Consommation d’énergie liée au transfert, stockage et visionnage d’une vidéo de 60s

STOCKAGE

Video file size

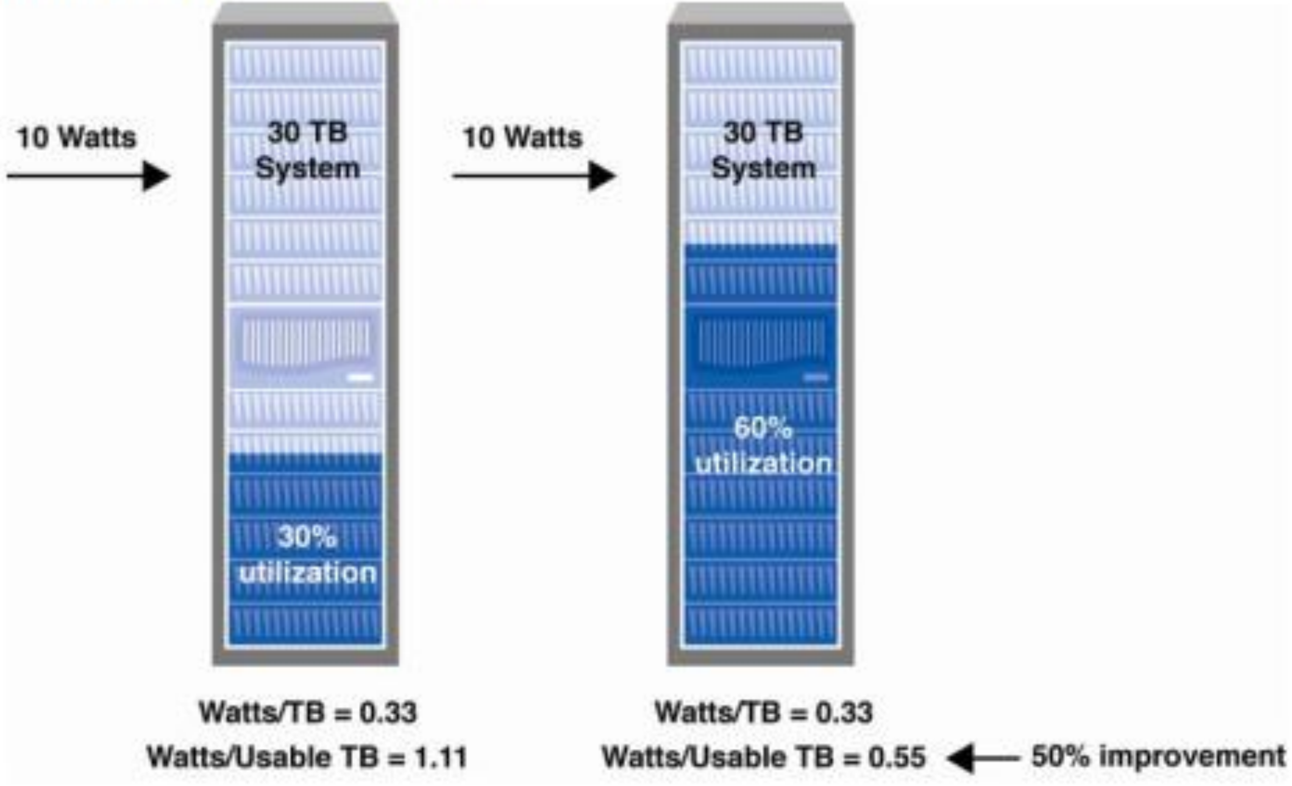
for 60 seconds @ 24 fps

Hulu HD (1080p25 = 1.4 Mbps)	10.4 MB
Netflix 4K (2160p25 = 15.6 Mbps)	28.1 MB
Netflix HD (1080p25 = 5.8 Mbps)	41.8 MB
Youtube HD (1080p25 = 8 Mbps)	57.6 MB
Youtube 4K (2160p25 = 45 Mbps)	81 MB
BluRay H.264 (1080p25 = 56 Mbps)	403 MB
Digital Cinema JPEG2000 NORM (2Kp24 = 75 Mbps)	527 MB
MPEG2 High (1080p25 = 80 Mbps)	576 MB
DCI JPEG2000 MAX (2Kp48 = 250 Mbps)	879 MB
Apple Prores422 (1080p25 = 220 Mbps)	1.58 GB
Monochrome 8-bit (uncompressed BMP/TIFF)	2.99 GB
RGB 3x8 bit (uncompressed BMP/TIFF)	8.96 GB
RGB 3x10 bit (uncompressed TIFF/DPX/TGA)	11.2 GB
RGB 3x12 bit (uncompressed TIFF/DPX/TGA)	13.4 GB
RGB 3x16 bit (uncompressed TIFF/DPX/TGA)	17.9 GB

$$\frac{\text{Watts to power system}}{\text{Total system TB} \times \text{\% System Utilization}} = \text{Watts per Usable TB}$$

To calculate the power efficiency of a particular storage system, divide the total watts per system by the total number of TBs in that system times the system utilization. System utilization is equal to that percent of your disks actually available for use. The figure below shows how this calculation reveals important differences between seemingly similar systems.

NetApp Storage Power Savings



Hypothèse : nouveau modèle (Etude de 2007)

→ 0,55 W/ TB

On a donc :

-video FullHD : 57,6 MB

-video 4K : 81 MB

<u>FullHD</u> : 0,55 W/TB * 57,6 MB

= 0,00003168 W

<u>4K</u> : 0,55 W/TB * 81 MB

= 0,00004455 W

UPLOAD

Fixed Broadband Speedtest Data
Q3-Q4 2017 United Kingdom

5,186,516 Unique Users	14,916,625 Samples
25,380,032 Tests	710,640,896 Data Points

SPEEDTEST by OOKLA

Fixed Broadband Speeds
Q3-Q4 2017

	Download Mbps	Upload Mbps
United Kingdom	50.16	9.96
England	50.41	10.14
Northern Ireland	27.01	6.95
Scotland	70.29	9.09
Wales	34.75	8.05

SPEEDTEST by OOKLA

Mobile Speedtest Data
Q3-Q4 2017 United Kingdom

850,876 Unique Users	1,807,703 Samples
2,619,384 Tests	110,014,128 Data Points

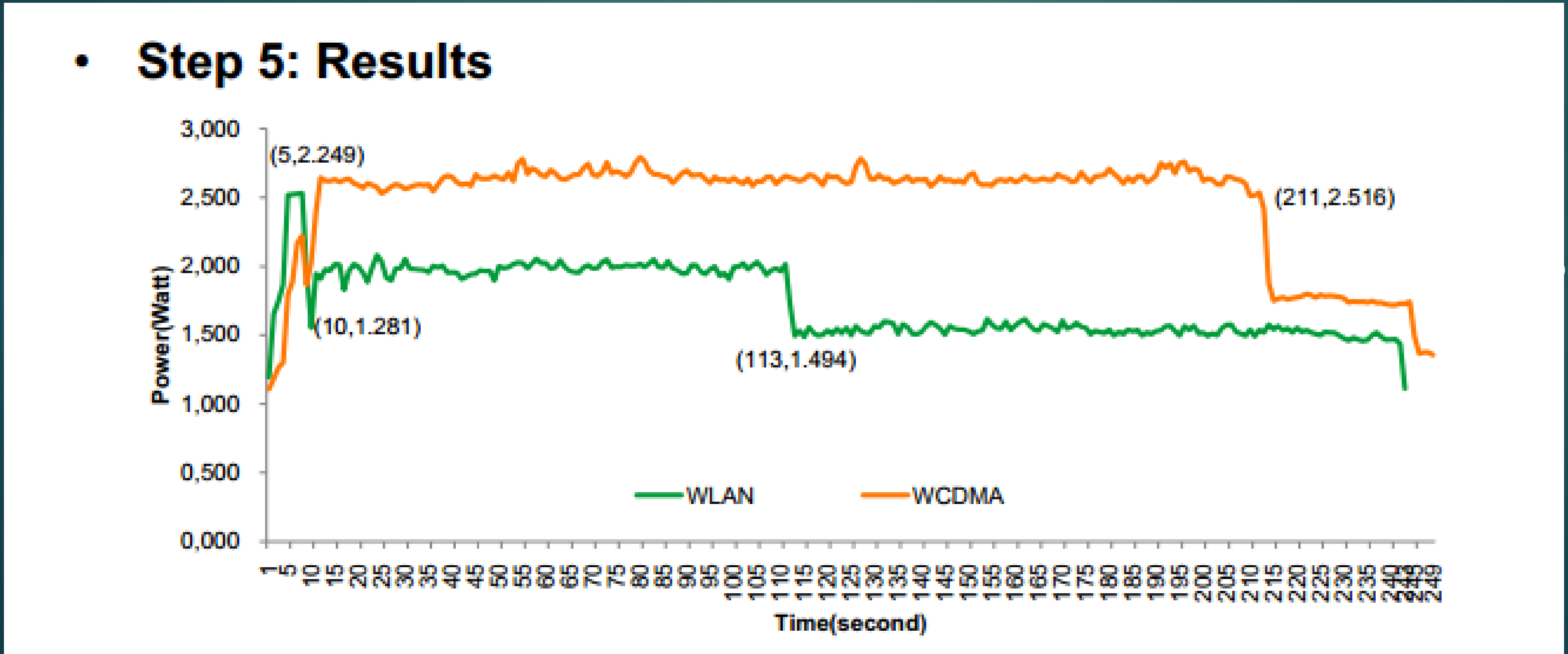
SPEEDTEST by OOKLA

Mobile Speeds
Q3-Q4 2017

	Download Mbps	Upload Mbps
United Kingdom	26.36	11.05
England	26.87	11.21
Northern Ireland	25.01	10.89
Scotland	25.12	11.08
Wales	25.46	10.15

SPEEDTEST by OOKLA

Hypothèse : Consommation téléphone équivalente en upload/download
→ 1,5 W



- Upload par GSM ou ordi quasi même vitesse → 10 Mbps
- Consommation ordinateur : 40 W
- Consommation GSM : 1,5 W

- Temps upload :
  - FullHD: 57,6 MB * 8 Mb/MB * / 10 Mbps = 46,08 s
  - 4K: 81 MB * 8 Mb/MB * / 10 Mbps = 64,8 s
- Consommation upload
  - Ordinateur : 40 W * 46,08s = 1843,2 J | 40 W * 64,8s = 2592 J
  - GSM : 1,5 W * 46,08s = 69,12 J | 1,5 W * 64,8s = 97,2 J

Consommation upload (J)		
	Ordi	GSM
FullHD	1843.2	69.12
4K	2592	97.2

Visionnage : 1000 personnes

- Ordinateur : 40W * 60s * 1000 = 2 400 000 J
- GSM : 1,5W * 60s *1000 = 90 000 J
- Mixte (50/50) = …

Consommation visionnage (J)		
Ordi	GSM	Mixte
2400000	90000	1245000

- https://toolstud.io/video/filesize.php
- Reducing Data Center Power Consumption Through Efficient Storage by Brett Battles, Cathy Belleville, Susan Grabau, Judith Maurier, February 2007 | WP-7010-0207 [PDF]
- http://www.speedtest.net/reports/united-kingdom/#fixed
- Power consumption of smartphones, Yu Xiao from Aalto University School of Science, April 2016

Aalto University
School of Science

Power Consumption of Smartphones

CSE-E5440 Spring 2016

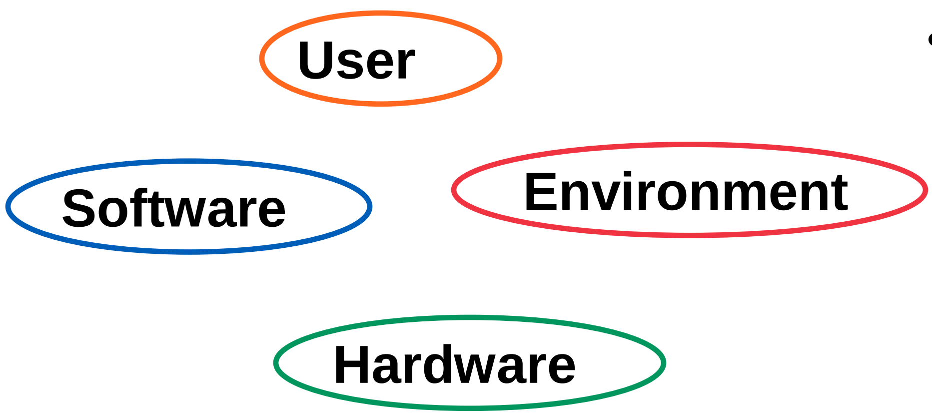
Yu Xiao
Yu.xiao@aalto.fi
19.4.2016

Agenda

- **Overview of energy causes**
- **Smartphone hardware architecture**
- **Energy-efficiency analysis**

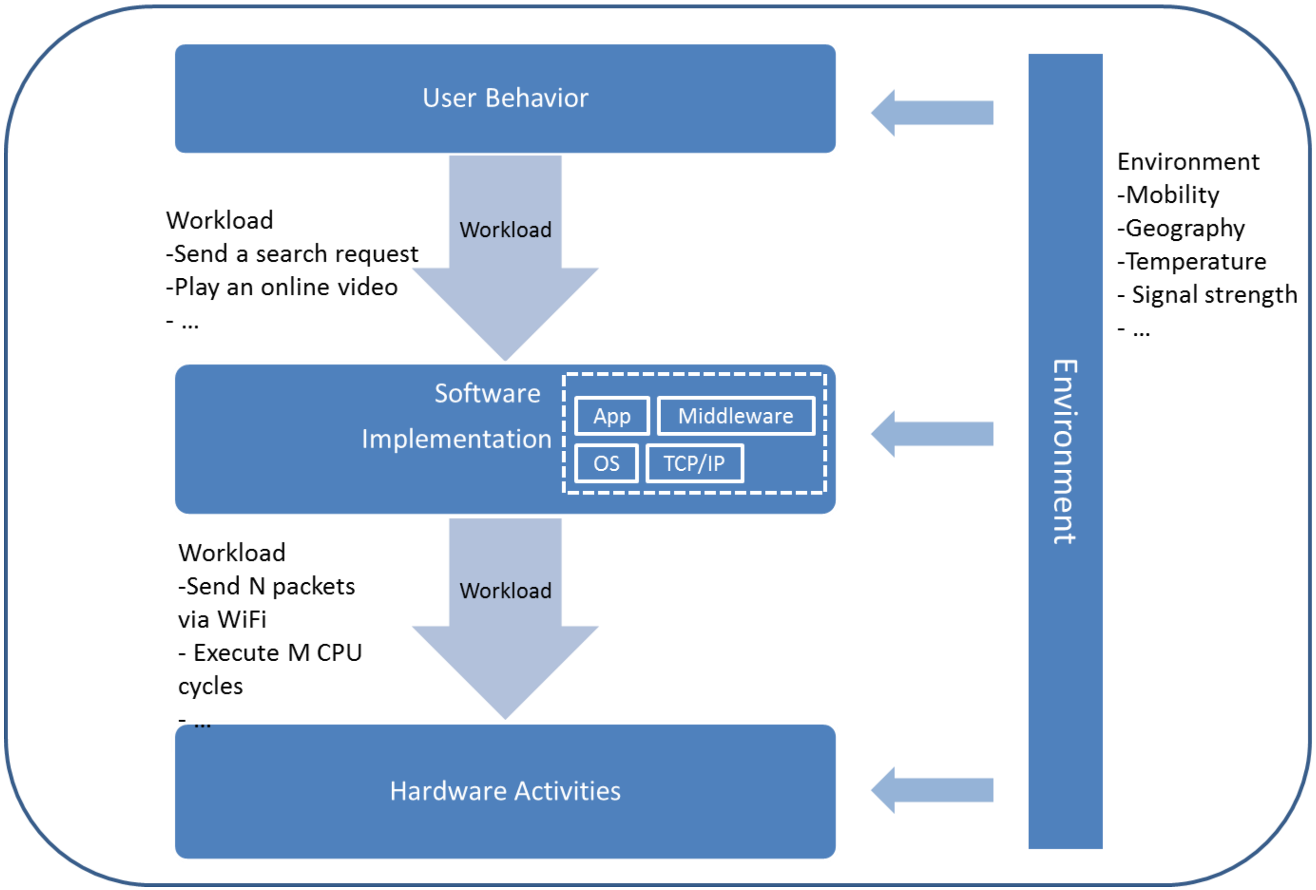
Group Discussion (10 min)

- From energy perspective, what is the relationship between the following items?



- What are the real energy consumers?
- What are the impacting factors of energy consumption?

Overview of Energy Causes

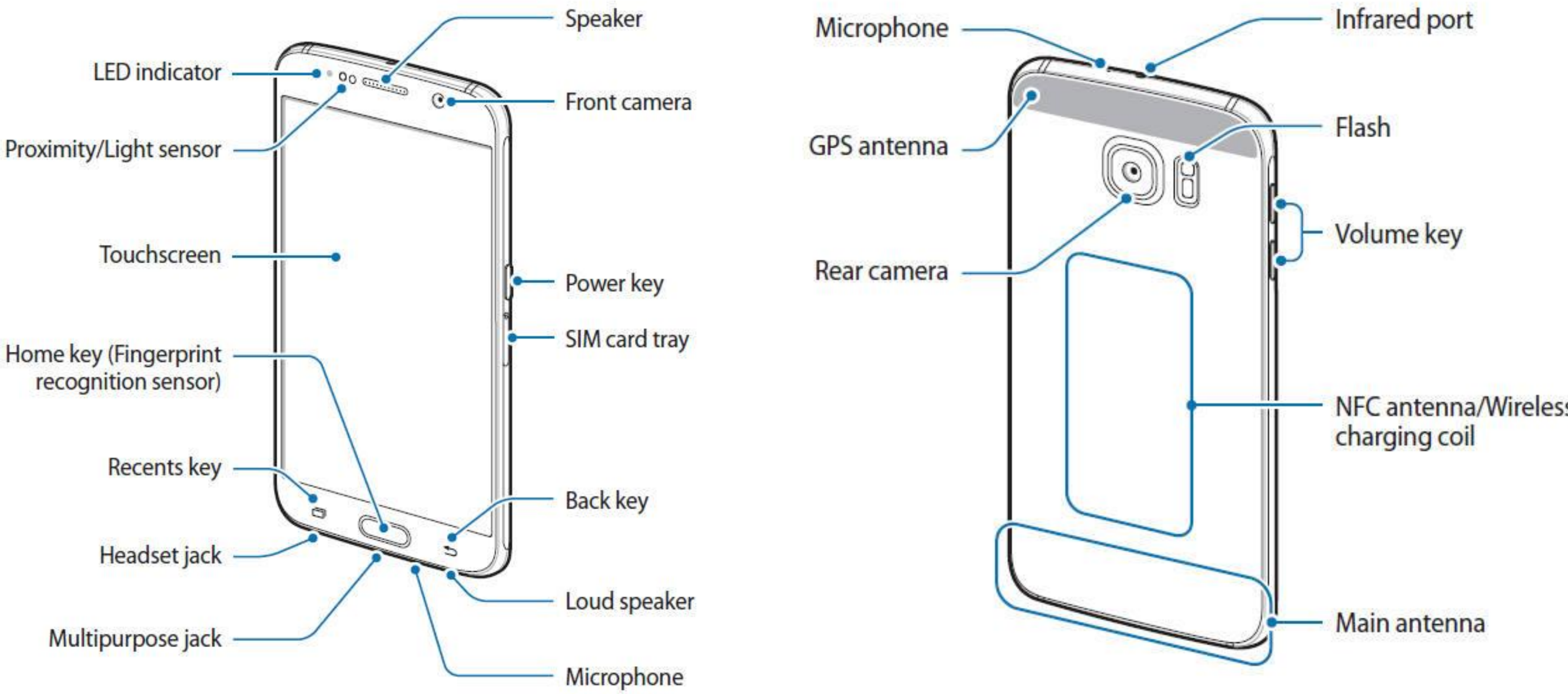


- **Hardware components are the real energy consumers**
- **Software including the OS and applications generate the workload of computing, I/O access, encoding/decoding, and other hardware operations.**
- **The work is transformed into a set of circuit activities on the corresponding hardware components, and the circuit activities consume energy.**

- **In this course, we focus on software solutions, not low-power hardware design**

- **How is software execution related to energy consumption of the underlying hardware?**

Galaxy S6 Layout



A Teardown of Galaxy S6

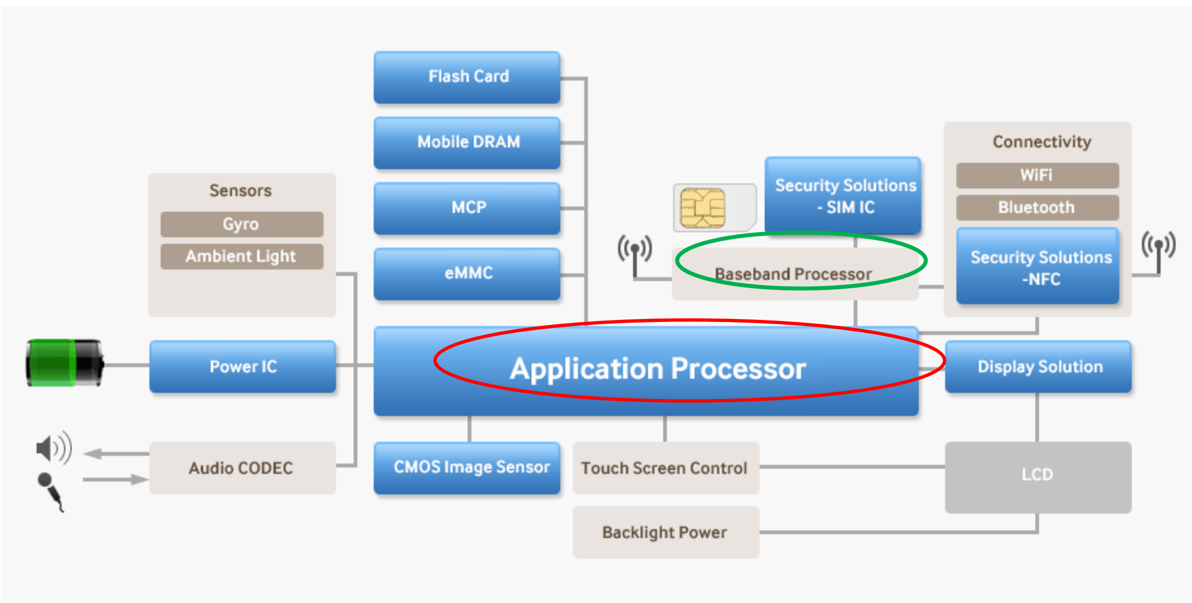
Main Printed
Circuit Board (PCB)

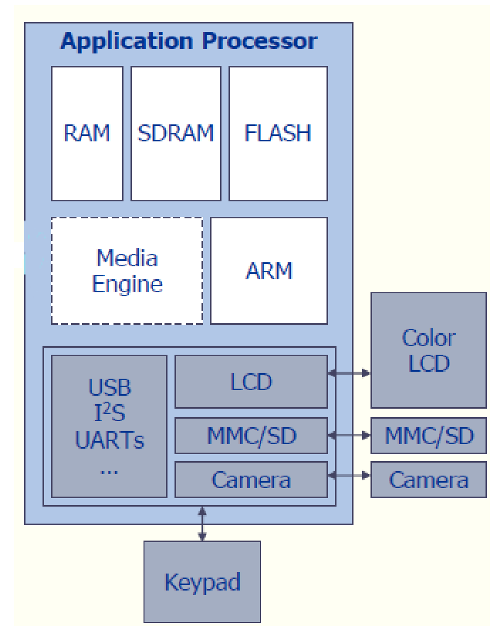
I/O Connector

Smartphone Hardware Architecture

A System-on-Chip (SoC) architecture with 3 primary components

- An **application processor** which executes users' application and related OS services
- A **baseband processor** which controls radio activities
- A number of **peripheral devices** for interacting with end users



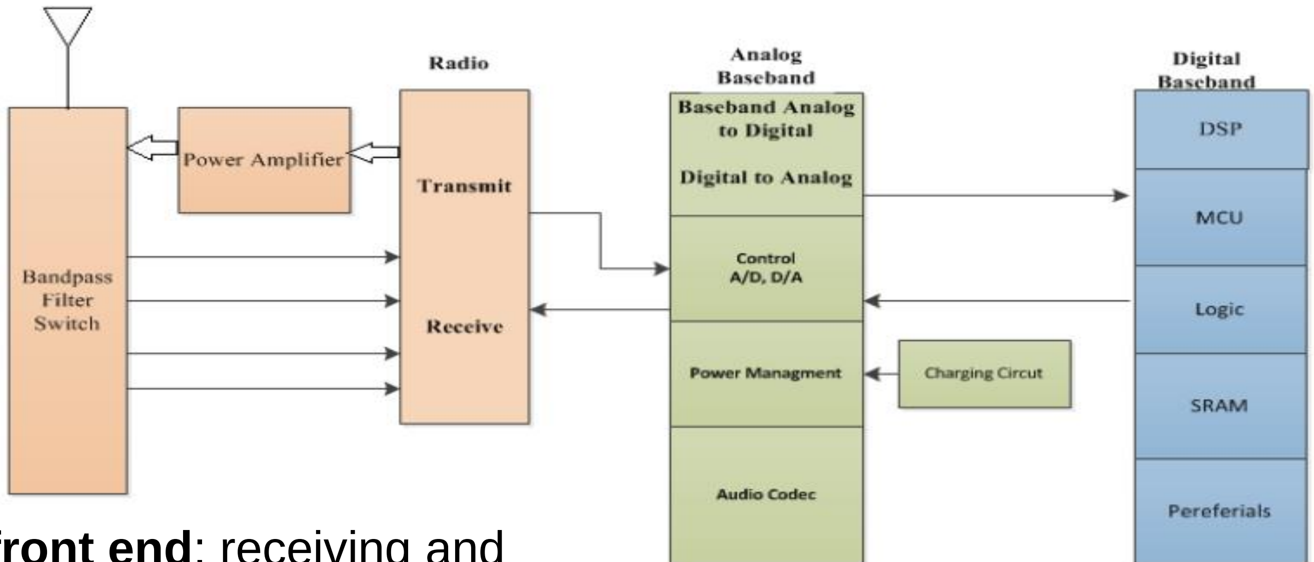


Application Processor

- Processor core (e.g. ARM based processor)
- Multimedia engine which is hardware implementation of one or more multimedia standards (e.g. JPEG module, MPEG module, audio module)
- Device interfaces which are used to communicate with peripheral device (e.g. USB, camera, display)

Baseband Processor

- It has a communication protocol stack which enables different types of wireless technologies, such as LTE, WCDMA, Wi-Fi, and Bluetooth.
- It provides radio communication related functions: signal modulation, RF shifting, encoding/decoding, and etc.



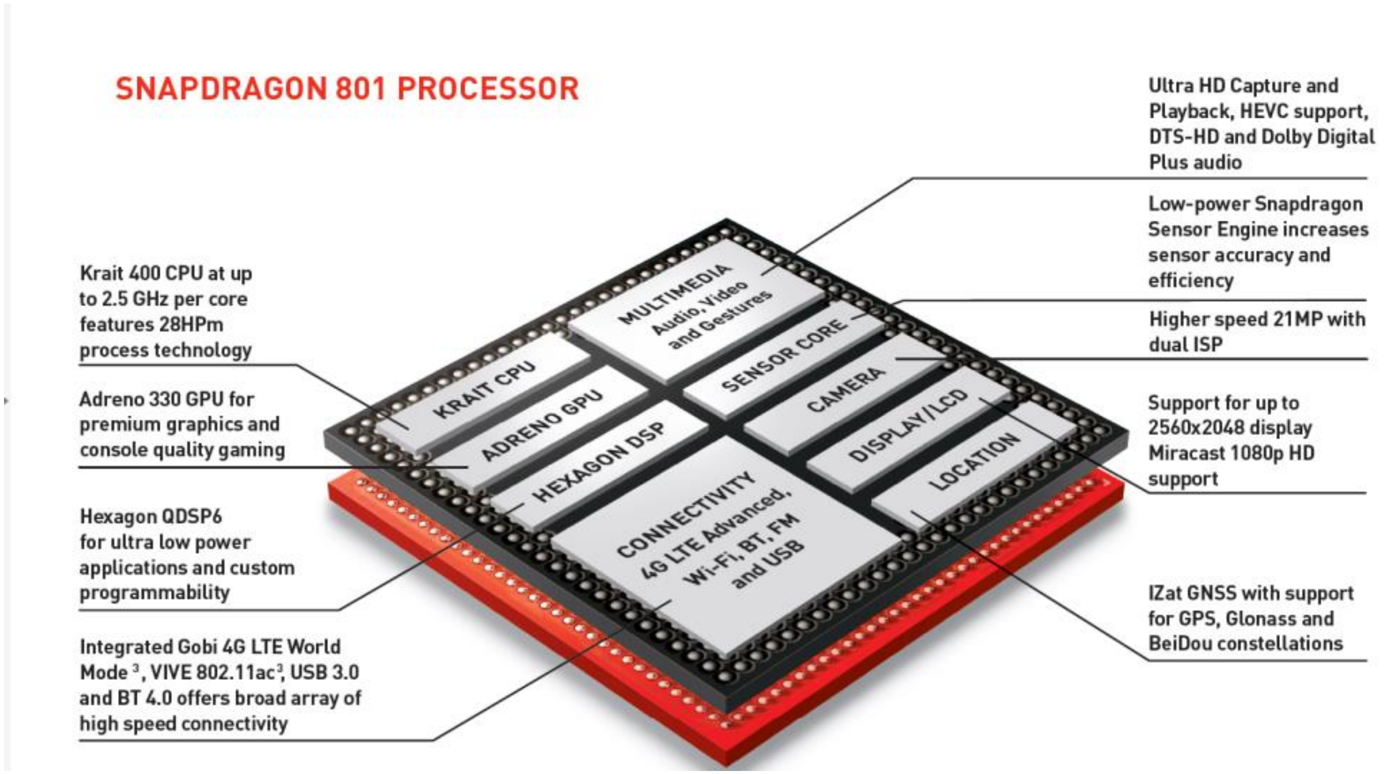
RF front end: receiving and transmitting on different frequencies

- In many ways, the SoC defines what a smartphone can and can’t do, plus it determines the device’s performance and battery efficiency.

- At the moment there are four major smartphone SoC makers
  – Qualcomm, with its Snapdragon range
  – Samsung with its Exynos chips
  – MediaTek with its MT and Helio processors
  – Huawei’s Kirin chips made by its subsidiary HiSilicon.

Examples

	Exynos 7420 (Galaxy S6)	Snapdragon 801
Architecture	ARMv8-A (32 & 64 bit)	ARMv7-A (32 bit)
CPU cores	4x ARM Cortex-A57 + 4x Cortex-A53 (big.LITTLE with GTS)	4x Krait 400
CPU clock	A57 - 2.1GHz A53 - 1.5GHz	Up to 2.45GHz
GPU	ARM Mali-T760 MP8	Adreno 330
GPU clock	772 MHz	578 GHz
RAM support	1552MHz LPDDR4	LPDDR3 933MHz 32-bit
Process	14nm FinFET	28nm


SNAPDRAGON 801 PROCESSOR
Krait 400 CPU at up to 2.5 GHz per core features 28HPm process technology
Adreno 330 GPU for premium graphics and console quality gaming
Hexagon QDSP6 for ultra low power applications and custom programmability
Integrated Gobi 4G LTE World Mode ³, VIVE 802.11ac³, USB 3.0 and BT 4.0 offers broad array of high speed connectivity
KRAIT CPU
ADRENO GPU
HEXAGON DSP
MULTIMEDIA Audio, Video and Gestures
SENSOR CORE
CAMERA
DISPLAY/LCD
LOCATION
CONNECTIVITY 4G LTE Advanced, Wi-Fi, BT, FM and USB
Ultra HD Capture and Playback, HEVC support, DTS-HD and Dolby Digital Plus audio
Low-power Snapdragon Sensor Engine increases sensor accuracy and efficiency
Higher speed 21MP with dual ISP
Support for up to 2560x2048 display Miracast 1080p HD support
IZat GNSS with support for GPS, Glonass and BeiDou constellations

Recommended Reading List

Up close and personal: how the Samsung Galaxy S6 uses its octa-core processor

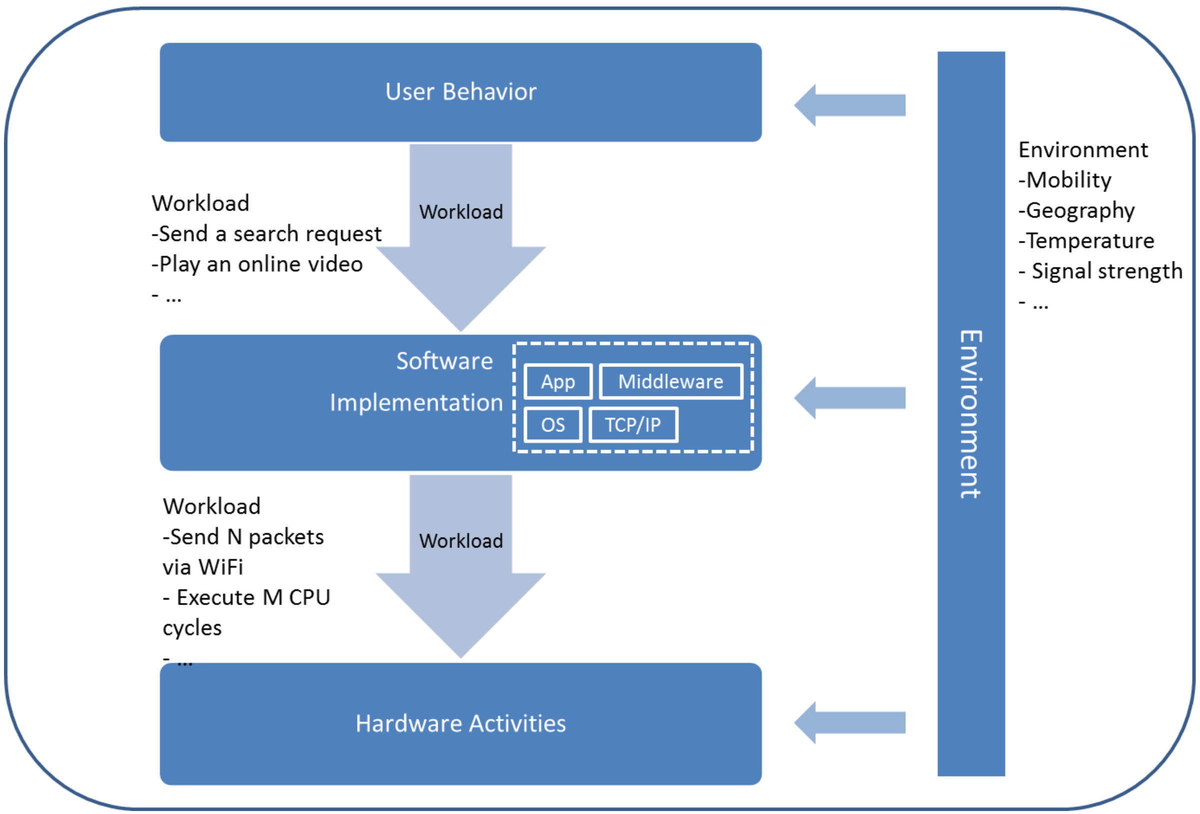
http://www.androidauthority.com/galaxy-s6-octa-core-processor-usage-617585/

What is your smartphone?

- **Which processors does it use?**
- **Does it have a dedicated GPU?**
- **How much storage does it have?**
- **What peripheral devices does it have?**

How to analyze energy efficiency of mobile software?

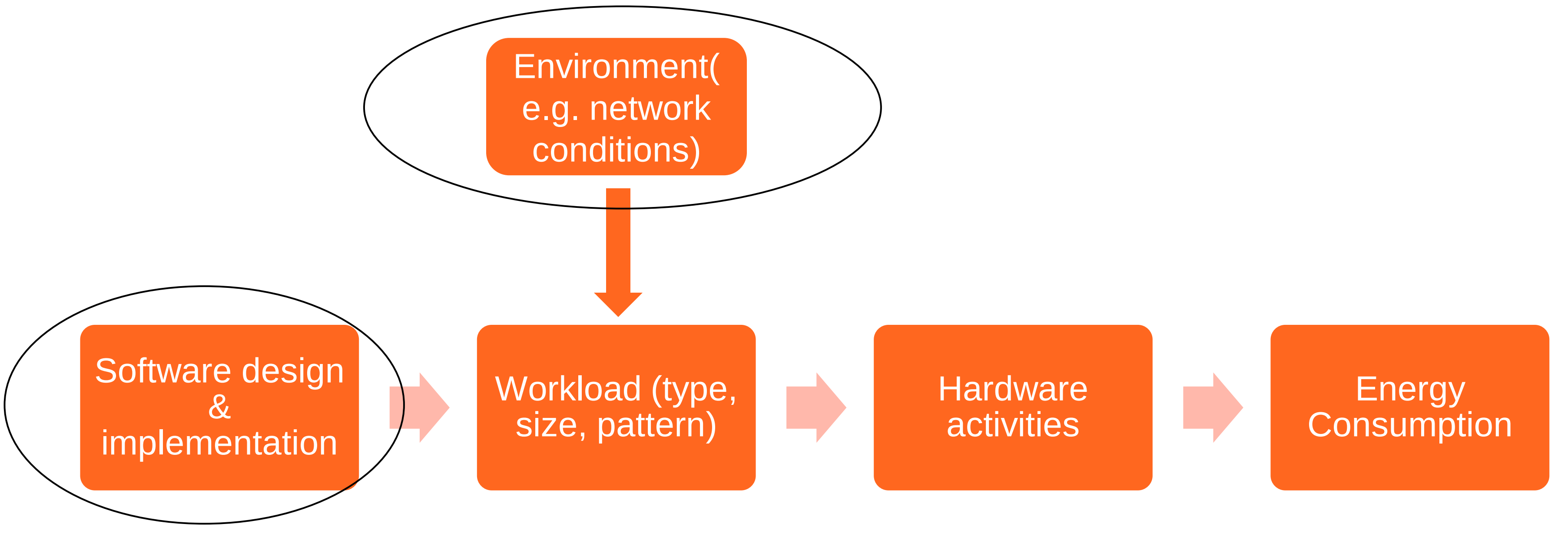
Overview of Energy Causes



Given an app, we would like to know

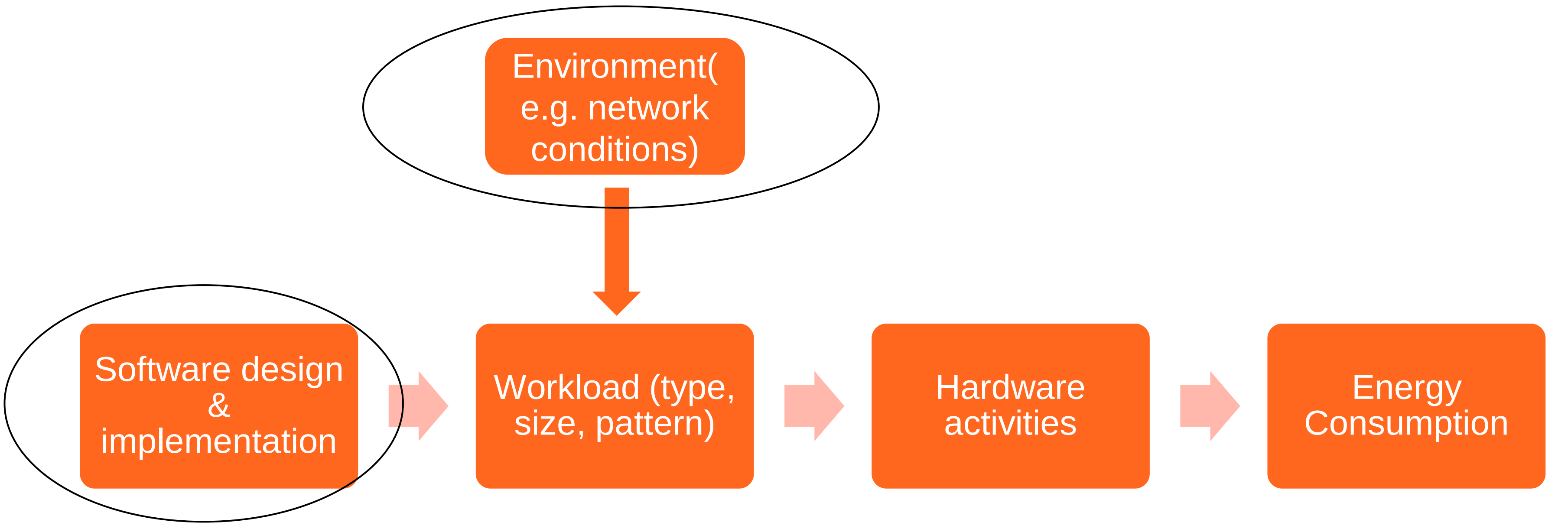
- How much energy is being consumed by the phone while running the application?
- Which operations are power hungry? Why are they power hungry? Is it due to heavy CPU processing, wireless networking, always-on display, intensive sensing, or other factors?
- Does the energy consumption vary with the operating status of the phone, the networking environment, the order of the user operations, and the location?

How to analyze energy-efficiency



Power measurement

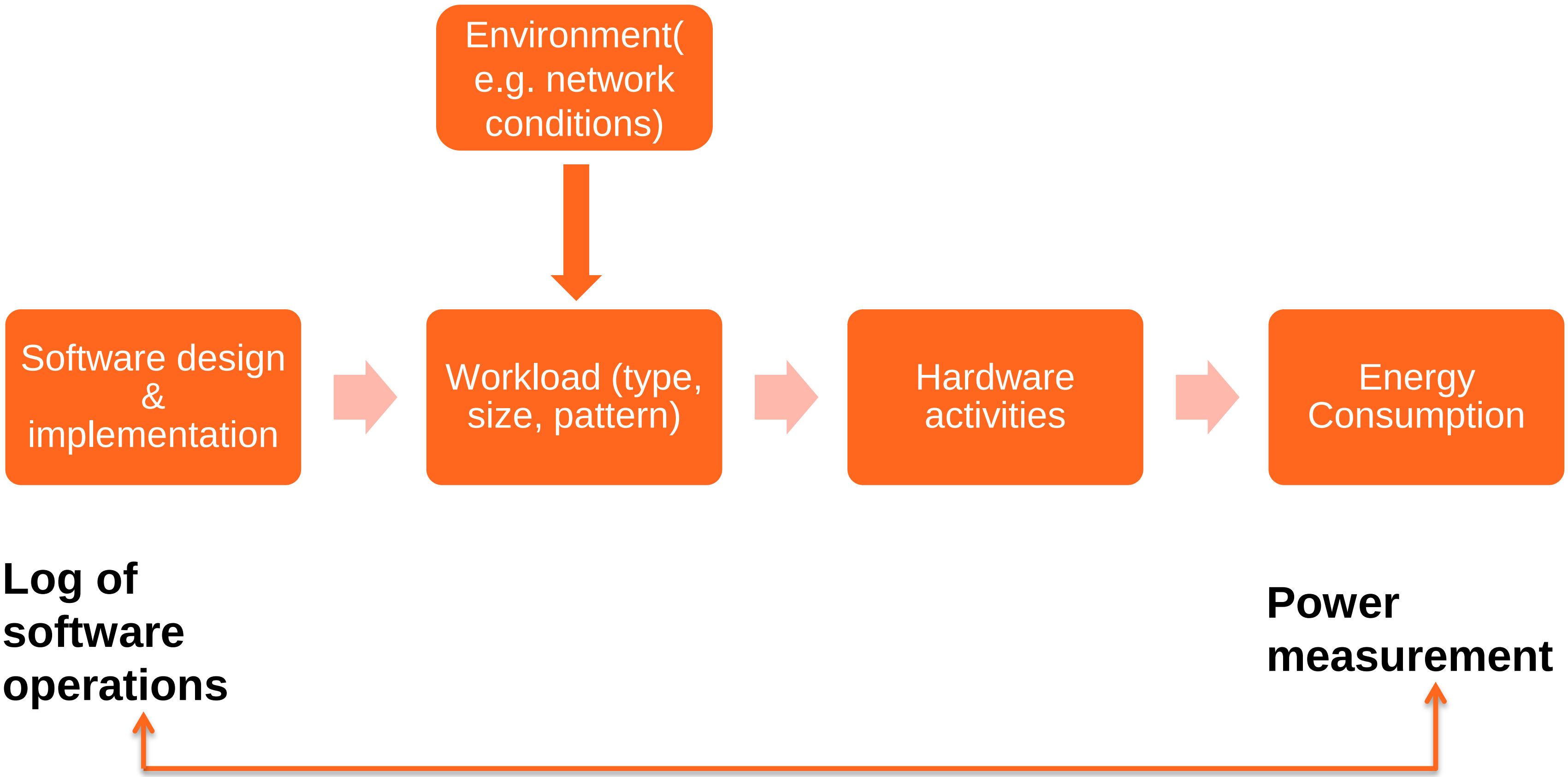
Group Discussion (10 min)



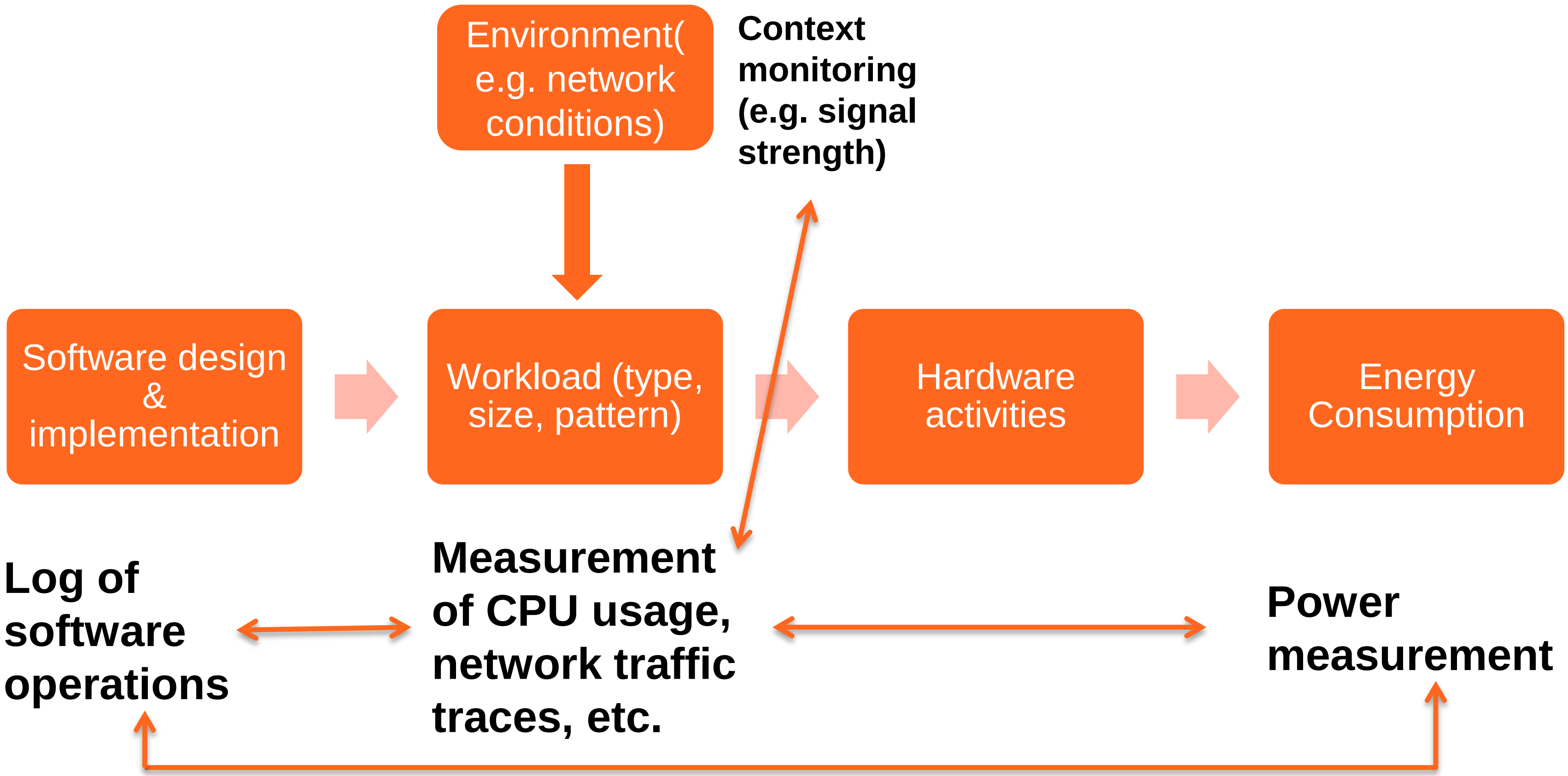
Which operations are power hungry?
How is the energy consumption affected by the environment?

Power measurement

Overview of Energy-efficiency Analysis



Overview of Energy-efficiency Analysis



What is a power model?

It is a mathematical model that describes the relationship between power consumption and …

Examples:

- Processor power ~ instruction (V.Tiwari et al.)
- Processor power ~ Hardware performance counters(HPC) (K.Singh et al., B.C.Lee et al. , C. Isci et al., B. Goel et al., D.Brooks et al.)
- Wireless transmission cost ~ network throughput (Y.Xiao et al.)
- ...

A power model can be built for a whole device, a certain hardware component, or a software component.

Example Energy Model

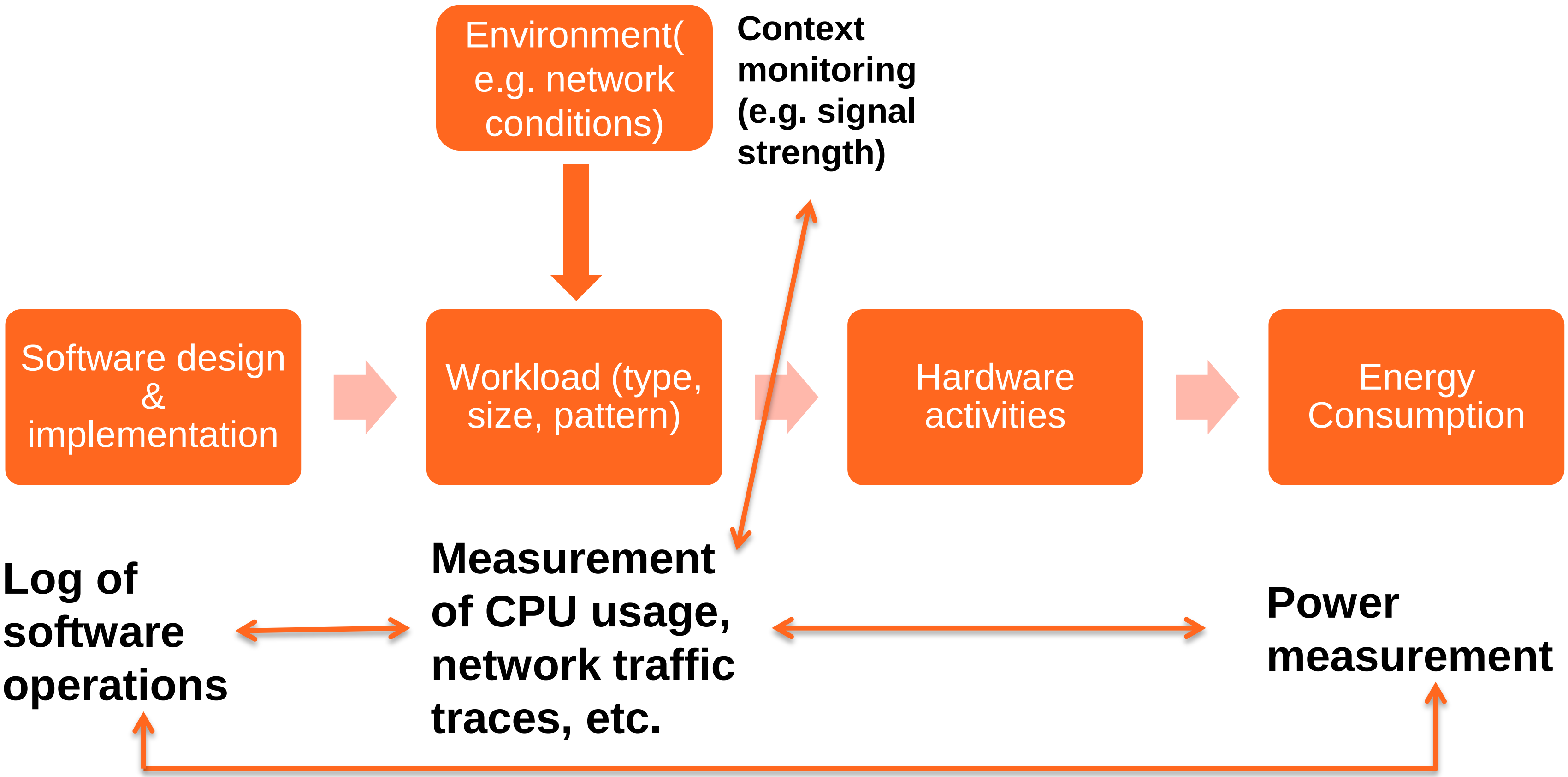
- An energy model can be formulated as follows for a component based system:

$$y(t) = f(x_1(t), x_2(t), \dots, x_n(t)),$$

where *y(t)* represents the energy draw in the time interval *t*, and the functions $x_1(t), x_2(t), \dots, x_n(t)$ represent the component level behaviors.

- The function *f* can be linear or non-linear.
- The overall energy drain for a given time period can be obtained by integrating *y(t)* over the period.

Overview of Energy-efficiency Analysis



How to build a power model?

Statistical power modelling

- ✓ Finding out the relationship between power consumption and the model variables based on statistical models like linear regression.
- ✓ The variables of statistical power models can be application-specific parameters, hardware performance metrics, and other variables that are related to power consumption.

$$
\begin{aligned}
Power(W) = {} & 0.7655 + 0.2474 \times g_0(x_0) + 0.0815 \times g_1(x_1) \\
& + 0.0606 \times g_2(x_2) + 0.0011 \times g_{17}(x_{17}) \\
& + 0.0015 \times g_{18}(x_{18}) + 0.3822 \times g_{19}(x_{19}) \\
& + 0.125 \times g_{20}(x_{20}).
\end{aligned}
$$

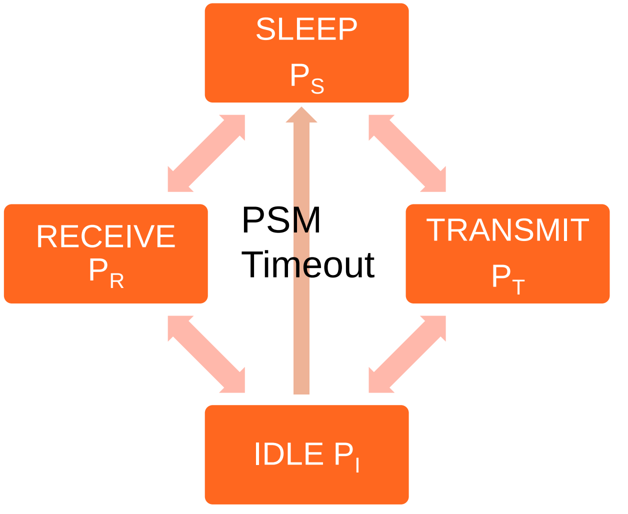
How to build a power model?

Deterministic power modelling

- ✓ map software operations to hardware activities based on expert knowledge and to estimate the power consumed by the hardware components involved based on their activities

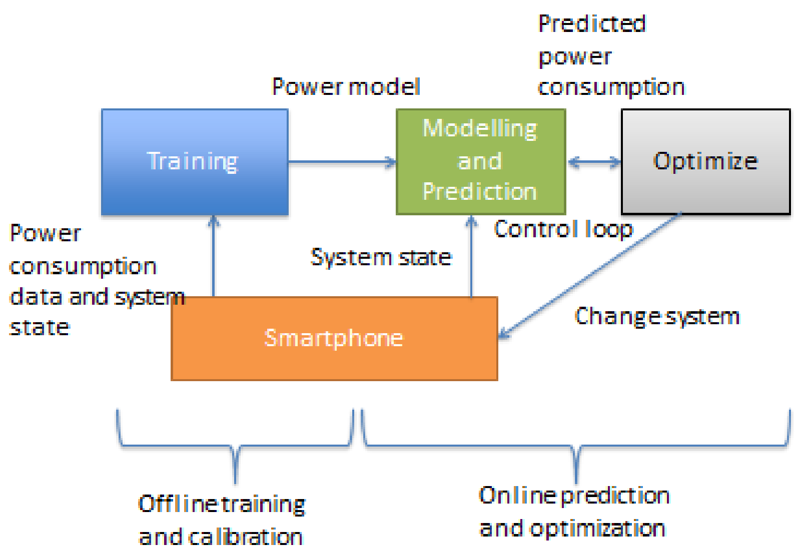
For example, power consumption behavior of a Wi-Fi interface can be described with a power state machine.

The Power(W) in each state is measured and used for calculating the variable coefficient.



Why do we need power models?

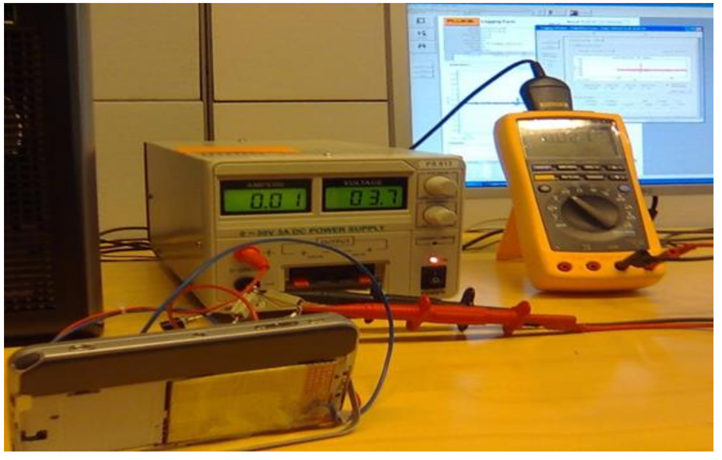
- **Power models can be used for estimating power consumption**
- **Power models quantify the impact of different influcing factors. They can provide hints on how to reduce energy consumption.**

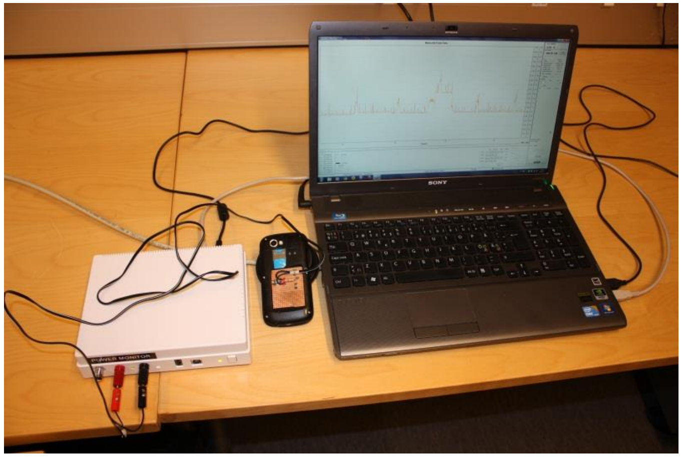


Power Measurement

Measurement Methods

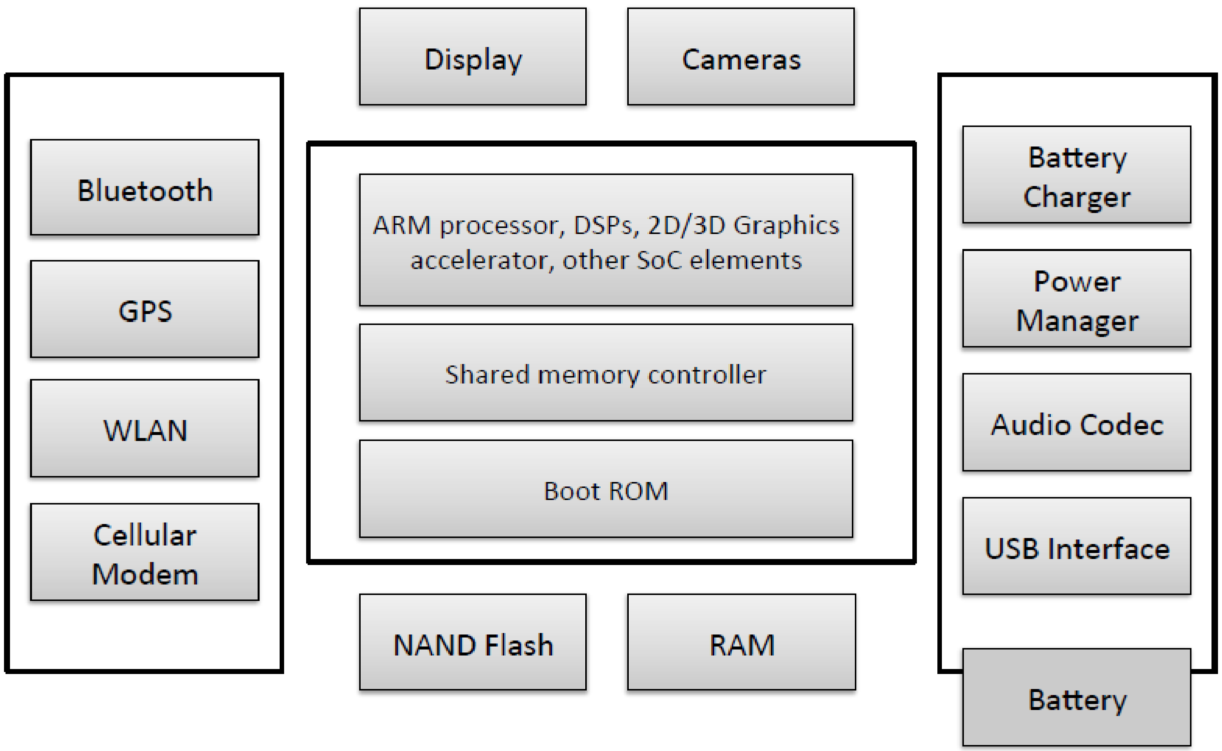
- **Hardware-based: using physical power meters**





- **Software-based: getting battery usage information through APIs**

Can I measure the power consumption of each hardware component?



Component-level Power Measurement

- **Requires information about power distribution network at the circuit level**

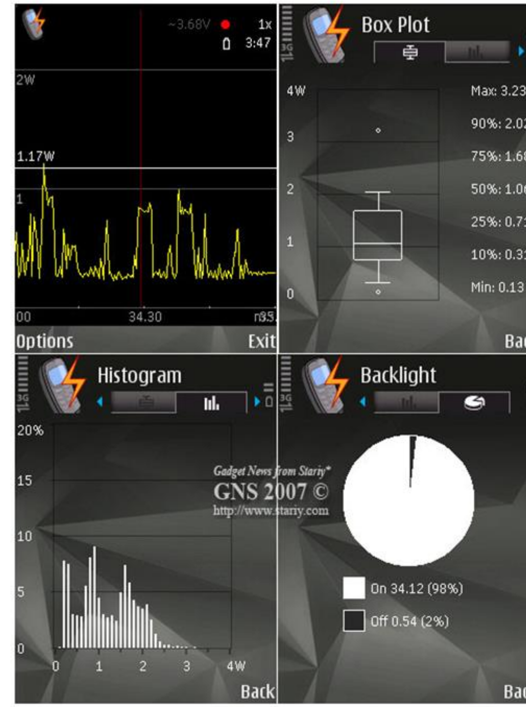
- **Only a few off-the-shelf devices can be measured on component-level**

  e.g. Openmoko Neo Freerunner

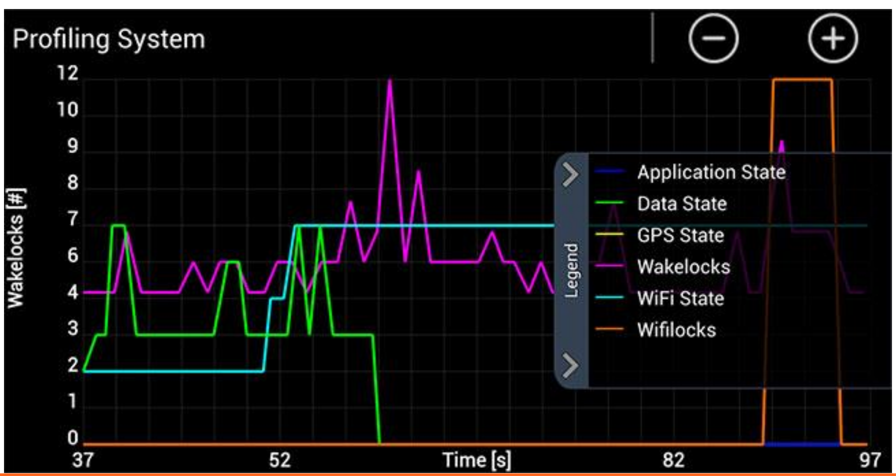
  It has a debug port with complete access to low-level hardware.

Software-based Power Measurement

- **Nokia Energy Profiler (for Symbian)**



- **Trepn Profiler for Android devices featuring Qualcomm Snapdragon processors**



Software-based Power Measurement

- **Smart battery APIs**
  - ✓ *A smart battery is a battery that has special hardware for monitoring its internal state and environment*
  - ✓ *The monitoring hardware usually estimates **voltage, current, and temperature of the battery***
  - ✓ *Smartphone OS and its drivers can access these values through a low-power serial bus*

Overview of Smartphone Battery APIs

API	SOC	Health	Battery capacity	Cycle count	Voltage	Current	Temperature
Android	Yes, 1% granularity	Yes (categories)	Not in the API (some devices support / sys/ access)	No	Yes	Not in the API (some devices support / sys/ access)	Yes
iOS	Yes, 5% granularity	No	No	No	No	No	No
Windows Phone	Yes	No	No	No	No	No	No
Blackberry	Yes	Yes (categories)	Yes	Yes	Yes	No	Yes
W3C Battery status API	Yes, 1% granularity	No	No	No	No	No	No

SOC: state of charge which gives the remained battery capacity in percentage.
Cycle count: the number of charge/discharge cycles

Example Smart Battery Interfaces

Battery unit	Update rate	Sampling rate	Resolution	Error
Maxim DS2784 (Google Nexus One)	0.28 Hz	18.6 kHz	104 μA	±1%.
Maxim MAX17040 (Samsung Galaxy Nexus)	2 Hz	32 kHz internal clock	Voltage: 1.25mV SOC: 1/256%.	±12.5mV
TI BQ27200 (Nokia N900)	0.39 Hz	100 kHz internal clock	2.7mv	±25 mV, Current gain variability ±0.5%

Hardware-based Power Measurement

Strengths:

- **High sampling frequency**
- **Does not cause energy overhead**

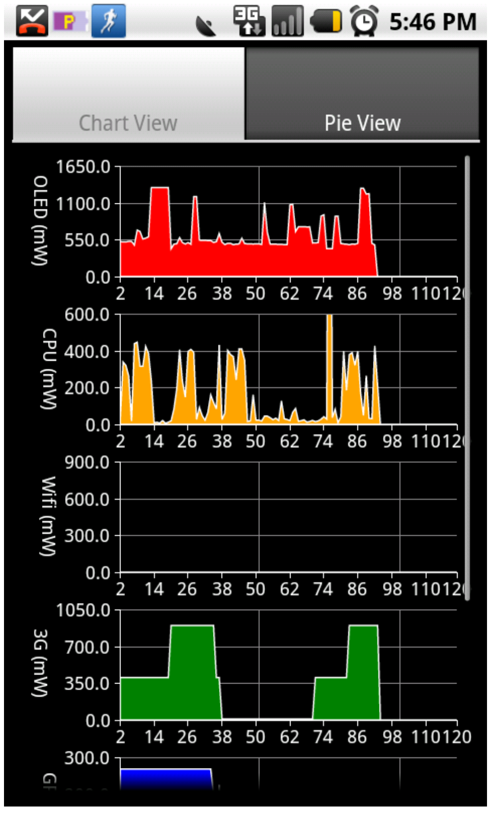
Weakness:

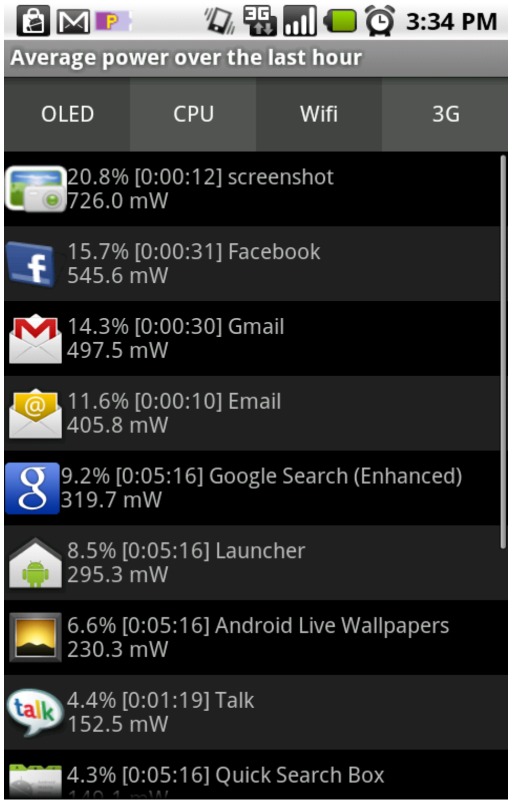
- **Not feasible for power measurement in mobility scenarios**
- **Require special hardware**

Limitations of Software-based Power Measurement

- The required information may not be available, namely the current.
- Update rate of the battery status is low
- The readings of the smart battery interface are not accurate

Can Apps like PowerTutor be used for power measurement?





- **Not all energy profiling software can provide ground truth of power consumption**

- **Accuracy of model-based energy profilers like PowerTutor depends on the accuracy of the power models in use**

- **Power models are usually hardware specific, which means the models built for Phone Model A may not be applied to Phone Model B**

Case Study

Case 1: Idle Power

- **How do you define an idle or standby state?**

Wi-Fi scanning	Off
Wi-Fi	1) Off 2) On(no traffic)*
3G/LTE	1) Remove SIM card 2) Idle(no traffic)*
Display	1)Turn off 2)Turn on with a fixed brightness level*
Background Services	Stopped
Sensors(e.g. GPS)	Off
CPU frequency	Fixed (no change in frequency during measurement)

Idle Power of Samsung Nexus S

Samsung Nexus S (Wi-Fi IDLE)

CPU Freq	Display	Power(W)
100MHz	Off	0.213
200MHz	Off	0.435
100MHz	On	0.742
200MHz	On	0.800
400MHz	On	0.890

In a study of Wi-Fi transmission cost, we notice
-- when the display is off, the CPU freq increases from 100MHz to 200MHz whenever the data sending rate increases from 256KBps to 512KBps.
-- due to CPU partial wakelock, the data rate cannot go over 512KBps if the display is off.

Case 2: watch YouTube video online

How would you analzye the power consumption of a YouTube client? Assume that the client is open source and you can use either Wi-Fi, 3G or LTE network. You can use the physical power meter in our lab for power measurement.

Group Discussion(12min)

Guideline for Group Discussion

1) Design criteria and description of test cases (e.g. what kind of power consumption behavior do you want to study through these test cases? Are your test cases sufficient?)

Hints: operations of the applications? environment?

2) Measurement metrics you choose(e.g. Power(W), Energy(J), unit cost, energy utility)

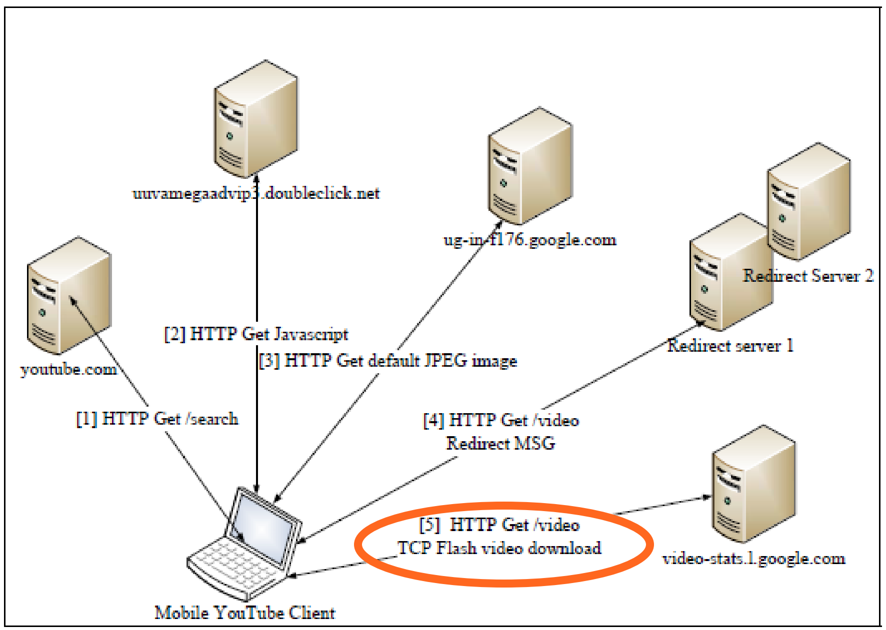
3) Experiment setup (e.g. how do you measure power consumption? How do you set up network connection? How do you monitor network traffic?)

Case 2: watch YouTube video online

- **Step 1**
  - ✓ What happen after a video request is sent from the phone?
  - ✓ How is video delivered from YouTube server to the phone?
  - ✓ When can playback start?

Case 2: watch YouTube video online

- **Step 1**
  - ✓ What happen after a video request is sent from the phone?



Case 2: watch YouTube video online

- **Step 1**
  - ✓ How is video delivered from YouTube server to the phone?
  - ✓ When can playback start?

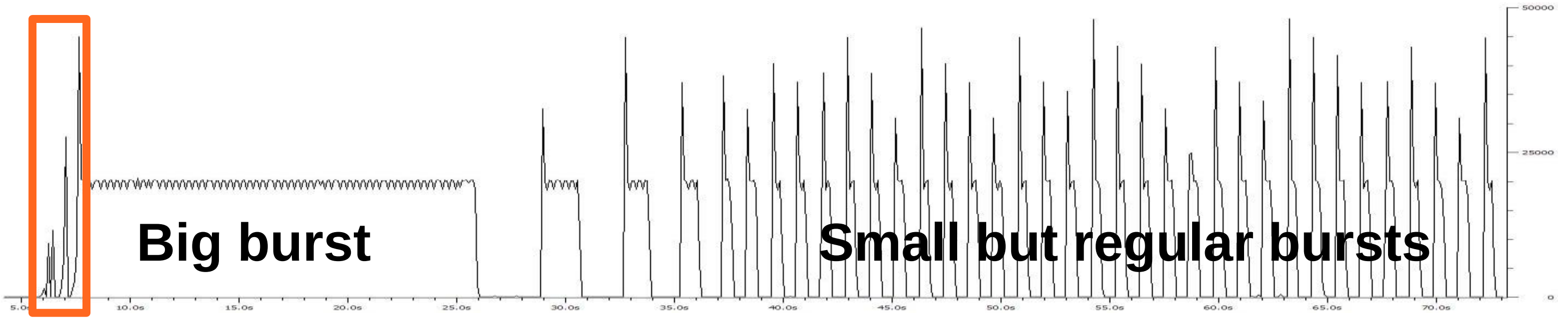


Figure: I/O graph of YouTube traffic (Byte/tick)

Case 2: watch YouTube video online

- **Online YouTube viewing includes 3 stages: download only, download+playback, playback only**

- **Step 2: design test cases**
  - ✓ How much energy is consumed by video download? How much is cost by video playback?
  - ✓ Is it more energy-efficient to use WiFi than 3G?

Example Test Cases

Test Case	Network	Storage
Online view via WCDMA	3G	Cache
Online view via 802.11g	Wi-Fi	Cache
Download-and-play via WCDMA	3G	Phone memory
Download-and-play via 802.11g	Wi-Fi	Phone memory
Playback from phone memory	Disabled	Phone memory
Playback from flash drive	Disabled	Flash drive
Replay	Disabled	Cache

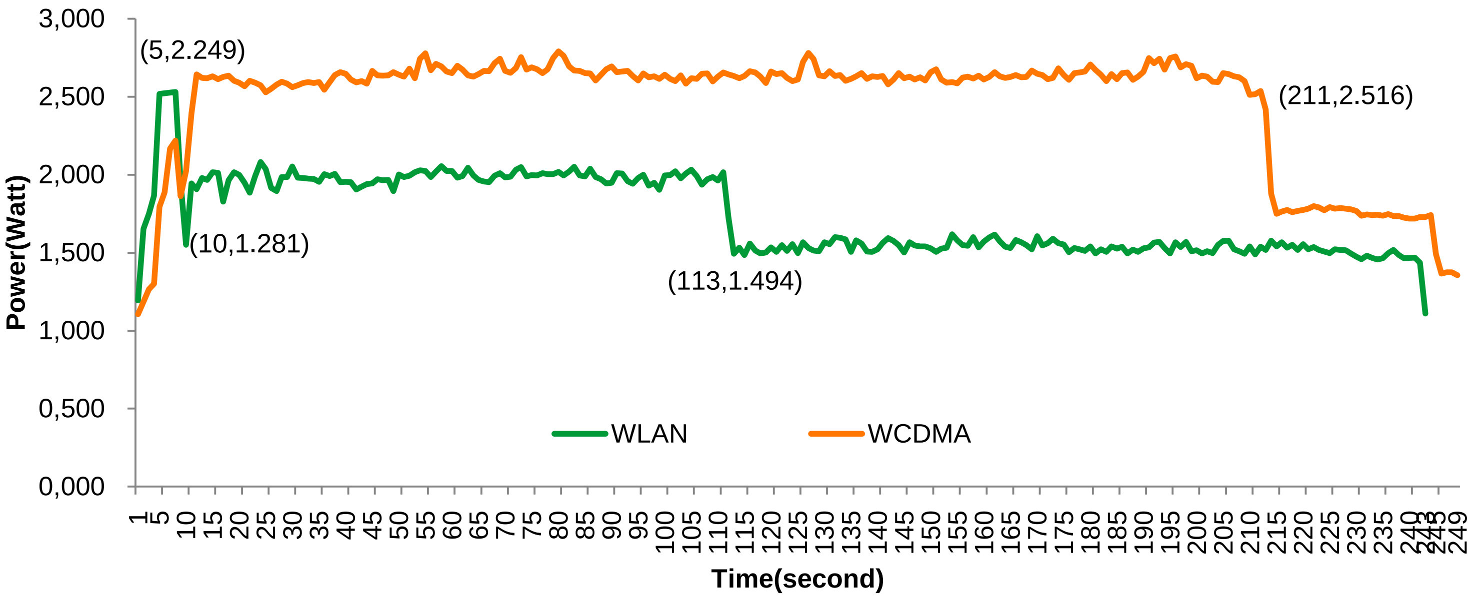
Case 2: watch YouTube video online

- **Step 3: Metrics**
  - ✓ Energy cost (J)
  - ✓ Average Power(W) during each stage
  - ✓ Duration(s)

- **Step 4: Experiment Setup**
  - ✓ Network connectivity
  - ✓ Software-based power measurement
  - ✓ Settings of Wi-Fi AP
  - ✓ Logging of software operations
  - ✓ Monitoring of network signal strength

Case 2: watch YouTube video online

- **Step 5: Results**

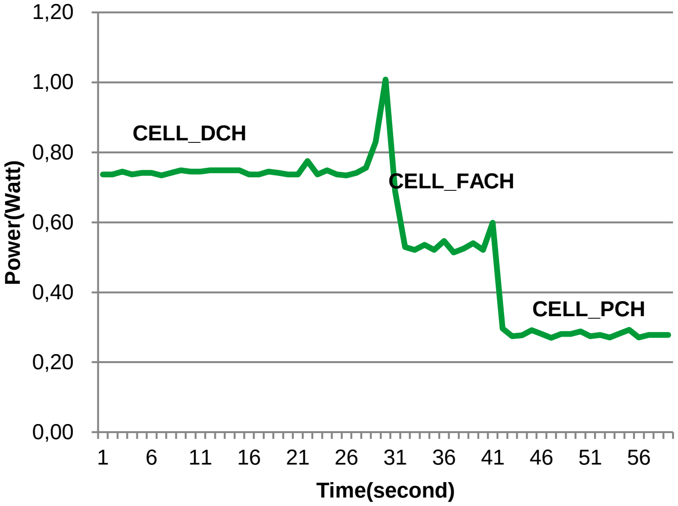


Results of Test Case 1&2 show that it is more energy-efficient to use WiFi than 3G

Case 2: watch YouTube video online

- **Step 6: Discussions**

✓ **3G Tail Energy**



If you would like to learn more about this case, please refer to

Yu Xiao; Kalyanaraman, R.S.; Yla-Jaaski, A., "Energy Consumption of Mobile YouTube: Quantitative Measurement and Analysis," *NGMAST '08.* pp.61,69, 16-19 Sept. 2008

Case 2: watch YouTube video online

- ✓ geographic and temporal variation

Table 1: Performance and power consumption of watching a YouTube video through WLAN.

	AP1	AP2
No. of users	1	multiple
SNR	63	41
Download duration(s)	147	172
Power consumption of video downloading+playback (mW)	1487	1563
Power consumption of playback alone (mW)	1265	1277

- ✓ Video codec/encoding rate/resolution ~ playback cost
- ✓ Location of the YouTube server ~ download cost

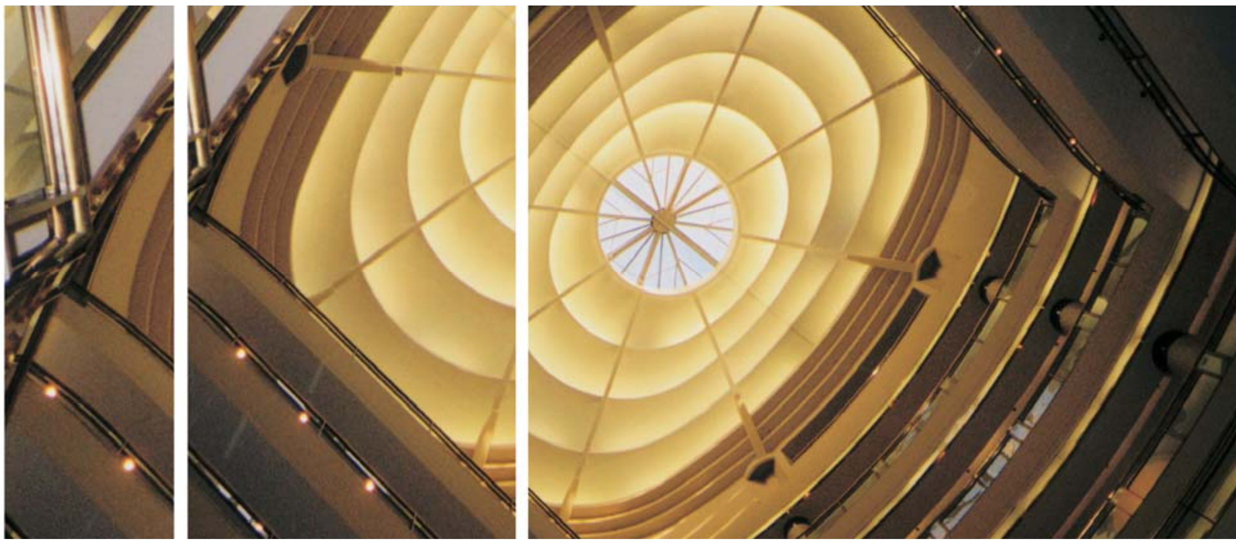
Summary

- Overview of energy causes
- Smartphone hardware architecture
- Overview of energy-efficiency analysis and basics of power modelling
- Case Study: How to analyze power consumption of YouTube

- **Reading sessions**

Guideline for Paper Reading

1) Overview of the paper
2) Design criteria and description of test cases
3) Measurement metrics
4) Experiment design
5) Experiment results (how do they analyze and present the results?)
6) Limitations of the work



NETAPP VISION SERIES

REDUCING DATA CENTER POWER CONSUMPTION THROUGH EFFICIENT STORAGE

Brett Battles, Cathy Belleville, Susan Grabau, Judith Maurier
| February 2007 | WP-7010-0207

AN EIGHT-POINT PLAN FOR FIGHTING POWER CONSUMPTION

The NetApp approach to fighting rapidly growing power consumption is simple: subtract machines and disks from the power equation by using storage more efficiently. This strategy has many corollary benefits: it lowers complexity, lowers people costs, lowers support and service costs, and improves network efficiency and performance. The NetApp eight-point strategy for reducing storage power consumption makes use of today's technology to halt power growth at its source.

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HITTING THE LIMITS

A WATT IN MEANS A WATT OUT

"We're at 100% of power capacity today. For every new watt I bring in, I've got to figure out how to take one out."

IT exec

Global Financial Services Company

New York City

Exponential data growth is a reality for most data centers. *IDC Worldwide Disk Storage Systems Forecast 2006–2010* predicts that worldwide data will grow at a compound annual growth rate of 50.6% through the decade. This growth is a huge concern for IT managers. Until recently, continuous improvements in price-performance and $/GB have made it both easy and affordable to solve storage concerns simply by adding more disks to existing storage systems. However, IT executives are discovering that there are limits to that easy growth: floor space, weight loads, rack space, network drops, power connections, cooling infrastructure, and even power itself are finite resources. Hitting any one of these limits significantly jeopardizes the ability of IT to meet the demands of business.

Hitting the Fan

Cooling is inextricably linked to power consumption. Every watt of power that enters the data center generates heat that must be removed from the environment—and to do so takes more power. As the heat increases, systems become more unstable and component failure rates rise. The cost of power to cool a system often is as much as powering the system itself.

But cost is not the only issue. In some cases, rack densities generate more heat than existing cooling infrastructures can handle. Where there is no room for additional cooling infrastructure, there is no room for growth.

Power Hungry

Storage companies have been steadily increasing storage density, inadvertently driving up data center power demands and cooling concerns. In the next 18 months, increases in average storage rack density are expected to drive average power consumption from 2kW per rack to 30kW per rack—and that's only half the story. For each watt used by the server or storage, A/C, power supplies, and other related equipment together require nearly 1.5 times that amount.

Putting Business at Risk

The combined effect of recent increases in the price of energy and the adoption of denser computing and storage architectures has driven energy costs for some data centers to 30% of their total operating budgets. If left unchecked, the cost to power IT equipment could exceed its acquisition cost in a matter of years. Without deliberate action, high energy costs will cripple an IT department's ability to grow and change in support of the demands of the business.

The Greening of Storage

Environmental issues are gaining serious commercial momentum and, fueled by the growing number of local and global green initiatives, they are rising ever more insistently up the corporate agenda. More power-efficient storage solutions provide for business growth while saving power. Every watt of energy saved in the data center is a watt that is removed from an organization's carbon footprint and the global warming equation.

THE NETAPP EIGHT-POINT PLAN FOR FIGHTING POWER CONSUMPTION

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1 CONSOLIDATE SERVERS AND STORAGE

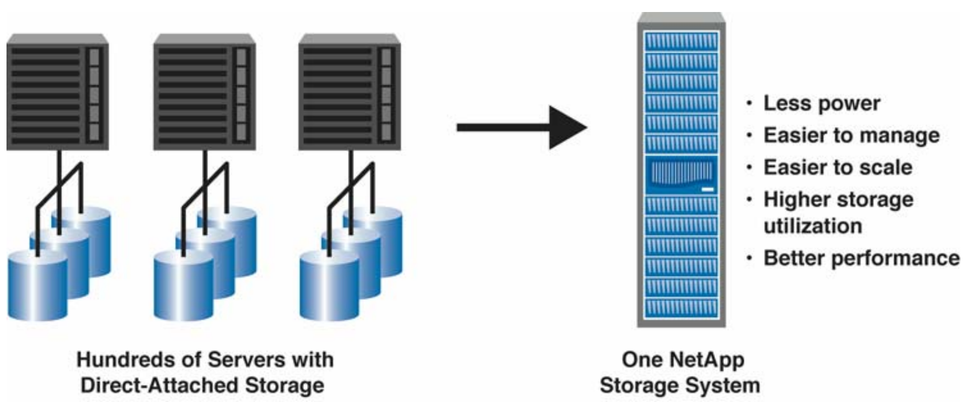
Servers alone can consume 50% of the power coming into the data center. The first step in reducing power consumption is to attack the power problem where you can reap the most gains—consolidating and virtualizing application servers.

Storage is the next largest consumer of energy after servers and cooling systems. In environments with lots of direct-attached storage, as much as 27% of the power going into the data center is being consumed by storage[1].

The dramatic growth of Windows® data has led to a proliferation of Windows file servers and direct-attached storage units. Not only are these server and storage assets poorly utilized, they are also difficult to manage, resulting in extremely high overhead costs.

Data centers that use lots of direct-attached storage can see significant power savings by implementing a storage network. Removing file servers immediately increases the total watts available in the data center. File server consolidation also increases your ability to scale in a power-efficient manner; instead of adding servers, you can scale by adding disks. Adding disks to an existing system has the additional advantage of allowing you to amortize operational costs over more drives.

In addition to reducing power loads, consolidating Windows data onto a highly available NetApp storage system dramatically simplifies the file-serving environment and creates valuable management, performance, and cost efficiencies.



2 USE HIGHER-CAPACITY DRIVES

Using higher-capacity drives can significantly alter the storage power equation. Typical SATA disk drives consume about 50% less power per TB than equivalent-capacity Fibre Channel drives. They also offer the highest available storage density per drive, further helping minimize power consumption. NetApp disk resiliency and data protection technologies have made SATA drives an increasingly viable alternative for many enterprise applications. Many companies are finding that SATA

[1] "Power, Heat and Sledgehammer." Maximum Throughput, Inc. April 2002.

performance is good enough to support many more applications than they originally thought possible.

Dramatic Benefits of Higher-Capacity Drives

For example, if you replace 11 older systems with one modern, high-capacity system, you can increase capacity by 16% while consuming 81% less power and 93% less space than was required for the old systems. With this arithmetic, it doesn't take very long to achieve a significant return on your investment.

Table 1: Potential Savings from Higher-Capacity Drives

	Old Systems	New Systems	Improvement
# of systems	11 Old Systems: 4 F880 3 F810 2 F820 1 F825 1 F840	1 FAS 3020 with 3 disk shelves	
Power* (kW HRs) *Does not include power for cooling.	113,651	20915	81% Decrease
Space (Cubic Feet)	63.0	4.3	93% Decrease
Capacity (GBs)	9,776	14,000	16% Increase

3 PROTECT AGAINST DISK FAILURES WITH FEWER DRIVES

When SATA drives are utilized for data storage, larger amounts of data are stored per drive when compared to smaller Fibre Channel primary disk drives. To insure that data reliability is not compromised. Network Appliance provides dual-parity RAID-DP™. When compared to RAID 10, data mirroring, RAID-DP offers 70% greater storage utilization[2]. In addition, RAID-DP provides superior fault tolerance by recovering from the simultaneous failure of two drives, unlike other RAID levels that can tolerate only a single drive failure.

4 MIGRATE DATA TO MORE EFFICIENT STORAGE

To ensure the most efficient use of your storage resources, minimize the use of primary storage by migrating data to more efficient secondary storage where appropriate. The Network Appliance™ IS1200 information server automates migration of infrequently accessed data from primary storage to the more storage-efficient secondary storage of NearStore®.

5 INCREASE UTILIZATION

According to industry estimates, storage utilization rates average 25–40%. That means 60–75% of all storage capacity that is being powered goes unused. Not only is such a low utilization rate a waste of storage, it is a waste of power.

In most systems, storage administrators allocate and dedicate storage space to a particular volume or LUN at the time of its creation. This creates two significant administrative challenges: (1) once a volume is created on physical storage, its size is extremely difficult to change, and (2) once storage is allocated to a particular application, it is not available for another use. Since it is difficult to predict actual storage requirements, application administrators typically request much more space than they think they will need to protect themselves should they need more storage down the line. This common practice guarantees overallocation. NetApp Flex Vol®

[2] Network Appliance testing

technology enables thin provisioning, a technique that lets storage administrators quickly and dynamically resize flexible volumes, eliminating the need for over-allocation.

With NetApp FlexVol technology, utilization rates of 60% are the average[3]. By making all disks available to all datasets through a common pool of storage, both performance and capacity utilization are maximized. When disk space is no longer needed by a particular application, it can be returned to the free pool and made available to other applications as their storage needs grow. Increasing utilization 50% results in a corresponding reduction in the number of disks that are required.

6 BACKUP: DO MORE WITH LESS

NetApp Snapshot™ copies provide two significant efficiency advantages, making them unique in the industry. First, because only changes to the data are saved, Snapshot copies consume minimal storage space. Second, these copies also let you leverage a single copy of your data for multiple uses, reducing your reliance on special-purpose storage systems. With other vendors, backup, compliance, and disaster recovery may each require a dedicated system, putting huge additional demands on your storage infrastructure. With NetApp technology, a single copy of your data can be used for multiple uses so your backup system can be used for compliance *and* asynchronous disaster recovery. Reducing the number of special-purpose storage systems you use can radically reduce your power requirements.

Countless copies of data files consume vast amounts of storage. De-duplication technology can help you free up this capacity. Network Appliance NearStore includes A-SIS de-duplication, a technology that eliminates duplicate data regardless of the amount of redundant data stored on the primary disk array. A-SIS de-duplication reduces the need to continuously add more storage capacity for secondary data storage.

7 ELIMINATE STORAGE OVERHEAD FOR TESTING AND DEVELOPMENT

Testing and development require numerous copies of your data, putting huge additional demands on your storage infrastructure.

NetApp FlexClone™ technology lets you make multiple, instant virtual copies of your data with virtually no storage overhead. As with NetApp Snapshot technology, only data that changes between a parent volume and a clone is stored. Data volumes and datasets can be instantly cloned without requiring additional storage space at the time of creation. This capability makes it possible to allocate many individual, writable copies of data in a fraction of the space that would typically be required.

Additionally, with NetApp FlexClone technology, activities that once had to be performed sequentially—due to previous storage limitations—can now be done simultaneously, increasing the speed of testing and deploying new applications.

8 MEASURE YOUR POWER EFFICIENCY

Our last step is something that we encourage you to do on an ongoing basis to get a handle on your storage power consumption: measure the power efficiency of your storage systems.

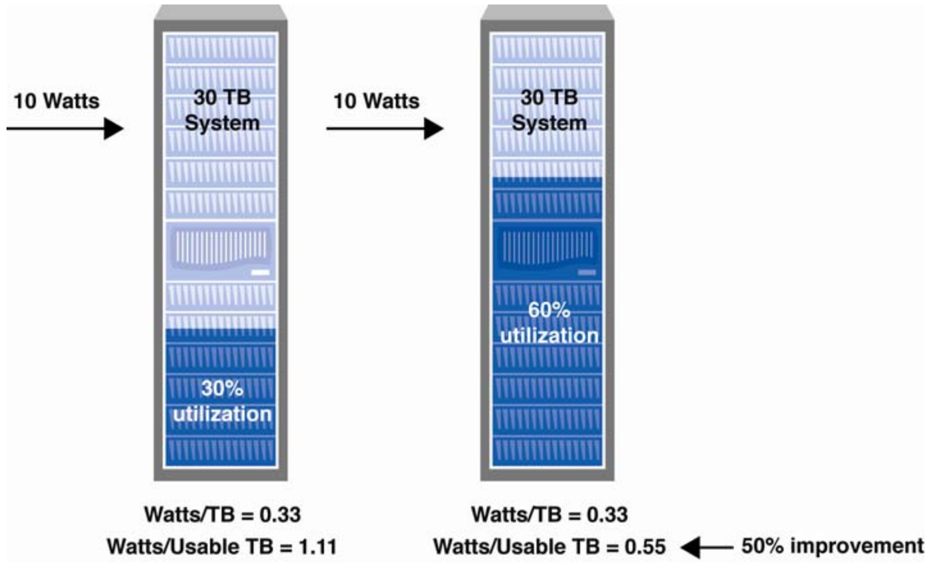
One common measure of power consumption is watts per terabyte (W/TB). This measure can be misleading, however, when comparing machines that operate at different efficiency levels. A better way of evaluating storage power consumption is to measure watts per usable terabyte. This can be expressed with the following formula:

[3] Customer reported utilization data

$$\frac{\text{Watts to power system}}{\text{Total system TB} \times \text{\% System Utilization}} = \text{Watts per Usable TB}$$

To calculate the power efficiency of a particular storage system, divide the total watts per system by the total number of TBs in that system times the system utilization. System utilization is equal to that percent of your disks actually available for use. The figure below shows how this calculation reveals important differences between seemingly similar systems.

NetApp Storage Power Savings



LOOKING AHEAD

We believe that following these steps will return enough power and headroom for growth to your data center to protect the ability of your storage infrastructure to support the demands of your business for many years to come. In the meantime, however, we will continue to look for ways to improve the efficiency of storage systems at every level.

Here are some of the power-saving technologies that are being investigated by our industry: larger SATA drives, in-line hardware data compression, file de-duplication, flash memory, improved power supply efficiency, energy-efficient CPUs, DC power, and intelligent control of the speed of individual drives in response to demand.

Just as today there is no single solution for reducing storage power consumption, future reductions will be attained through a combination of efforts and by attacking the issue on all fronts.

THE NETAPP COMMITMENT

Runaway power consumption in the data center is an issue that storage vendors simply must address. At NetApp, we take this responsibility seriously and we will continue to devote our resources and talents to the development of data management and storage technologies that will help you overcome the challenges that power consumption realities pose to your success.

In our ongoing efforts to simplify data management, we will continue to reduce infrastructure complexity and cost and provide you the flexibility you need to stay competitive and meet your business challenges.

By focusing on data management and storage efficiency, not only can your organization realize substantial cost savings, you can do so while contributing to the health of our planet.

FURTHER READING

For more information, please check out these other papers at www.netapp.com:

- "NearStore Storage Efficiency," TR-3539
- "Maximizing Storage Utilization" white paper, WP-7003-1106