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Energy Consumption in mobile devices

IoT Node Architecture

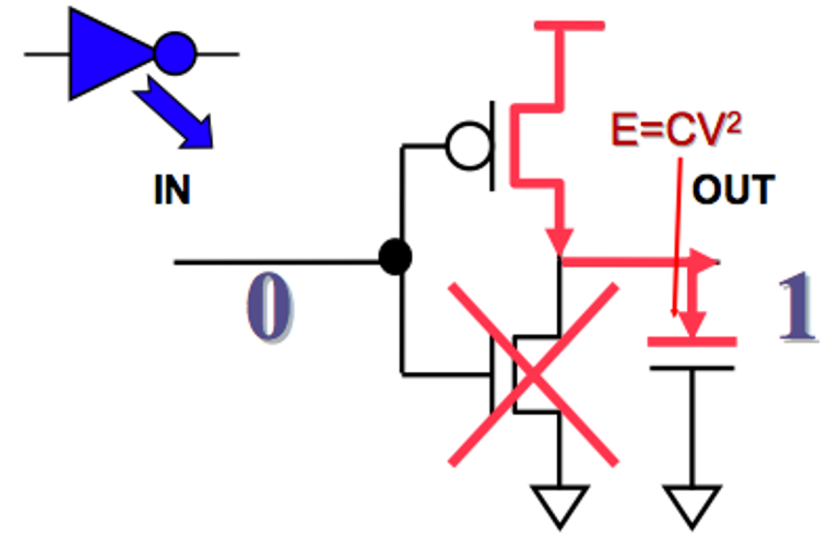
Where is energy spent?

□ CMOS

- Energy = $1/2 C_L * V_{dd}^2$
- Power = $1/2 C_L * V_{dd}^2 * \text{freq} \sim 1/2 C_L * V_{dd}^3$
- $C_L \rightarrow$ wire capacity, gates...

□ Switching signals

- Registers, wires
- Memories



- Aaron Carroll y Gernot Heiser. *An Analysis of Power Consumption in a Smartphone*. 2010

Device Under Test (DuT)

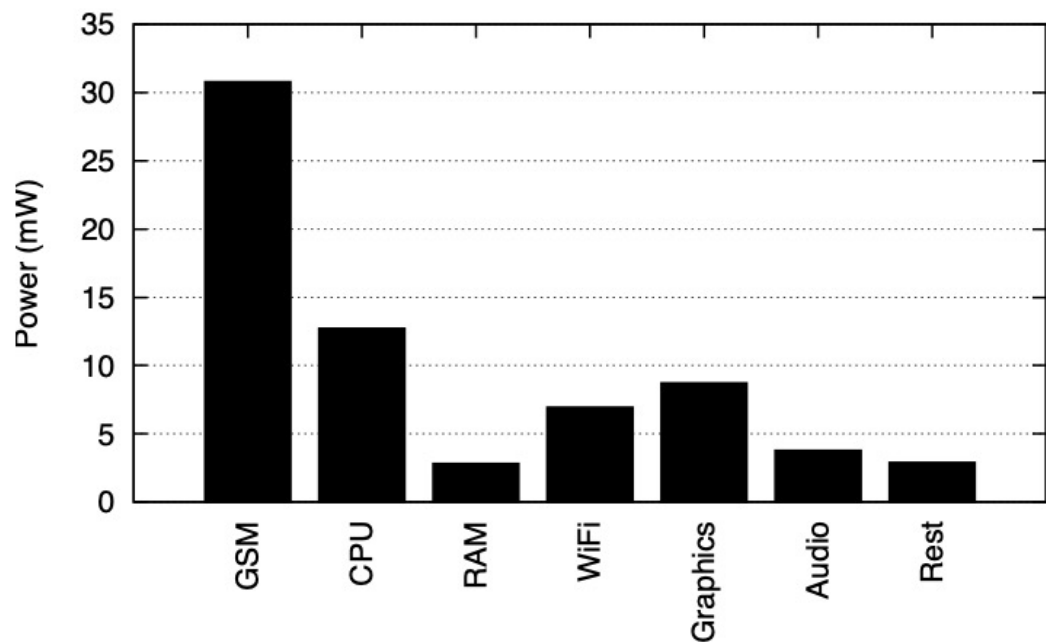
Component	Specification
SoC	Samsung S3C2442
CPU	ARM920T @ 400 MHz
RAM	128 MiB SDRAM
Flash	256 MiB NAND
Cellular radio	TI Calypso GSM+GPRS
GPS	u-blox ANTARIS 4
Graphics	Smedia Glamo 3362
LCD	Topploy 480 × 640
SD Card	SanDisk 2 GB
Bluetooth	Delta DFBM-CS320
WiFi	Accton 3236AQ
Audio codec	Wolfson WM8753
Audio amplifier	National Semiconductor LM4853
Power controller	NXP PCF50633
Battery	1200 mAh, 3.7 V Li-Ion

Data Acquisition (DAQ) NAT INSTPCI-6229

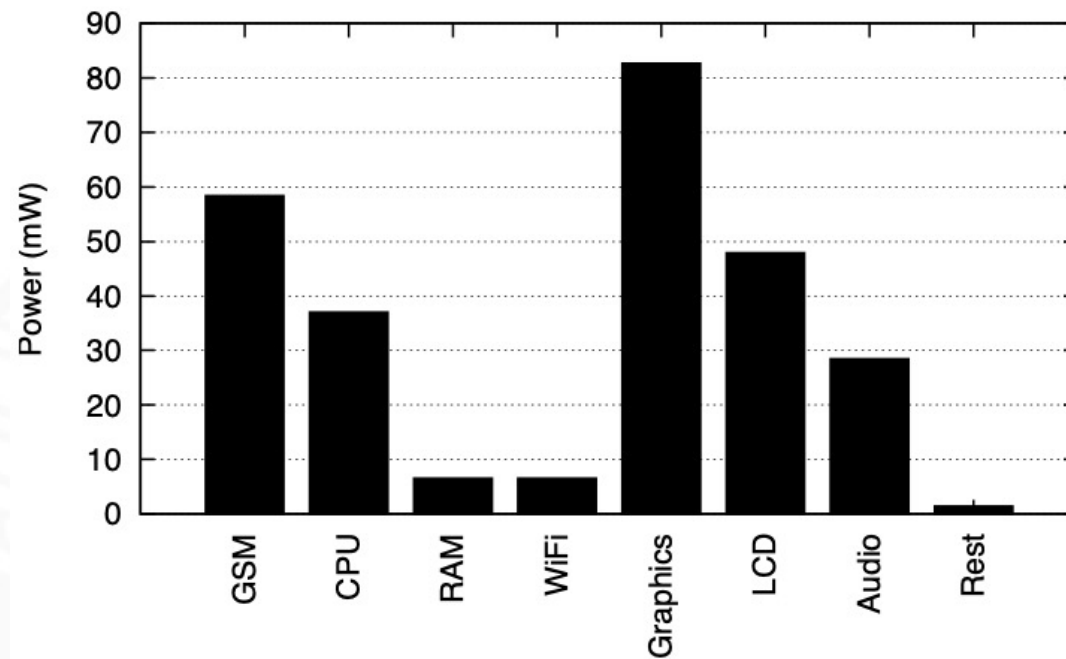
Characteristic	Value
Max. sample rate	250 kS/s
Input ranges	±0.2 V, ±1 V, ±5 V and ±10 V
Resolution	16 b
Accuracy	112 μV @ ±0.2 V range 1.62 mV @ ±5 V range
Sensitivity	5.2 μV @ ±0.2 V range 48.8 μV @ ±5 V range
Input impedance	10 GΩ

Sense resistors included in the *power rail* of target components

Mobile energy breakdown (2010)

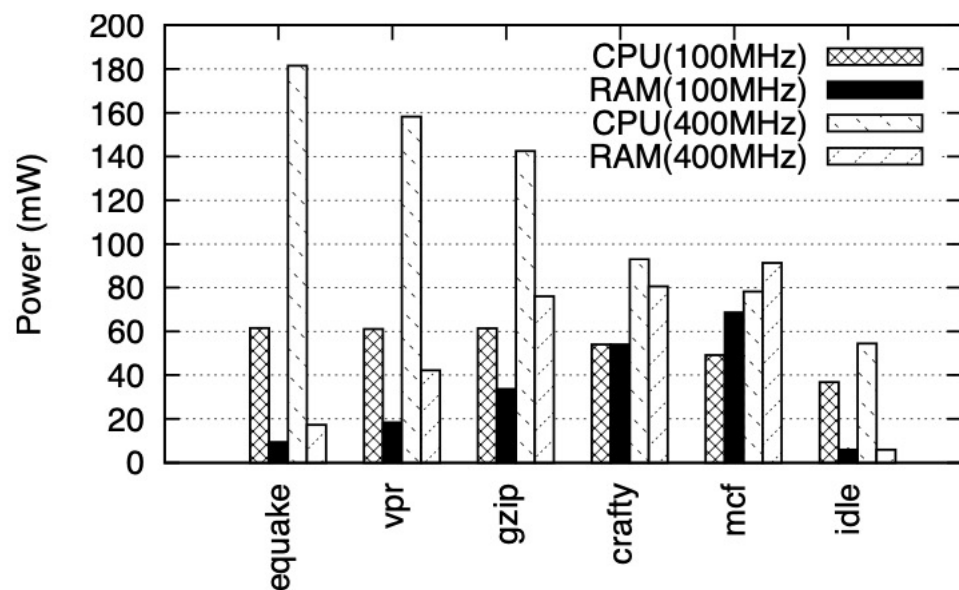


Suspended State. CPU and memory in low power state. Radio active to receive calls. Average: 68mW



Idle State. CPU y and memory actives but no application running. *Backlight* off. Average: 268 mW

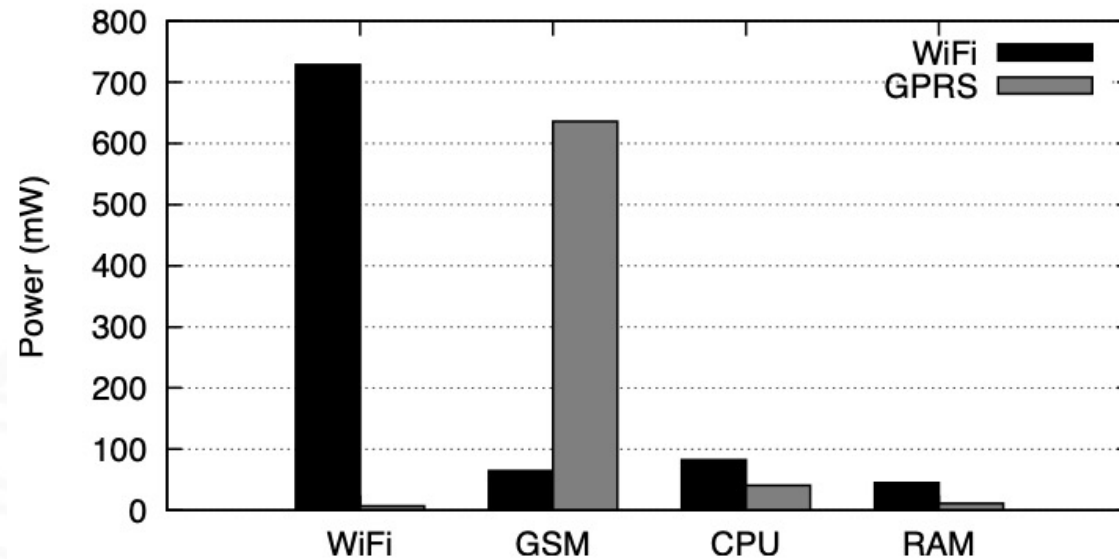
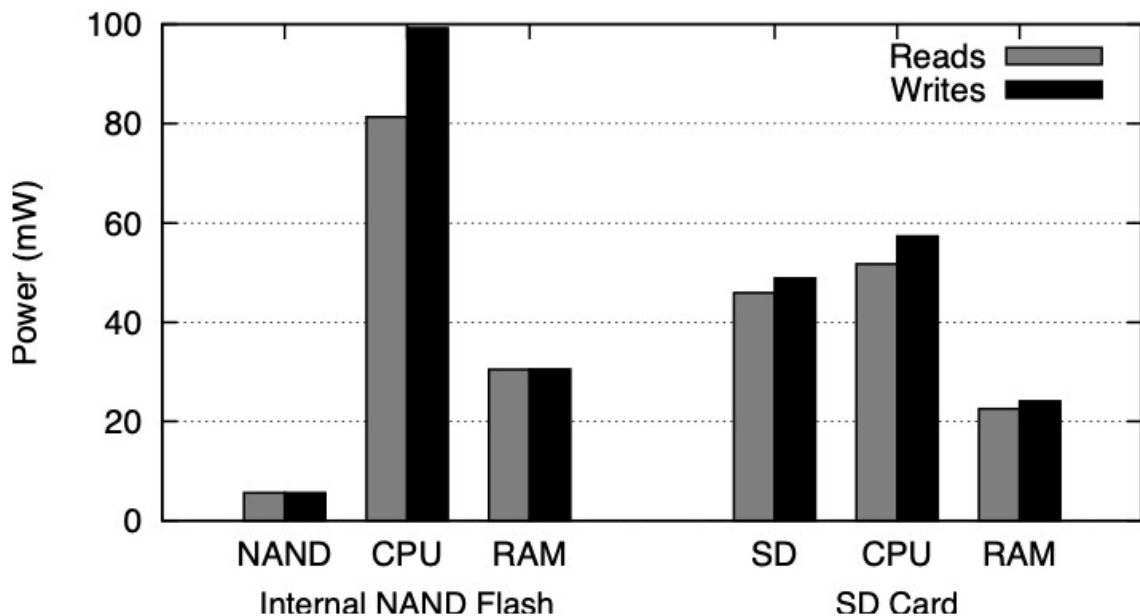
Power vs. Energy



Power consumption @100MHz and @400MHz

Benchmark	Performance	Power	Energy
equake	26 %	36 %	135 %
vpr	31 %	40 %	125 %
gzip	38 %	43 %	112 %
crafty	63 %	62 %	100 %
mcf	74 %	69 %	93 %
idle	-	71 %	-

Performance, energy and power of 100MHz compare to 400MHz frequencies



Consumo de WiFi - GPRS

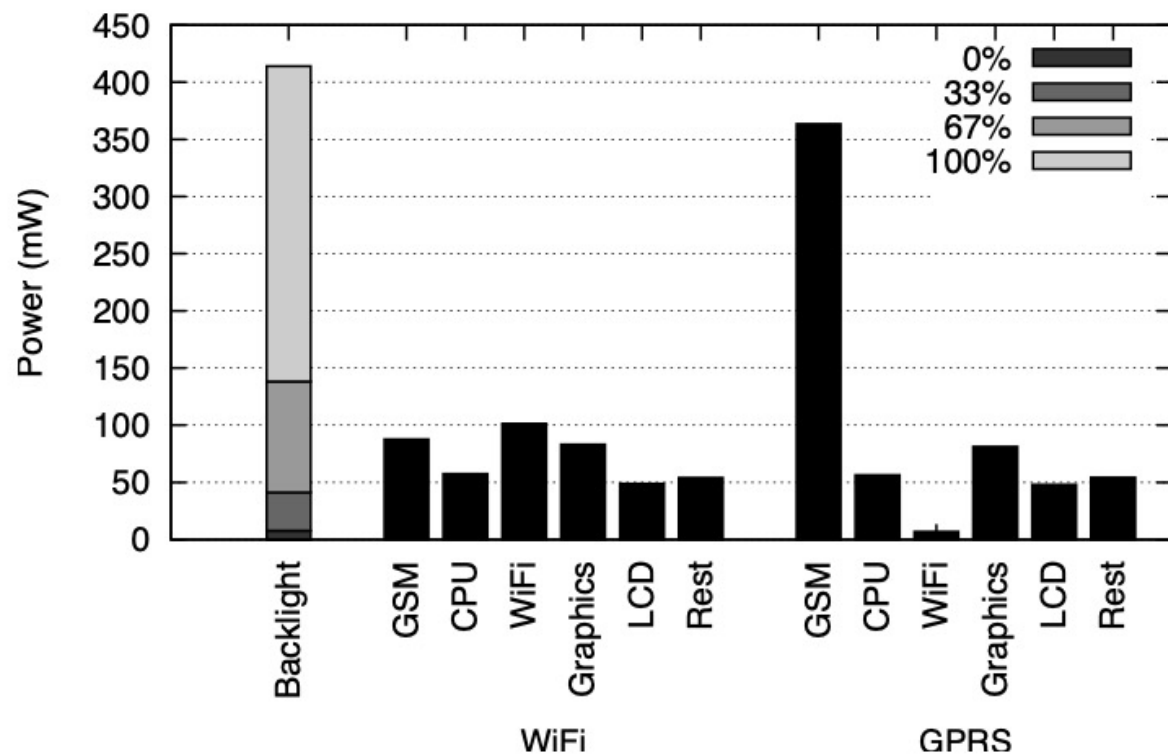
Metric	NAND	SD
Idle (mW)	0.4	1.4
Read		
throughput (MiB/s)	4.85	2.36
efficiency (MiB/J)	65.0	31.0
Write		
throughput (KiB/s)	927.1	298.1
efficiency (MiB/J)	10.0	5.2

Internal NAND
Flash vs SD card

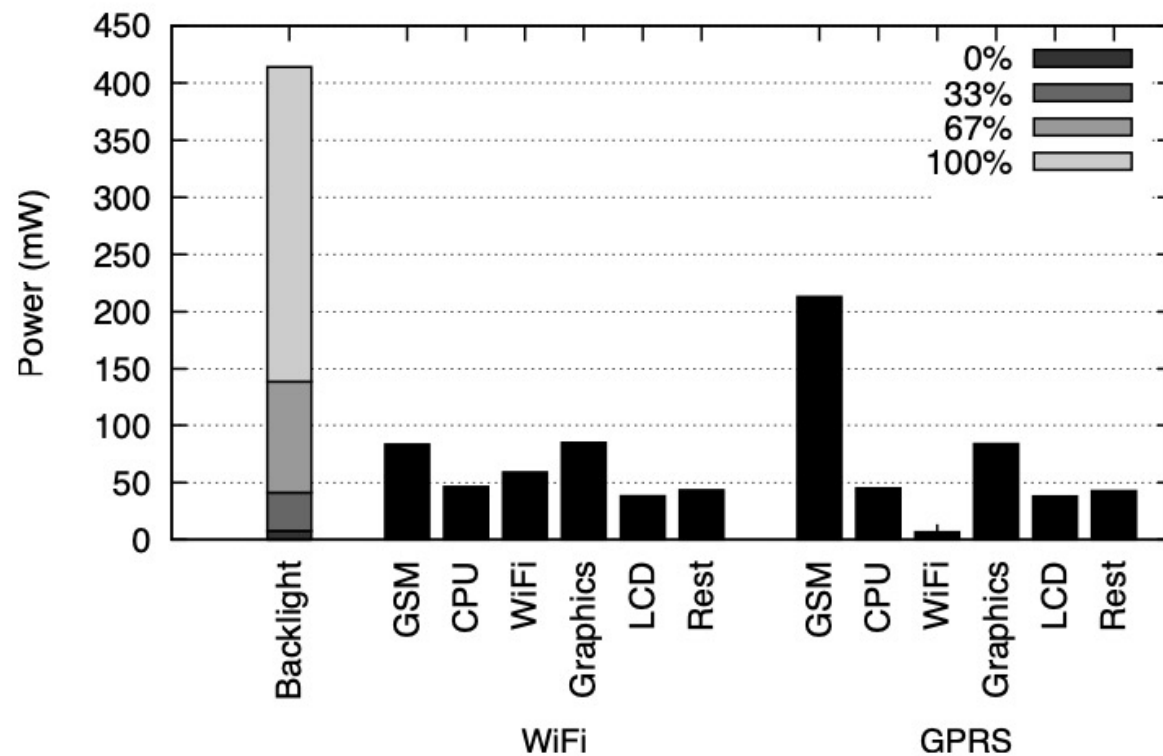
State	Power (mW)
Enabled (internal antenna)	143.1 ± 0.05 %
Enabled (external antenna)	166.1 ± 0.04 %
Disabled	0.0

GPS

Global energy consumption

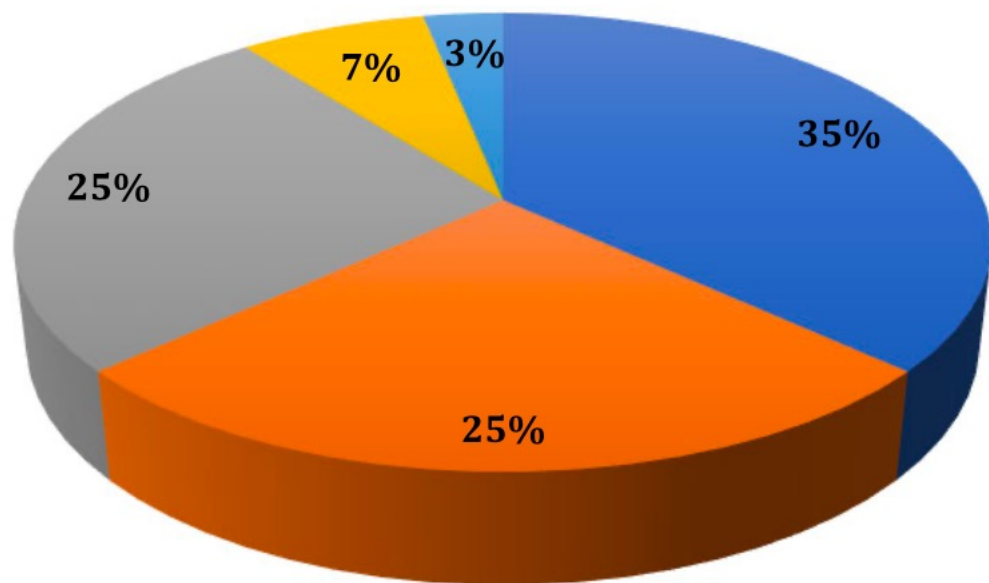


Sending an email
610 mW with GPRS – 432 mW with WiFi
(excluding *backlight*)

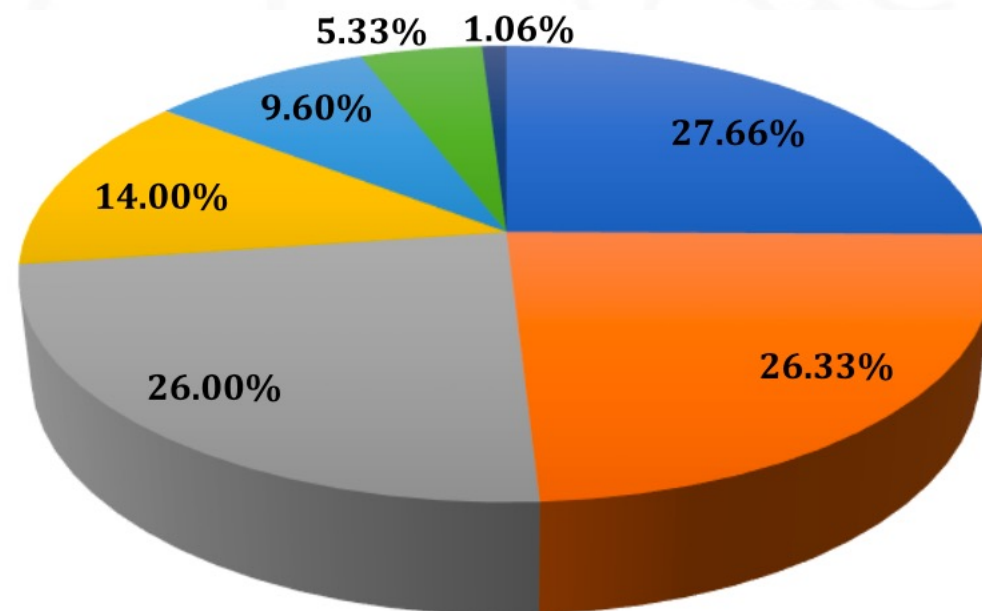


Web browsing.
429 mW with GPRS – 352 mW with WiFi
(excluding *backlight*)

❑ Power Consumption Analysis, Measurement, Management, and Issues: A State-of-the-Art Review of Smartphone Battery and Energy Usage. 2019



■ CPU
■ Wi-Fi
■ Backlight
■ Mobile network
■ Bluetooth



■ CPU
■ OLED
■ Wi-Fi
■ GPS
■ Video
■ Normal mode
■ Airplane mode

- ❑ Beware of backlight....
- ❑ Radio (especially sending data), is the most energy consuming element
 - Huge differences between technologies
 - More on that from January !
- ❑ Try to send as little data as possible
 - Better to compute a bit more if we can save swicthing on the radio