Aalto University
School of Science

Energy-Efficiency of Recharging a Mobile Device

Based on

- Ruutu, J., Nurminen, J.K., Rissanen, K., "Energy Efficiency of Recharging a Mobile Device," Fifth International Conference on Next Generation Mobile Applications, Services and Technologies (NGMAST'11) Cardiff, Wales, UK, September 2011
- Heikkinen, M.V.J. and Nurminen, J.K., "Measuring and modeling mobile phone charger energy consumption and environmental impact". Unpublished manuscript

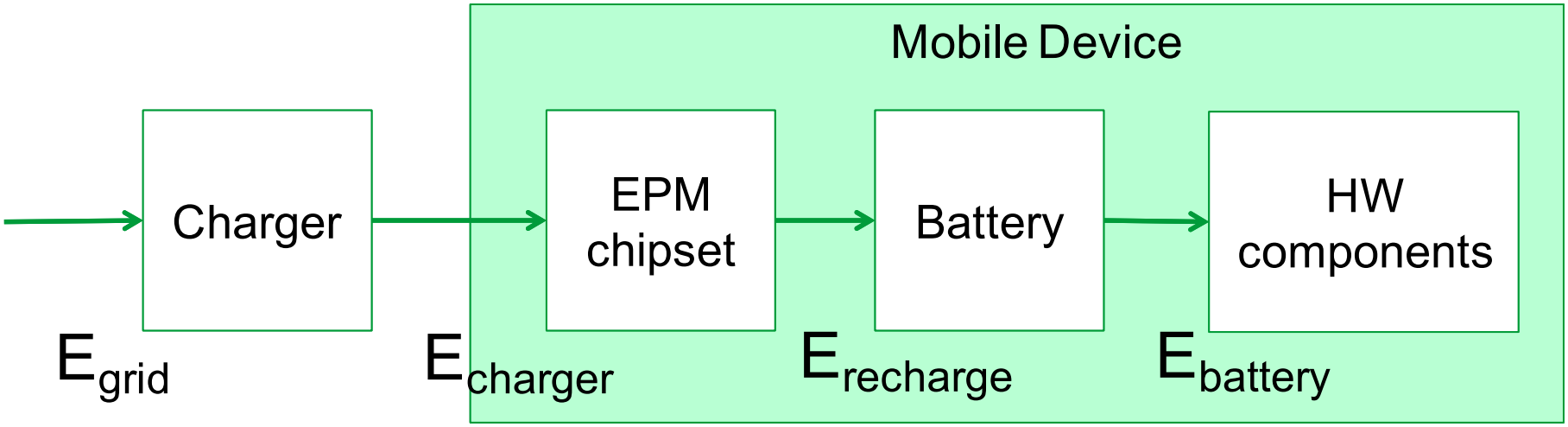
Our target: Understand the Energy-Efficiency of Recharging

- Because of losses in different components only part of the electricity is available for useful work
  - How many Joules of electricity from power grid are needed to perform one Joule of work in the mobile device?

Why this is relevant?

- Electricity cost is not a prime concern of mobile phone users
- As the number of phones is big the aggregate electricity consumption starts to be meaningful
- But in some cases it influences also the individual user
  - Access to electricity is limited: developing countries, hiking, etc.
  - Self-generated energy

Recharging Chain



- What is the efficiency of each component?

$$\alpha_{charger} = \frac{E_{charger}}{E_{grid}} \quad \alpha_{chipset} = \frac{E_{recharge}}{E_{charger}} \quad \alpha_{battery} = \frac{E_{battery}}{E_{recharge}}$$

- and the whole system? $\alpha_{total} = \alpha_{charger}\alpha_{chipset}\alpha_{battery}$

Measured Efficiency Rates

	Efficiency (%)	Energy left (%)
E_{grid}		100
$E_{charger}$	70	70
$E_{recharge}$	72	51
$E_{battery}$	27	14

- Less than 20% of electricity is used for useful work
  - The rest is lost in the conversions as heat
- To produce 1 Joule of useful work about 7 Joules of electricity is needed from power grid
- The efficiency of battery was surprisingly low in our experiments

Recharging electricity consumption and environmental impact

Measurements of charger electricity consumption + Recharging behavior from panel studies = Estimate of recharging electricity consumption

Phone	OS	Recharging (W)	Idle (W)
Apple iPhone 4	iOS	3–4	1–2
Ericsson U20i	Android v2.1	4–5	0–1
Ericsson X10i	Android v2.1	4–5	0–2
Motorola Milestone	Android v2.2	4–5	0–1
Nokia 6020	S40	3–6	0–0
Nokia 6120c	S60 v3.1	1–6	0–0
Nokia 6300	S40	1–6	0–0
Nokia E71	S60 v3.1	1–6	0–0
Samsung Omnia 7	Windows 7	2–5	0–1
ZTE Blade	Android v2.1	4–5	2–3

DURATIONS OF RECHARGING AND IDLE PERIODS PER PANELIST (H/DAY)

	10th percentile	90th percentile	Mean
Panel P07			
Recharging	0.05	2.01	0.67
Idle	0.01	4.92	1.10
Panel P08			
Recharging	0.08	1.67	0.60
Idle	0.02	4.22	1.14

Yearly consumption, cost, and CO2 emission per subscriber

RESULTS FROM THE MODEL: ANNUALLY PER SUBSCRIBER

	Min	Max	Average	Unit
Europe				
Recharging	0.08	3.02	0.92	kWh
Idle	0.00	1.15	0.14	kWh
No-load	0.17	2.59	1.27	kWh
Total	**0.25**	**6.76**	**2.34**	**kWh**
Recharging	0.01	0.50	0.15	EUR
Idle	0.00	0.19	0.02	EUR
No-load	0.03	0.43	0.21	EUR
Total	**0.04**	**1.11**	**0.38**	**EUR**
Recharging	0.05	1.75	0.53	CO_2-e kg
Idle	0.00	0.66	0.08	CO_2-e kg
No-load	0.10	1.50	0.74	CO_2-e kg
Total	**0.15**	**3.91**	**1.35**	**CO_2-e kg**

= 39 h of 60W light bulb

= 8 km of driving a car

Estimates for recharging electricity consumption (1E9 KWH/YEAR)

Mobile phones Japan 2006	0.03
Mobile phones Germany 2000	0.6
Mobile networks Germany 2000	0.7
Mobile phones USA 2004	1.3
Google total energy consumption 2010	2.3
Mobile networks Japan 2006	4.6
Data centers Western Europe 2005	41.3
USA standby power 1998	44.3
Data centers USA 2005	56.0
Total Electricity Net Generation Europe 2008	3,421
Total Electricity Net Generation USA 2009	3,953

Aalto University
School of Science

Thank You!

Questions?