



Who Killed My Battery: Analyzing Mobile Browser Energy Consumption

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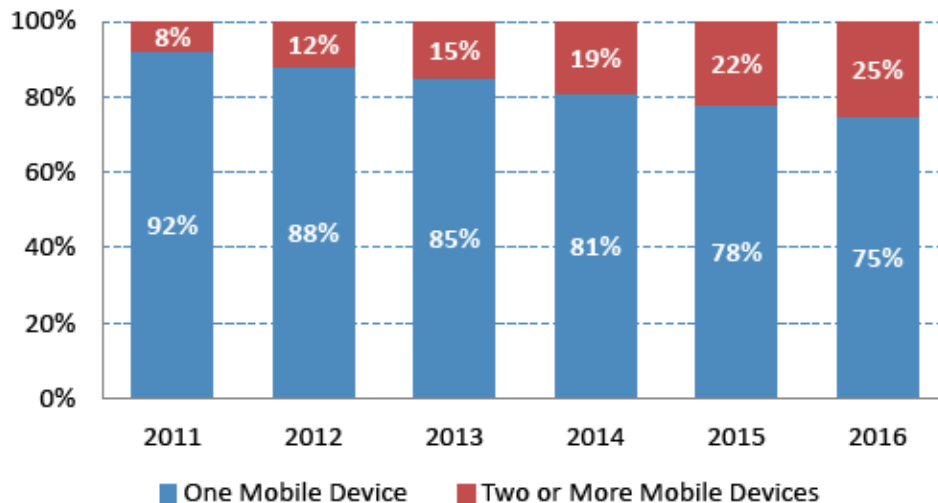
June 26, 2012



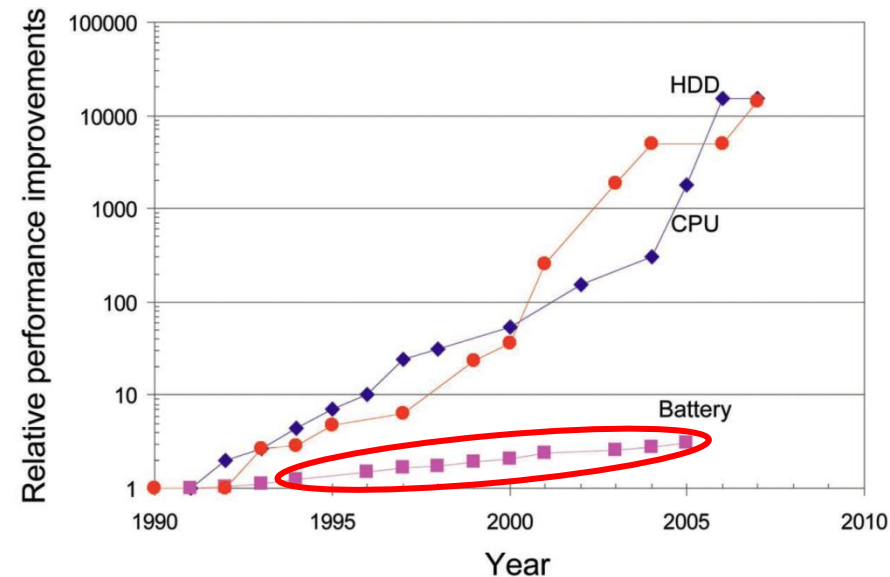
Challenges in Today's Global Mobile Industry

- 788 million mobile-only Internet users by 2015
- Global mobile traffic will increase by a factor of 26 by 2015
- 3% of all worldwide web browsing is done on mobile browser

More than one-quarter of mobile users will own two or more mobile-connected devices by 2016



*Source: Cisco VNI Mobile, 2012



Widening Energy Gap – Chalamala, Proceedings of the IEEE, 2007

Slow battery energy density growth



*Source: Cisco's Global Mobile Data Traffic Forecast, 2012

**Source: NetMarketShare, 2012



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Mobile Browser Energy Consumption

- Energy consumed by a phone browser while surfing the web is poorly understood
- Mobile version for many popular web sites
- Many mobile sites are poorly optimized for energy use
- Rendering the web sites takes more power than necessary

Web site
m.gmail.com
m.picasa.com
m.cnn.com
apple.com
worldpress.com
m.microsoft.com
m.yahoo.com



Phone utility is limited by battery life



Intelligently design web pages to reduce energy consumption



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A Software Infrastructure for Measuring the Precise Energy Used by a Mobile Browser

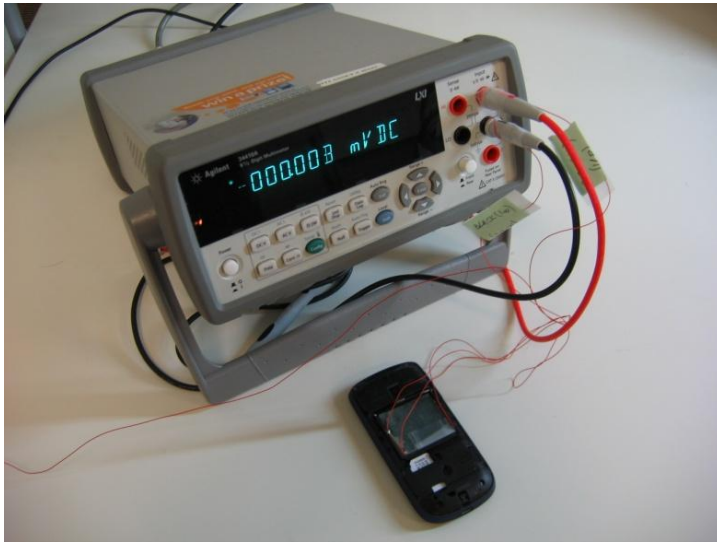
Challenge: How much energy does the phone use to render a particular web page?

Impact of the structure of web pages on battery usage in phone browser?

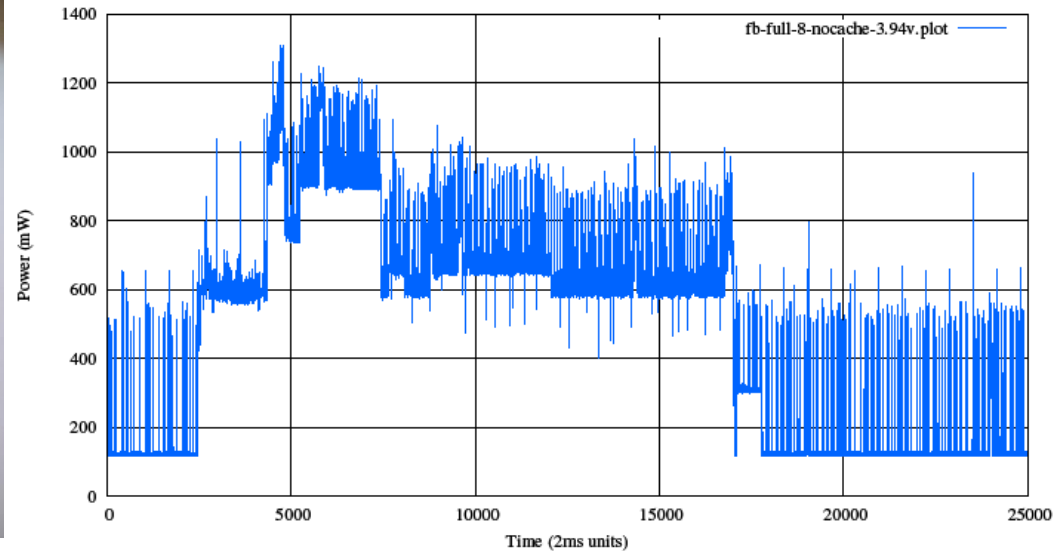
How to design web pages to minimize the energy needed for rendering?



Measuring Fine-Grained Energy Consumption



Hardware power multimeter and an open battery



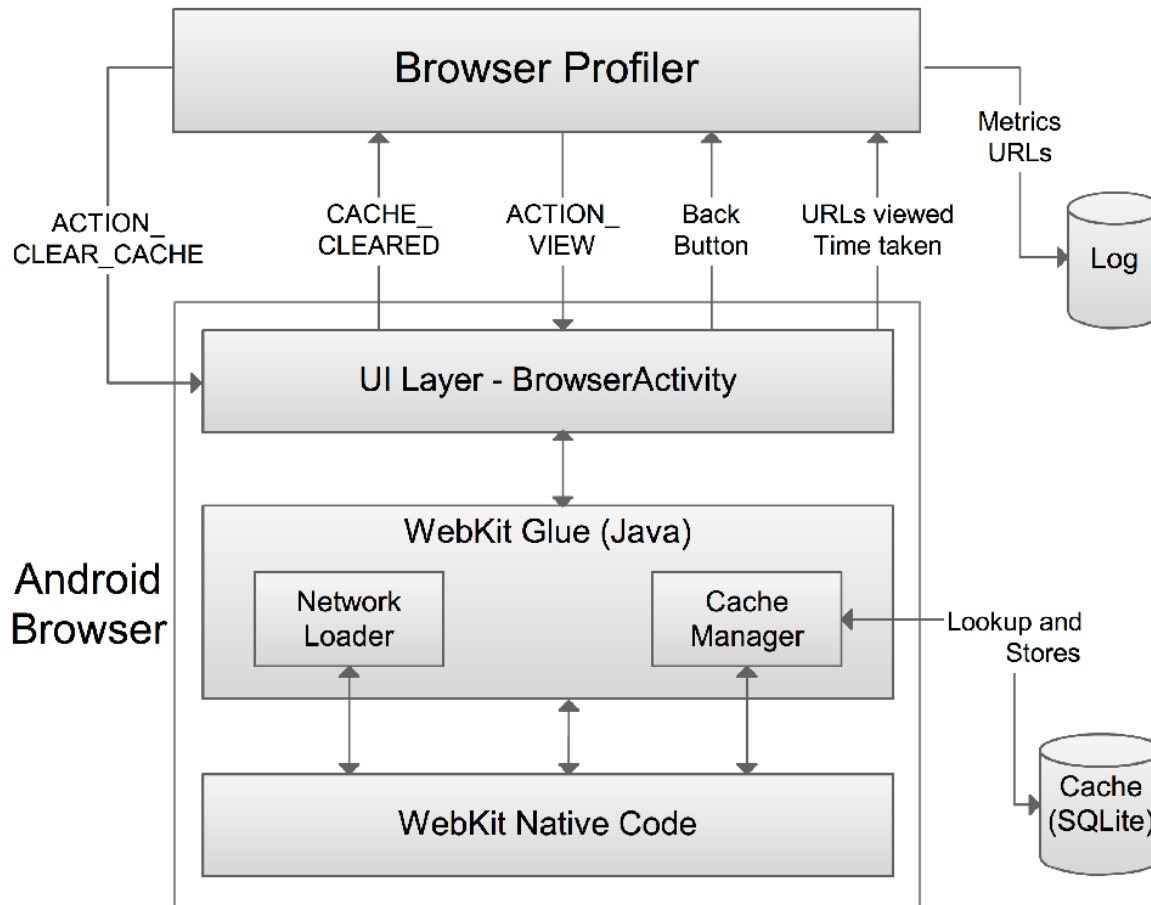
Sample multimeter output graph for a Facebook page

Measuring precisely the energy used for processing a web page, including rendering individual web elements such as images, Javascript, cascade style sheets (CSS) and plug-in objects



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System Architecture



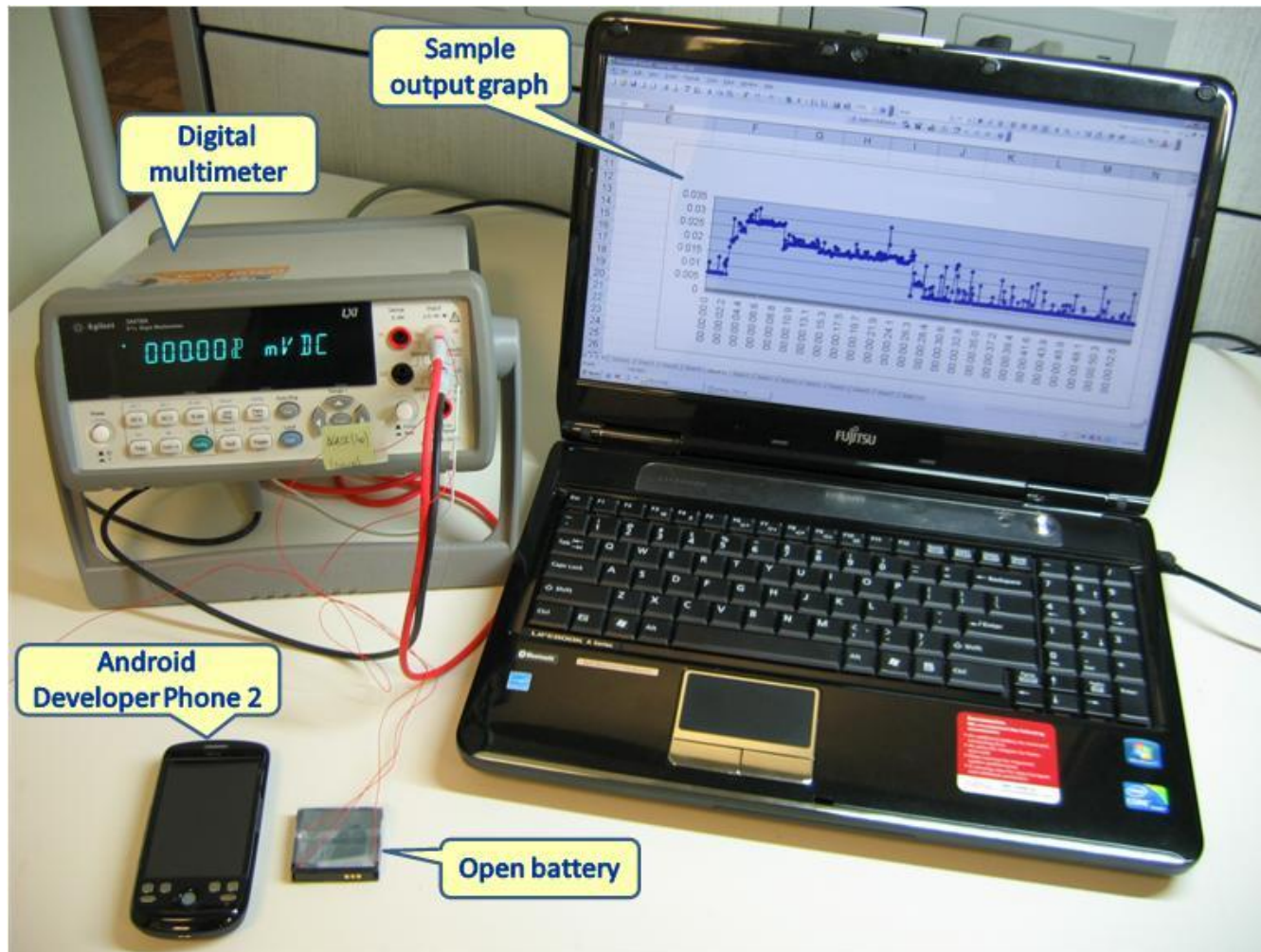
Implementation

- Layered architecture
- Modular design that contains:
 - Browser Profiler
 - Modified Android Browser
- Loading an URL in two modes:
 - ✓ No Cache
 - ✓ With Cache
- Cache Management
- Intercept page load
- Track metrics
- Android (2.1-update1) based



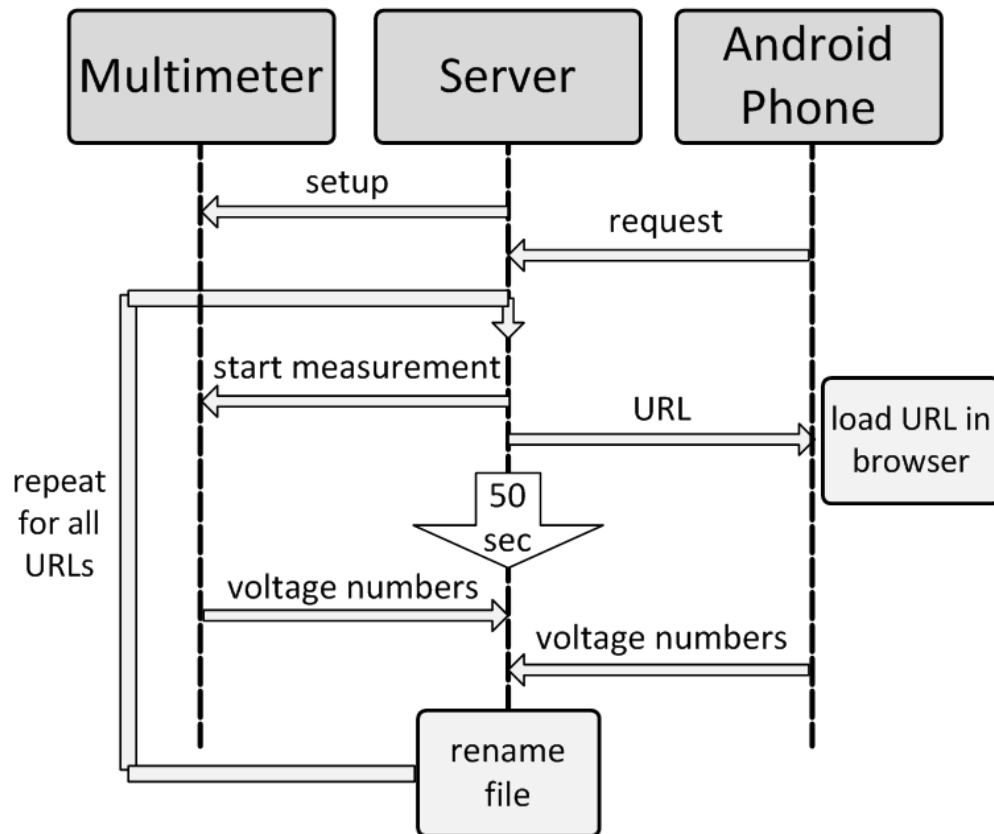
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Automated Energy Measurement System



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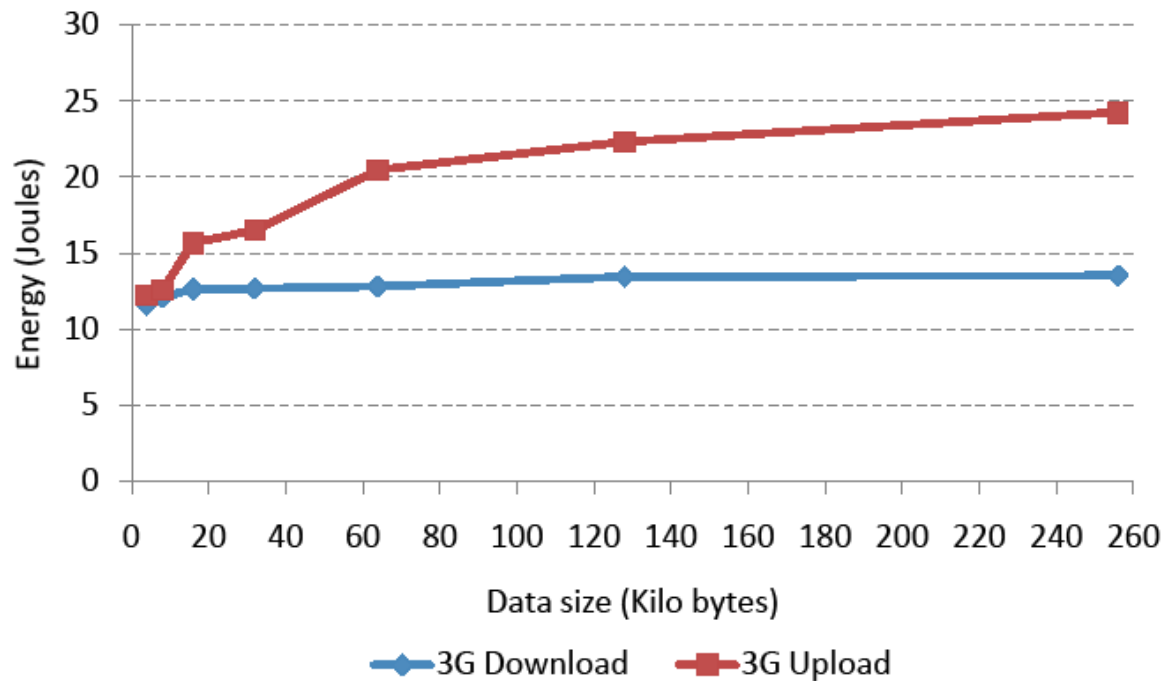
Automated Energy Measurement System



Server controls the phone and multimeter:

- 1 Server communicates with the Browser Profiler app on the phone
- 2 Server instructs the Browser Profiler app to request the running phone browser to repeatedly load a specific URL, either with or without caching
- 3 Server starts the multimeter measurement
- 4 All measurements recorded on the multimeter are transferred to the server for processing

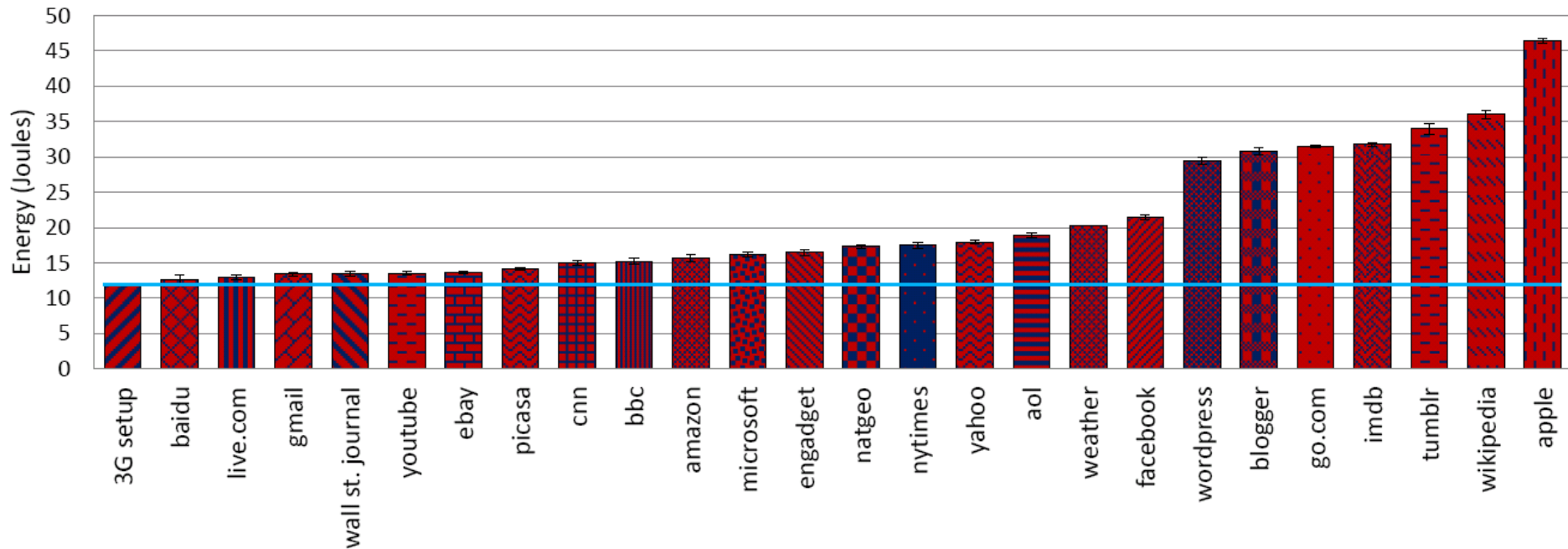
Energy for Download & Upload Data over 3G



- Average energy needed for downloading & uploading 4kB to 256kB over 3G
- Setup cost of roughly 12 Joules before the first byte can be sent
- Download energy – mostly flat (up to 256kB)
- Upload energy – increases with the amount of data being uploaded



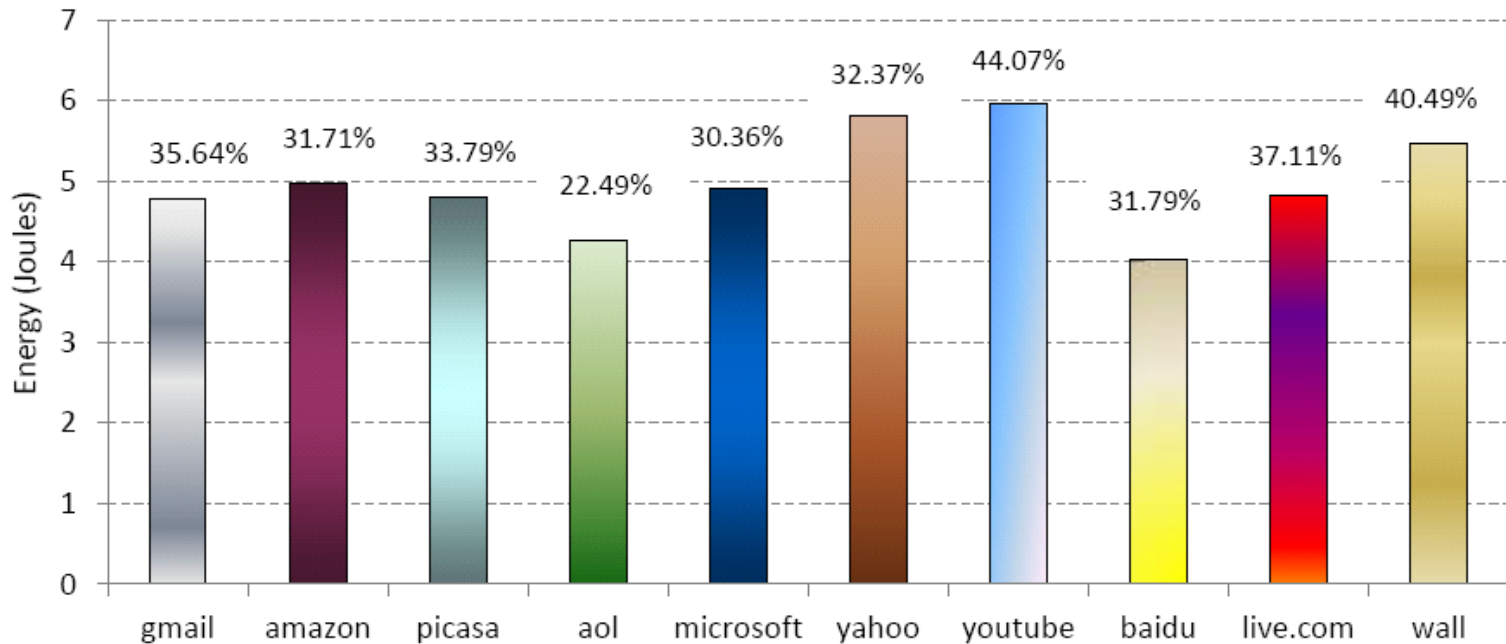
Energy Consumption of Top Web Sites



- Energy to download and render the web page
(energy for 3G communication + parsing + rendering web page)
- Average power consumption when the browser is idle $\Rightarrow$ 170 mW



Rendering Energy Consumption of Top Web Sites



- Energy needed to parse and render the page (no energy for 3G communication)
- Energy used to render the content from local cache
- How the complexity of the web page affects the energy needed to render it
- Dynamic Javascript can greatly increase the power usage of a web page

Challenge: How much energy is used by different web elements?

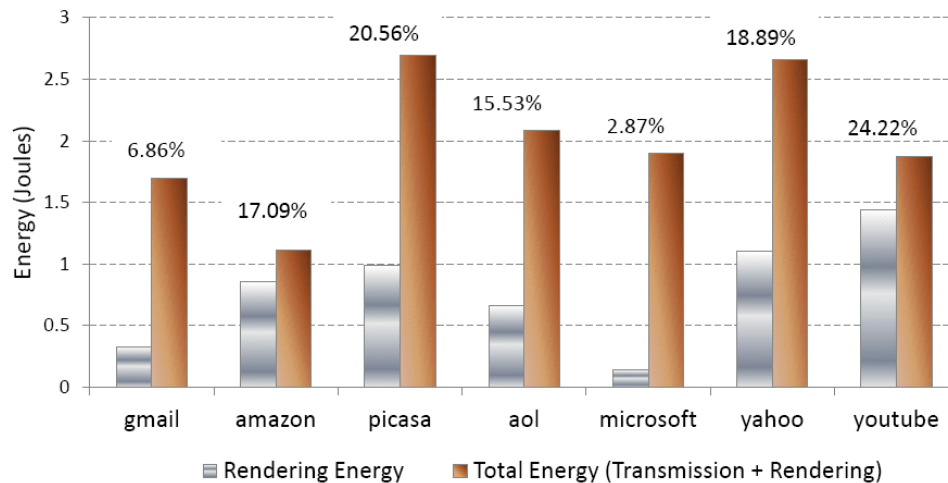


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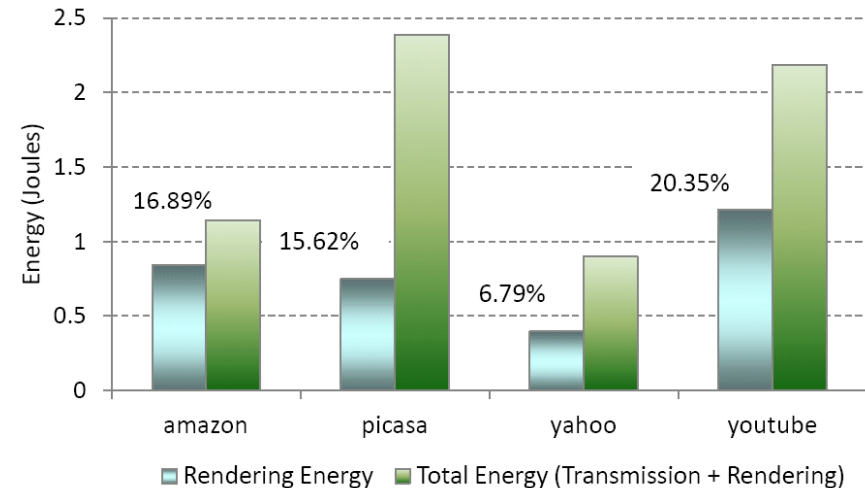
Energy Consumption of Web Components

Images, Javascript, CSS

Energy consumption of Images



Energy consumption of Javascript



Evaluation:

- 1 Energy used for loading and rendering each component (rendering + transmission)
- 2 Energy used for parsing and rendering page alone

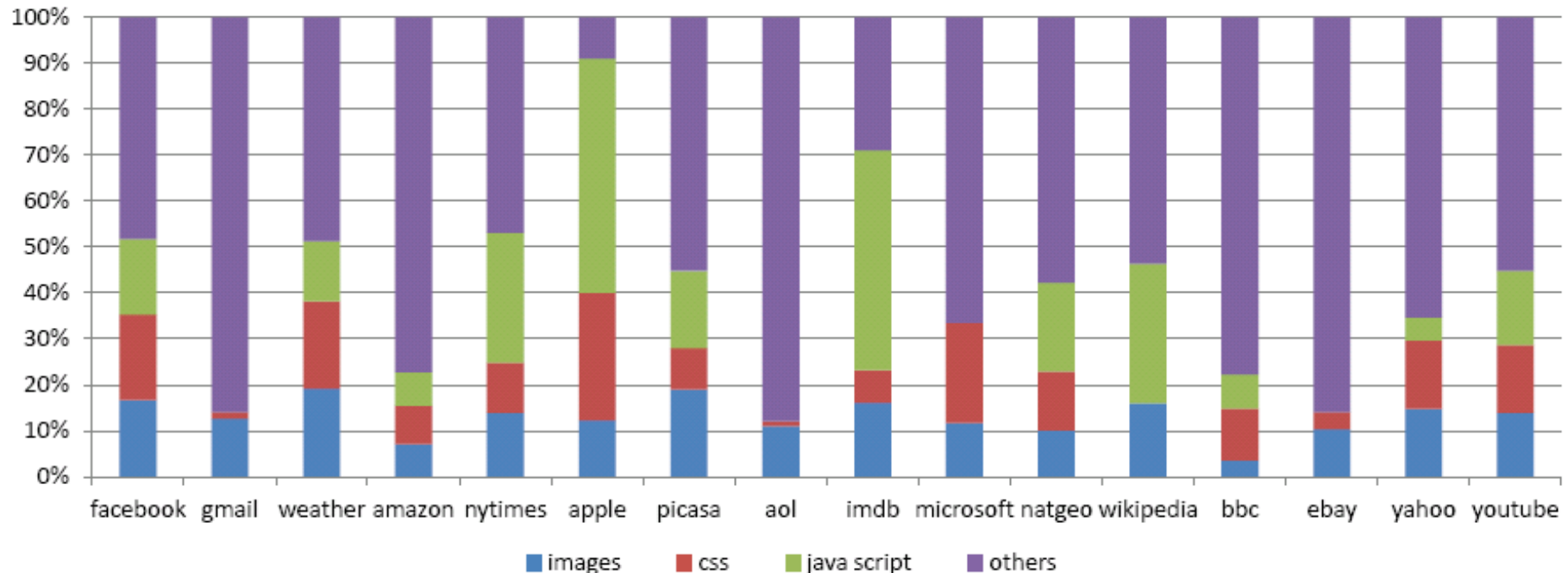
Results:

- ✓ Rendering images takes a significant fraction of the total rendering energy
- ✓ Energy used to render images is proportional to the number and size of images on the page
- ✓ Large rendering cost => large and complex Javascript file
- ✓ Rendering cost of CSS depends on the # of items styled using CSS



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Energy Consumption of Web Components (Transmission + Rendering)



Evaluation:

- Relative energy costs of individual web components

➤ Results:

- ✓ CSS and Javascript – most energy consuming components in the transmission and rendering of a web site
- “Others” – mainly includes the 3G connection setup and text rendering



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Optimizing Mobile Web Pages

Reducing Javascript Power Consumption

- Javascript – one of the most energy consuming components in a web page
- **Optimizations:**
 - ✓ Shrinking Javascript on a mobile page to contain only functions used by the page greatly reduces energy cost

Reducing CSS Power Consumption

- Large CSS files with unused CSS rules consume more than minimum required energy
- **Optimizations:**
 - ✓ CSS should be web page specific and contain only the rules required by the elements in the web page



Optimizing Mobile Web Pages

Image Formats: Comparison and Optimization

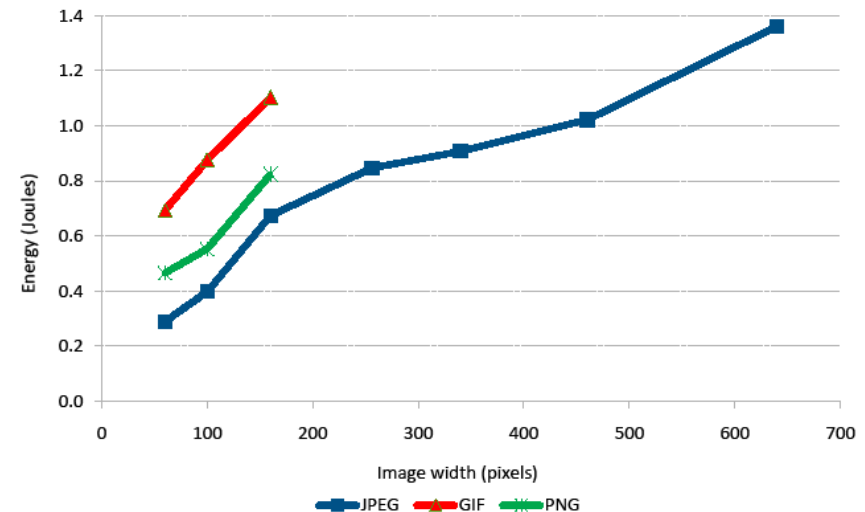
- Most common image formats: JPEG, GIF, PNG
- Energy needed to render an image depends on the encoding format

Evaluation:

- Energy needed to download and render images of different sizes in three formats
- **Results:**
 - ✓ JPEG – the most energy efficient format for *all* image sizes
 - ✓ Converting images to JPEG saves energy

Image formats for different dimensions

Image download + rendering energy



Site	Amazon (Joules)	Facebook (Joules)
Original	2.54	3.43
JPEG	2.04	2.39
Savings	20%	30%



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Offloading Browser Computation

The Benefits of Offloading Images

➤ Offloading via a Front-end Proxy:

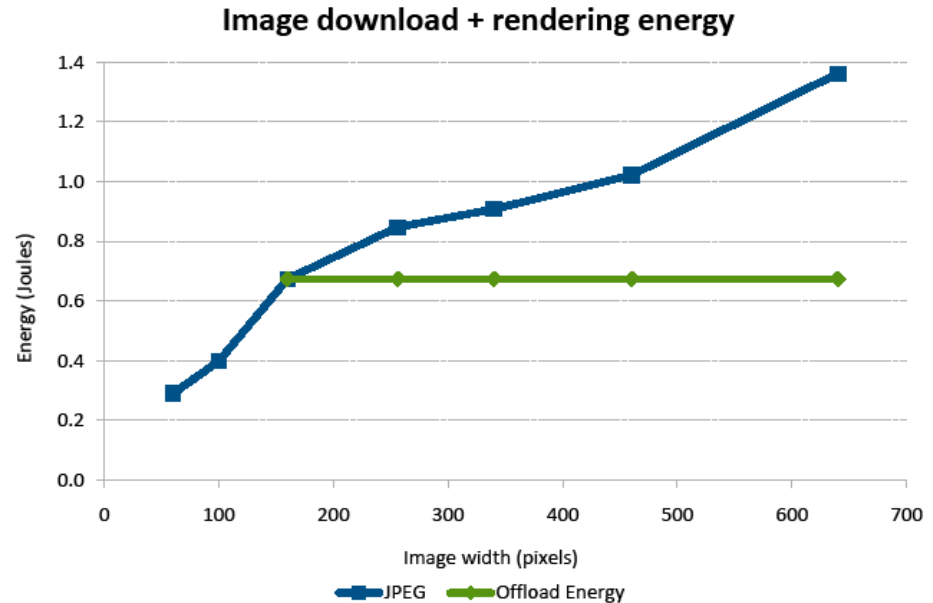
- ✓ A web proxy examines all traffic to the phone and partially renders the page
- ✓ Proxy decides how the content should be modified before it is sent to the phone

➤ Results:

- ✓ Down-scaling images saves energy

➤ Offloading via a Back-end Proxy:

- ✓ Phone downloads web content
- ✓ Offload certain operations to a server
- ✓ Phone decides what needs to be offloaded
- ✓ JPEG – the most efficient encoding
- ✓ Back-end offloading of image rendering is not viable with today's technology



Amazon images converted to:	Page size (kB)	Energy (mJ)
JPEG	26.45	224.68
PNG	65.53	268.05
Bitmap (BMP)	75.19	362.49



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Guidelines for Designing Energy-Efficient Web Sites

- JPEG is the best image format for the Android browser and holds for all image sizes
- Using HTML links instead of Javascript greatly reduces the rendering energy for the page
- Using links to third party tools can greatly increase the power usage of a phone
- Using simple HTML table element to position elements on the page instead of CSS saves energy
- Building a mobile site optimized for mobile devices conserves energy
- Guidelines also produce a faster UX and reduced data consumption



Conclusion

- Mobile web browsing on smartphones is energy hungry
- A framework and tools for measuring the precise energy consumption of web pages, including specific components on the page such as images, Javascript, CSS and plug-in objects
- Estimated the effectiveness of offloading browser heavy computations to a remote server
- By redesigning web sites the energy consumption can be dramatically reduced
- Guidelines for designing energy-efficient web sites
- A prototype on Android OS and the improvement in energy efficiency have been demonstrated



Thank You!



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