

Energy Modelling Mobile Devices

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Possible High-Level Goals for Thesis Topics

- ▶ Understand how mobile software consumes energy
 - ▶ Mobile operating systems, platforms
 - ▶ Android, Dalvik Virtual Machine, Java
 - ▶ Management of energy consumption
- ▶ Investigate energy saving opportunities, tradeoffs
 - ▶ In networking technologies
 - ▶ Processors, asymmetric
- ▶ Construct and evaluate energy models for hardware devices
 - ▶ Bluetooth, WiFi, 3G, 4G
 - ▶ Machine learning, statistical tools

Measuring Energy Consumption

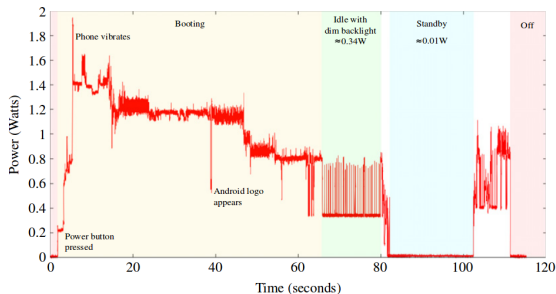


Figure: Power consumption during boot¹.

- ▶ Measurements are complicated
 - ▶ Lack of instrumentation
 - ▶ Cumbersome manual setups
 - ▶ Synchronization

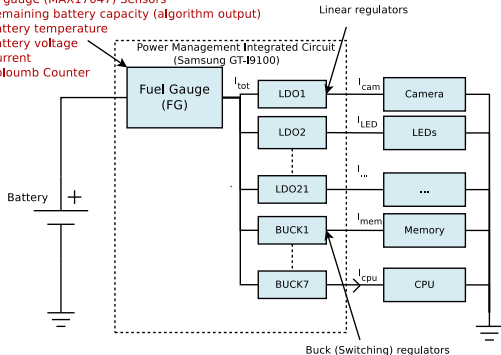
- ▶ Power and energy
 - ▶ $P(t)[Watt] = V(t)[Volt] \cdot I(t)[Ampere]$
 - ▶ $E_{t_1, t_2}[Joule] = \int_{t_1}^{t_2} P(t)dt$

¹Andrew Rice and Simon Hay. "Measuring mobile phone energy consumption for 802.11 wireless networking". In: *Pervasive and Mobile Computing* 6.6 (2010), pp. 593–606.

Measuring Energy Consumption (2)

Fuel gauge (MAX17047) Sensors

- Remaining battery capacity (algorithm output)
- Battery temperature
- Battery voltage
- Current
- Coulomb Counter



On Android:

```
cat /sys/class/power_supply/battery/current_now  
cat /sys/class/power_supply/battery/voltage_now
```

► Several methodologies to measure energy based on available sensors

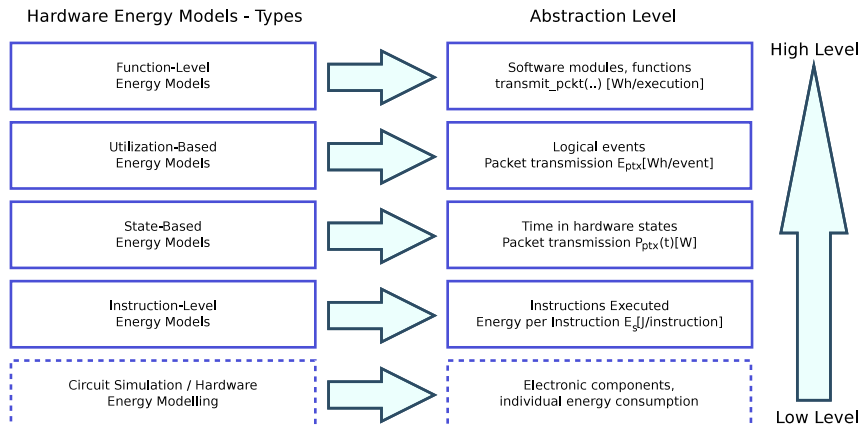
- % Batt. capacity
- Current sensor²
- Voltage sensor³
 - Fluctuations⁴

⁴ Jung et al., "DevScope: a nonintrusive and online power analysis tool for smartphone hardware components"; Dong and Zhong, "Self-constructive high-rate system energy modeling for battery-powered mobile systems".

⁴ Zhang et al., "Accurate online power estimation and automatic battery behavior based power model generation for smartphones".

⁴ Xu et al., "V-edge: fast self-constructive power modeling of smartphones based on [battery voltage dynamics](#)".

Energy Modelling Software Systems



Flinn and Satyanarayanan, "PowerScope: A tool for profiling the energy usage of mobile applications".

Xiao et al., "Modeling and managing energy consumption of mobile devices".

Brandolese et al., "Energy estimation for 32-bit microprocessors".

Example: Platform Level Energy Modelling

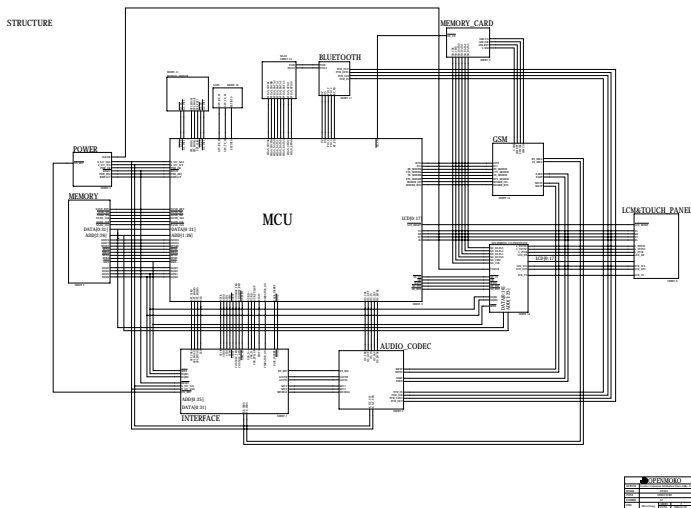


Figure: Schematic over modern smart phone components⁵

⁵<http://wiki.openmoko.org/>

Example: Platform Level Energy Modelling (2)

- ▶ $P_{total} = \beta_0 + \sum_{i=1}^P \beta_i g_i(x_i)$
- ▶ $P_{total}[W]$ proportional to *utilisation*
- ▶ Finding β_i ?
 - ▶ Machine learning
 - ▶ Statistical tools

Component	Predictor	Description
CPU	x_1	CPU_CYCLES
	x_2	DCACHE_MISS
	x_3	TLB_MISS
	x_4	ITLB_MISS
	x_5	CYCLES_DATA_STALL
	x_6	INSN_EXECUTED
	x_7	DTLB_MISS
	x_8	DCACHE_ACCESS
	x_9	DCACHE_MISS
	x_{10}	EXP_EXTERNAL
	x_{11}	DCACHE_ACCESS_ALL
	x_{12}	IFU_IFETCH_MISS
	x_{13}	BR_INST_MISS_PRED
	x_{14}	CYCLES_IFU_MEM_STALL
	x_{15}	LSU_STALL
	x_{16}	PC_CHANGE
	x_{17}	BR_INST_EXECUTED
WNI	x_{18}	Download rate [$\frac{KB}{s}$]
	x_{19}	Upload rate [$\frac{KB}{s}$]
	x_{20}	CAM-PSM switch
Display	x_{21}	Brightness level

Possible Master Topics in Energy Modelling

- ▶ Study state of the art mobile systems
 - ▶ Energy as a computing resource
 - ▶ Management, new OS techniques
 - ▶ Android: WakeLocks, activity destroy?
 - ▶ Applicability of virtual machines in mobile environments
- ▶ Build energy models for state of the art devices
 - ▶ Modern devices, opportunities for energy saving
 - ▶ Ex. big.Little, multicore processors, wireless
 - ▶ Other computing devices, routers, servers
- ▶ More thesis topics
 - ▶ <http://www.mn.uio.no/ifi/studier/masteroppgaver/dmms/>

