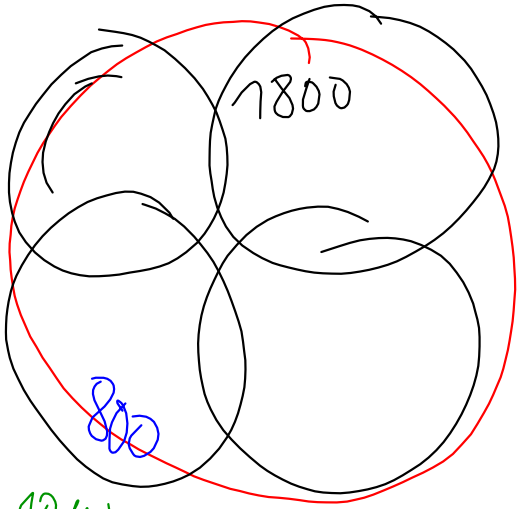
2+2 operators

2+1

17.5 MHz each

2.5 MHz 6 y LTE

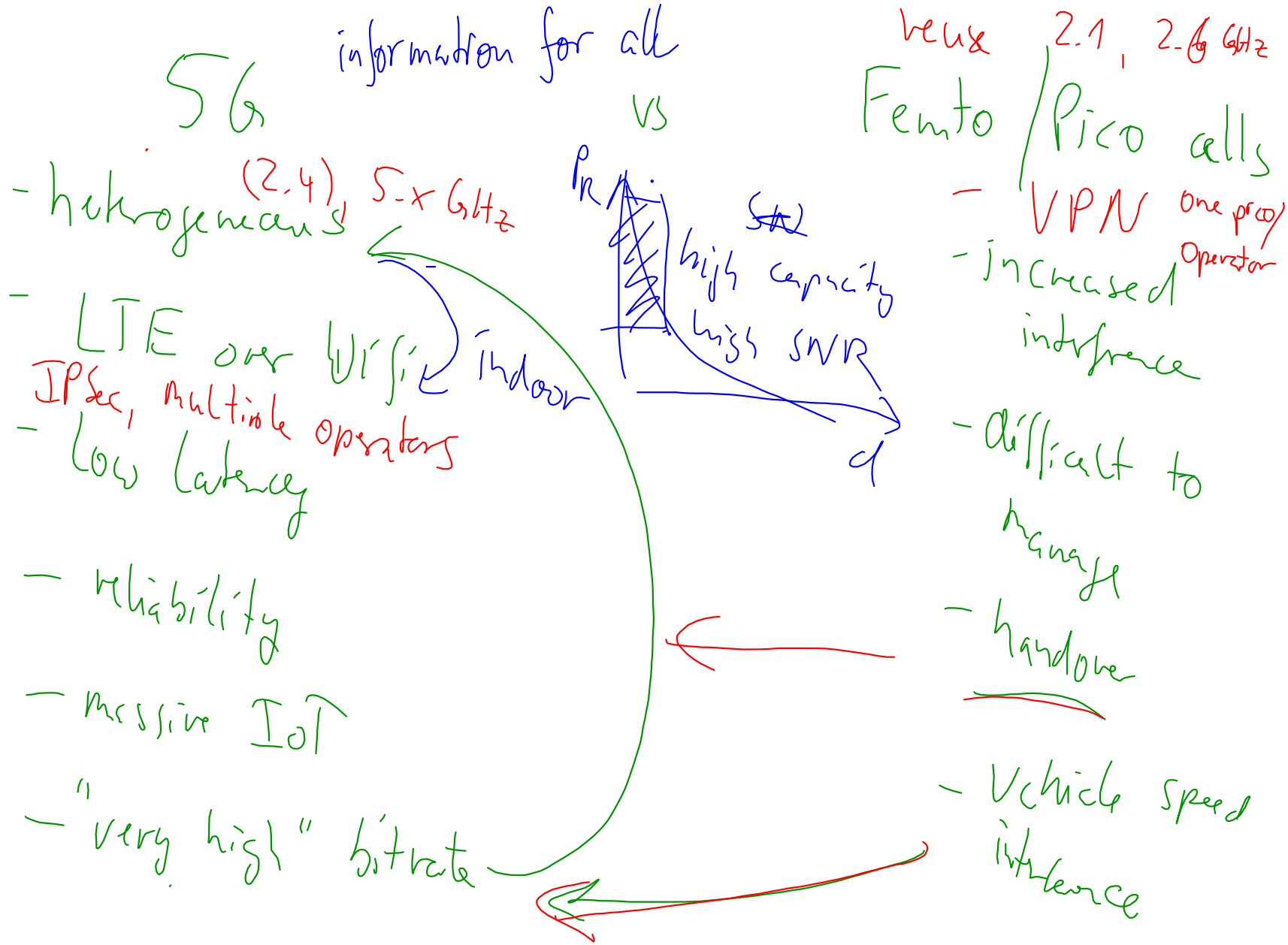
10 MHz

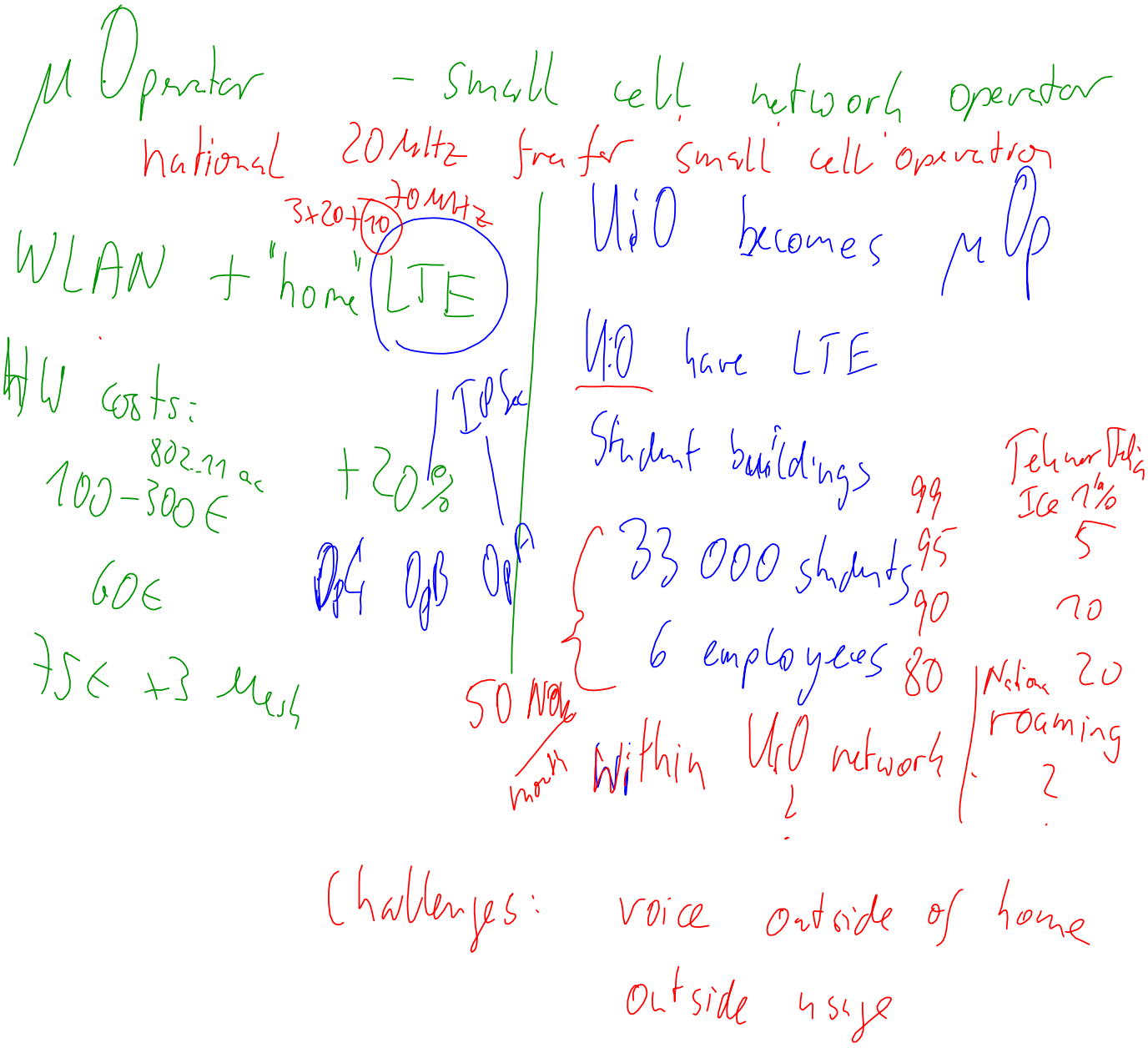


Reframing: Topology Capacity

850 GSM + LTE

- alarm
- payment tunnels

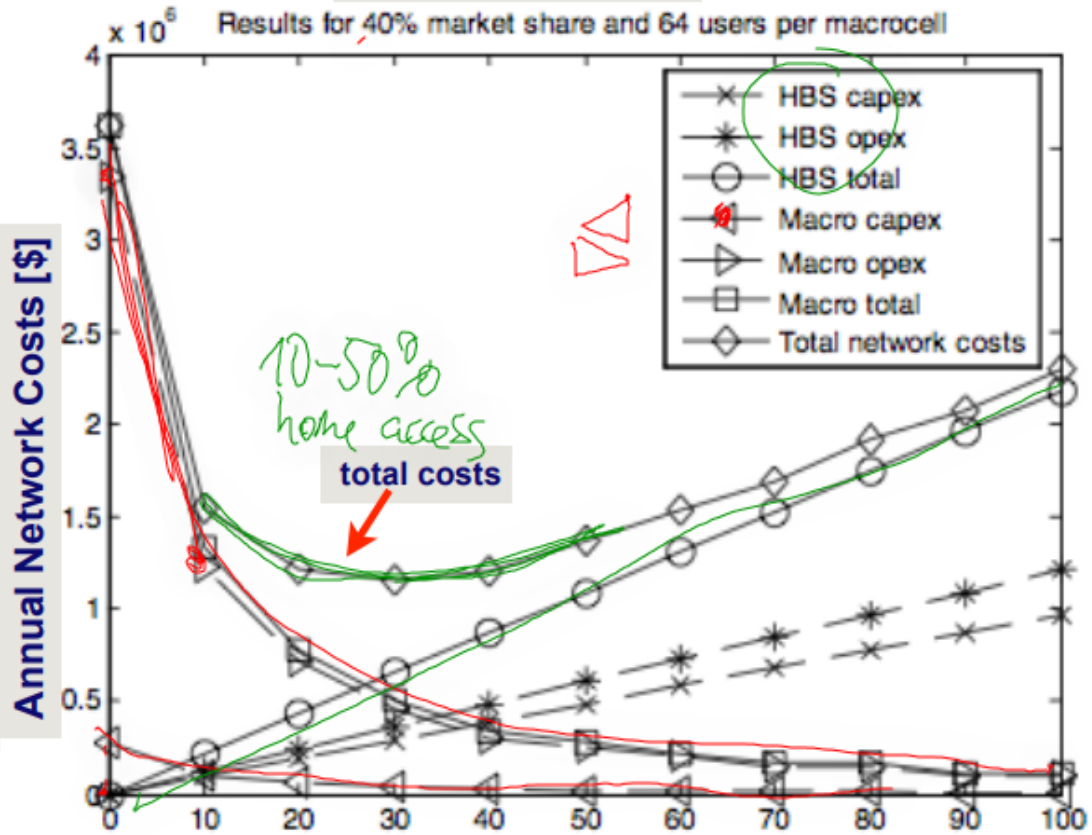

5G
information for all
vs
reuse
2.1, 2.6 GHz
Femto / Pico cells
- heterogeneous
(2.4) 5.x GHz
- LTE over WiFi
IPSec, multiple operators
- low latency
- reliability
- massive IoT
- "very high" bitrate
indoor
high capacity
high SNR
- VPN one proxy Operator
- increased interference
- difficult to manage
- handover
- vehicle speed influence


μ Operator - small cell network operator
national 20 MHz from for small cell operation
3×20+70 MHz
WLAN + "home" LTE
HW costs:
802.11ac
100-300 €
60 €
75 € +3 Mbit
+20%
IPSec
UiO becomes μ Op
UiO have LTE
Student buildings
33 000 students
6 employees
99
95
90
80
50 NOK/month
within UiO network
Telenor/Tele Ice 1%
5
10
Nation 20
roaming
2
Challenges: voice outside of home
outside usage

40% market share

OpEx and CapEx calculations based on "free provisioning" of home base stations

[source: H. Claussen, 2007]



UMTS Traffic Simulations

FDD-Results			Pedestrian		Vehicular	
			UL	DL	UL	DL
Speech						
	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
LCD-MM						
	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
UDD-HM						
	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

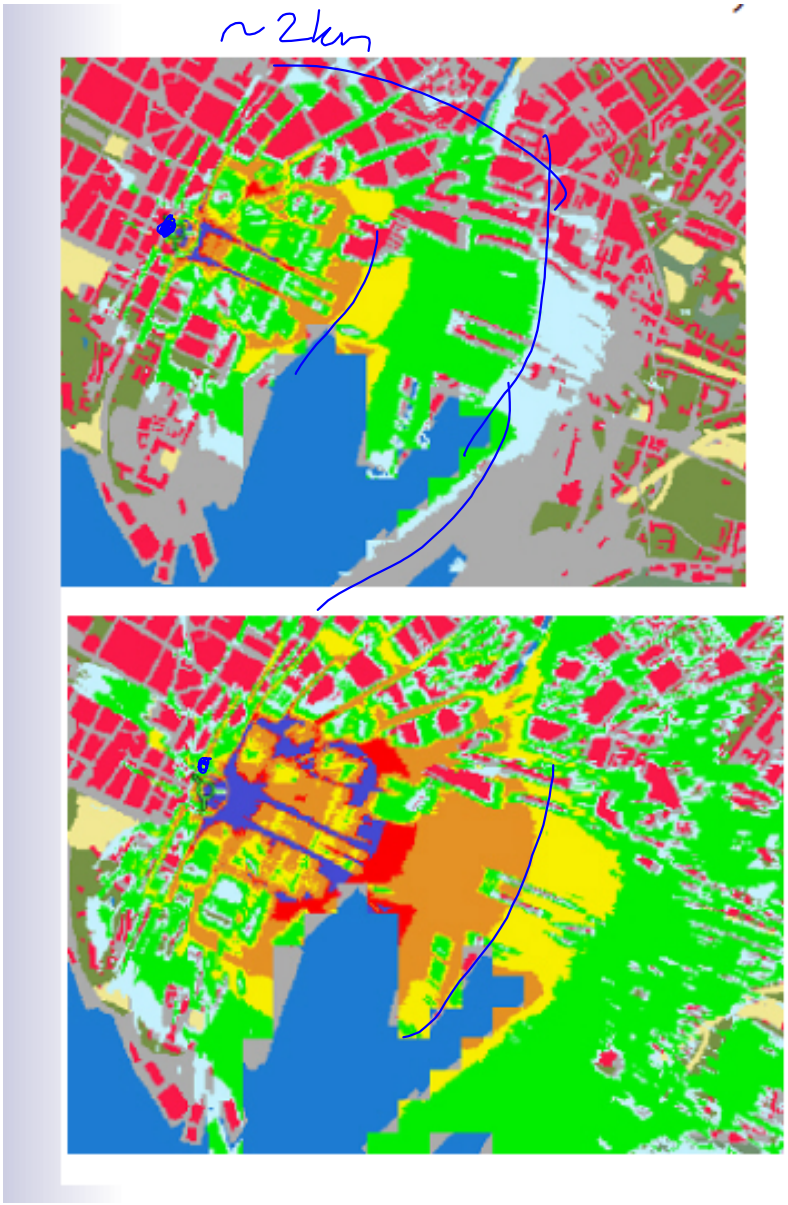
UMTS cell capacity ? Mbit/s

Voice

Low constraint delay streaming

Unconstrained data delay ftp, burst

(Source: Telenor FoU report 3-99)



T_{x_1}

brown GMH

+10 dB ~ double coverage

$T_{x_2} = 10\,dB + T_{x_1}$