User equipment receiver sensitivity: The forgotten mobile network efficiency factor

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Outline

- Mobile network efficiency
  - Efficiency test standards
  - Network energy consumption and efficiency improvement
- Does RX sensitivity matter?
  - Radio-link budget
  - Sensitivity variation of user equipment
- Receiver sensitivity impact on network performance
  - User equipment impact on link budget
  - User equipment impact on capacity
- Conclusions

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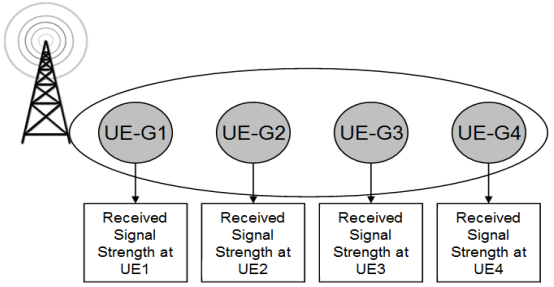
Radio base station efficiency standard

- RBS efficiency test standards are available from ETSI and ATIS
- ETSI TS 102 706 provides power consumption measurement procedures and defines KPIs for capacity and coverage
  - The static efficiency KPI is based on measured power consumption and theoretical throughput of the tested configuration
  - The dynamic capacity efficiency KPI is based on measured RBS power consumption and throughput with varying load from several UEs at certain defined distances



$$EE_{equipment} = \frac{\sum_{ALx=1}^{l} c_{ALx} \cdot DV^{ALx}}{\sum_{ALx=1}^{l} c_{ALx} \cdot E_{equipment}^{ALx}}$$

DV = data volume

E = energy consumption

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Green standards for user equipment

- Energy efficiency
  - No efficiency standard similar to the RBS standard
  - Efficiency standard for mobile phone chargers (Energy Star, ITU-T)
  - Multiple ”Green mobile phone” labels from different Telecom operators
    - Some are based on use phase energy consumption
    - Others are life cycle based

- Environmental impact (not UE specific)
  - Life cycle assessment: ETSI TS 103 199, ITU-T
  - JRC (European Commission): Product environmental footprint

- Non of above methods takes specific UE radio performance into account

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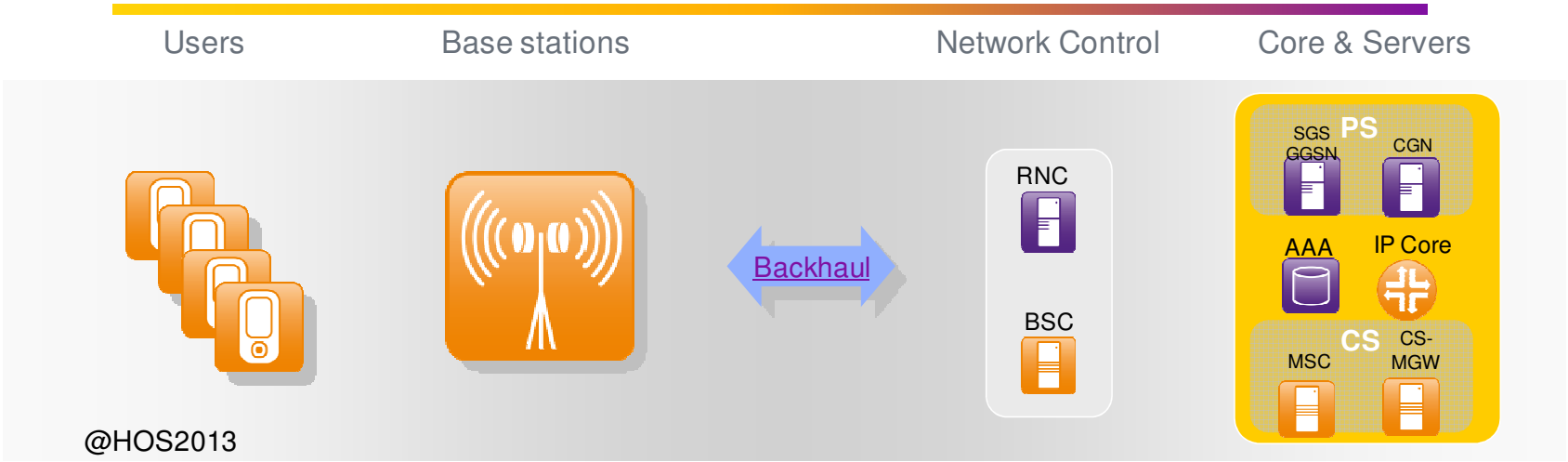
Energy consumption distribution in cellular networks



Mobile phone	~7TWh/a	~100TWh/a	~10TWh/a	~5TWh/a	~10TWh/a
Other user devices	*~70TWh/a*				
	7 billion Subscriptions	**7 million Radio Stations**	**20.000 Controller**	**Other elements**	

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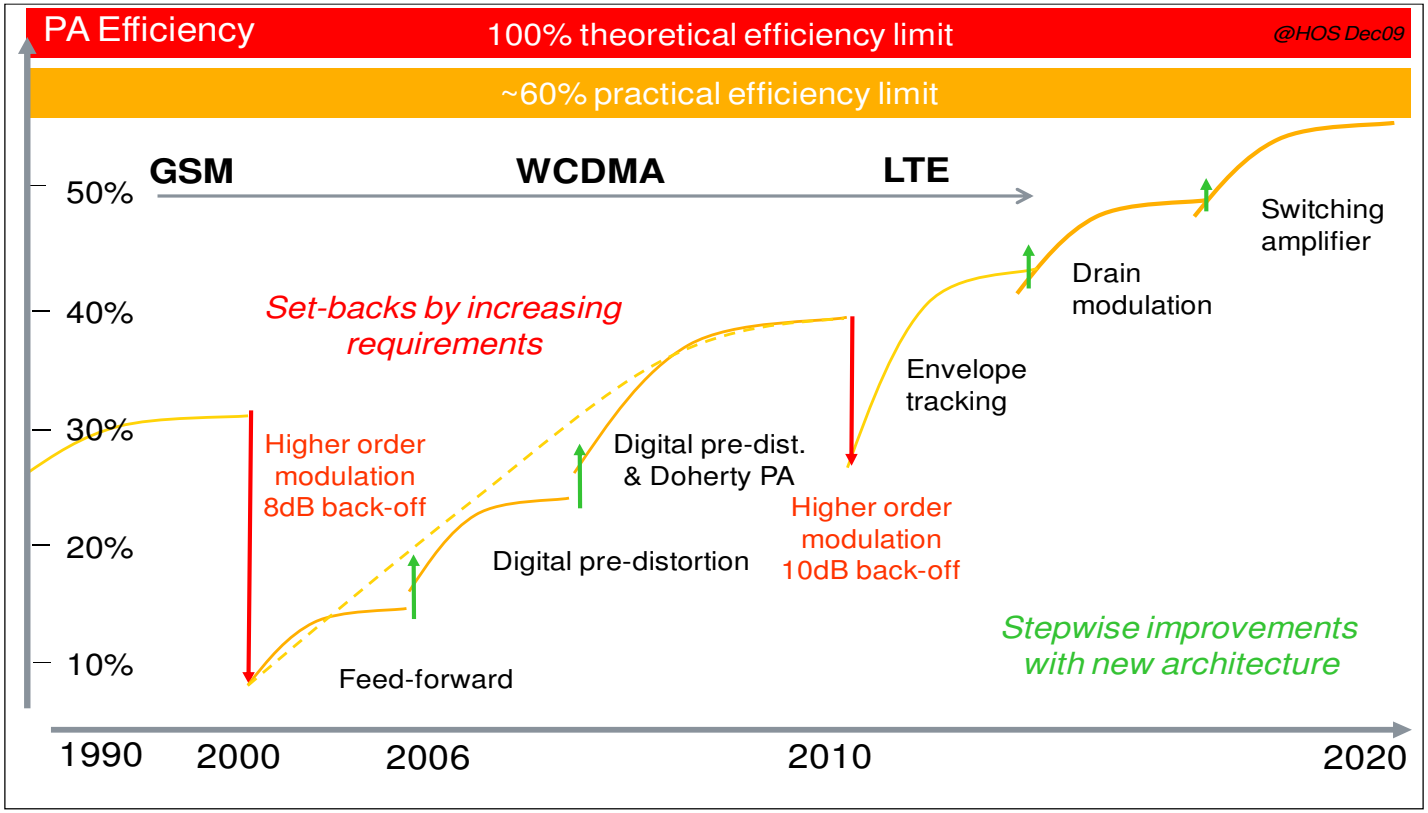
Historical efficiency focus on power amplifiers



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Does receiver sensitivity matter?

1. Radio link budget
   1. Impact of RX sensitivity on coverage area
   2. Does coverage area matter?

2. Network performance
   1. Key challenge how to deal with growing data traffic
   2. Does RX sensitivity impact capacity?

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Does coverage matter?

- About 2000 years ago some indigenous Northern Australians improve the range of their voice: Blowing into a long cylindrical piece of bamboo - the dawn of the didgeridoo.

Source: RTT Technology Topic
http://www.rttonline.com/

- The way you can tell that your didgeridoo is better than everyone else's didgeridoo is to blow into it and find out how far the sound goes.
- So naturally when an Australian goes in to buy a 'Next G' mobile phone from a Telstra shop the first question is 'how far does it go mate?
- Telstra tests phones in the laboratory and if they perform well they go off for a drive in the outback for some comparative testing.
- And Europe? Scandinavian Telecom operators replaces phone lines in remote areas and people complain a lot about bad coverage!

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Radio link budget

- ETSI defines a KPI for radio base station coverage efficiency:

$$EE_{coverage} = \frac{A_{coverage}}{P_{site}}$$

- UL coverage is a sensitivity test for the BTS
- UE sensitivity has significant impact on the DL performance
- UE sensitivity is calibrated in the BTS EE standard

Frequency	900	MHz
BCCH TX power	36,0	dBm
A (v.1.3.1)	*146,8*	
BTS antenna height (h_b)	*40*	m
UE antenna height (h_m)	*1,5*	m
a(h_m)	*0,016*	dB
Downlink:		
Combiner loss (L_Bcom)	0	dB
Feeder loss (L_Bf)	*3*	dB
BTS antenna gain (G_Ba)	*17,5*	dB
UE antenna gain (G_Ma)	*0*	dB
Indoor penetration loss (L_in)	*12*	dB
Body loss (L_Ph)	*3*	dB
UE sensitivity (P_Msen)	*-104*	dBm
Shadow fading margin (P_margin)	*6*	dB
Downlink loss (L_Pd):	*133,5*	*dB*
DL Coverage radius (d):	***1,8***	***km***
DL Coverage area	***6,4***	***km²***

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User equipment receiver sensitivity variance

List of most sold phones in Denmark (2011 & 12) and their receiver sensitivity:

Phone	GSM900 Tis [dBm]	GSM1800 Tis [dBm]	UMTS B8 TIS [dBm]	UMTS B1 TIS [dBm]
Iphone 4	-95,8	-99,3	-98,4	-99,7
Iphone 4s	-93,3	-94,9	-101,6	-98,6
Iphone 5	-88,8	-87,3	-98,2	-97,5
Samsung SII	-93,2	-99,8	-94,7	-99,9
Samsung SIII	-89,9	-101,0	-95,3	-104,0
HTC Wildfire S	-93,5	-101,0	-94,1	-100,1
Nokia 1800	-96,0	-95,9		
Nokia C2-01	-93,1	-99,9	-95,2	-98,8
Nokia C1-01	-93,9	-95,8		
Difference:	7,2dB	3,7dB	7,5dB	6,5dB

Source: Gert Frølund Pedersen, Aalborg University, Limit values for Downlink Mobile Telephony in Denmark

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Impact of receiver sensitivity on cell range

- UE receiver sensitivity can be theoretically balanced with base station transmit power
- Coverage area is usually defined by network planning via pilot power allocation
- A 6dB receiver sensitivity loss half's the coverage area
- Requires more BTS (in rural areas)
- Gives fewer satisfied customers

Frequency	900	MHz	900	900	MHz
BCCH TX power	36,0	dBm	36,0	36,0	dBm
A (v.1.3.1)	*146,8*		146,8	146,8	
BTS antenna height (h_b)	*40*	m	40	40,0	m
UE antenna height (h_m)	*1,5*	m	1,5	1,5	m
a(h_m)	*0,016*	dB	0,016	0,0	dB
Downlink:					
Combiner loss (L_Bcom)	0	dB	0	0	dB
Feeder loss (L_Bf)	*3*	dB	3	3,0	dB
BTS antenna gain (G_Ba)	*17,5*	dB	17,5	17,5	dB
UE antenna gain (G_Ma)	*0*	dB	0	0	dB
Indoor penetration loss (L_in)	*12*	dB	12	12	dB
Body loss (L_Ph)	*3*	dB	3	3	dB
UE sensitivity (P_Msen)	*-104*	dBm	-96	-88,8	dBm
Shadow fading margin (P_margin)	*6*	dB	6	6	dB
Downlink loss (L_Pd):	*133,5*	*dB*	*125,5*	*118,3*	*dB*
DL Coverage radius (d):	***1,8***	***km***	***1,1***	***0,7***	***km***
DL Coverage area	***6,4***	***km²***	***2,2***	***0,8***	***km²***

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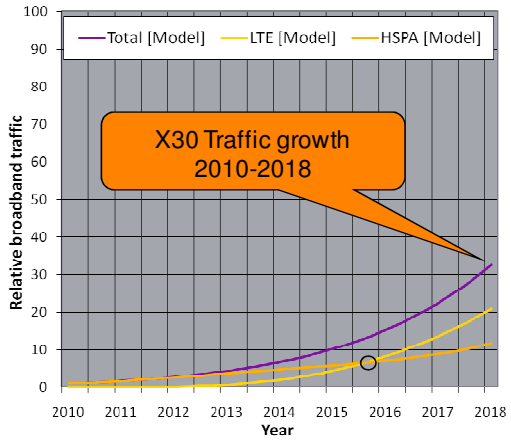
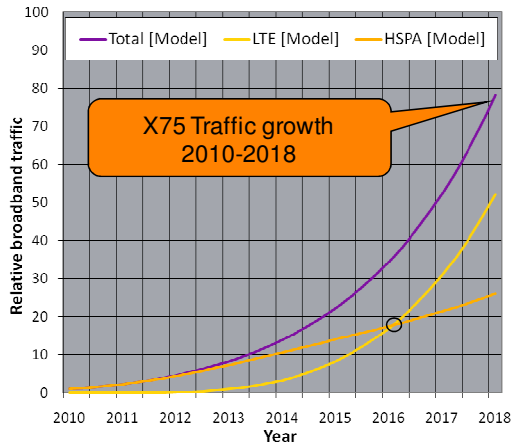
User equipment impact on cellular network
1. Growing traffic

- Two traffic growths scenarios (35x and 75x compared to 2010)
- Minimum data rate requirement: 512 kbit/s for delivery of high quality video

TF 1: moderate traffic growth



TF 2: high traffic growth



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User equipment impact on cellular network
2. Need for network upgrade

- Study on the impact of user equipment with dual receiver antennas in a real network
- Results are comparable to an UE sensitivity improvement of 3dB

NSN - UE Receiver type models used for evolution study

	1x2 RX diversity	1x1 RX no diversity
SINR loss	0 dB	-2 dB
Effective RX antenna gain	0 dBi	-3 dBi

Year when network upgrades are required:	256 kbps minimum data-rate		512 kbps minimum data-rate	
	1x1 RX	1x2 RX	1x1 RX	1x2 RX
Traffic Forecast 1	2014	No Upgrade	2012	No Upgrade
Traffic Forecast 2	2011	2012	2011	2012

Note: Scenarios with mixed UE types have not been evaluated!

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Summary

- User equipment sensitivity plays a significant role in cellular network performance:
  - Network upgrades can be delayed
  - Improved coverage in rural areas
- There is a significant difference in UE receiver sensitivity between different models on the market.
- Radio base station efficiency testing applies calibrated user equipment.
- “Green” labels for user equipment have to take UE radio performance into account

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