Interpreting the significance of Android energy optimisation by collecting large-scale usage information

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August-2011
Part 1: We want to know how much energy a particular action will consume

Part 2: We want to know if this is significant in real usage
Example: joining the wireless network consumes 6 Joules

HTC G1 (or Magic), Android 1.1, 194 trials
We measure energy consumption by intercepting the power supply.

Both voltages are sampled at 250 kHz.

Power \( \propto V_1 \times V_2 \)
Trace of the G1 boot process

HTC G1 (or Magic), Android 1.1
Joining a wireless network

HTC G1 (or Magic), Android 1.1
Access point beacons correlate with spikes in the power trace

HTC G1 (or Magic), Android 1.1
Timestamped events from the phone must be aligned with the appropriate sample points
The synchronization information is embedded in power trace
Hypothesise matching pulses

HTC G1 (or Magic), Android 1.1
Find alignment from autocorrelation with a hypothesised signal

HTC G1 (or Magic), Android 1.1
ARP probing wastes a lot of energy

HTC G1 (or Magic), Android 1.1
Remove the DHCP overhead by using static addressing

HTC G1 (or Magic), Android 1.1
Static addressing reduces the connection cost to 1.5 Joules.
We could remove the ARP probes from our client implementation

RFC2131 “...the client SHOULD probe the newly received address, e.g., with ARP.”

RFC2119 – SHOULD “...there may exist valid reasons in particular circumstances to ignore a particular item”
Android 2.1 doesn't ARP probe in our tests

Google N1, Android 2.1
Dynamic addressing now costs 1.5J

Google N1, Android 2.1, 100 trials / HTC G1 (or Magic), Android 1.1, 194 trials
How much energy is 5 Joules?

- 5 seconds of talk time
- 8 minutes of standby time
- 3.5 minutes of idle wireless (the extra cost of having the wireless on is approx. 0.024W)
Knowing the connection cost helps with system design

- How long should the wireless stay active whilst idle?
  - 6J connection → 250 seconds idle cost
  - 1.5J connection → 62 seconds idle cost
- Is it worth forcing programmers to tell the system explicitly?
It's not clear whether it's worth the effort to apply these optimisations

- Wifi connection – should we change the API to get more detail of an application's intent?
- Sending data – should we change the operating system to support packet level co-scheduling?
- Changes to API are costly
  - To implement
  - To migrate existing applications
We are attempting to build a substantive dataset of smart-phone use.

PhD work by Daniel Wagner
We collect everything...

Handset: on/off, OS version, device type
Screen: on/off, brightness
Storage: size/free/type
Telephony: ringer/mode/roaming/sigstrength/data
Tel events: calls/text/mms/data
Battery: charging/voltage/level
Wifi: connects/scans/data
Bluetooth: connects/scans/data
Apps: source/running/resource use

Some of these require polling
More features coming over the summer
We remove direct identifiers from trace

- Your contacts each get a unique pseudonym
- This doesn't give you anonymity
- You can assign a readable name for your use
- We will only release data which is at least 3 months old → you can opt out retroactively
- Pause functionality available
Current progress (6-Aug-2011)

active devices per week

Release date May 9th

Jun 19th Engadget

Server fail
Implementation lessons…
timestamps are not reliable

- Users manually change the time
  - Travelling, daylight saving
- Sometimes the OS reports invalid dates
  - e.g. after an update for some reason
- How do network corrections get applied?
- Solution: record phone uptime and insert real-time clock events to anchor it
Users are highly sensitive to the size of your application

- Consider effective methods of minimizing size
- Android sorts by size – don't be the biggest!
Please install Device Analyzer
and/or
Please tell us if you have concerns

http://deviceanalyzer.cl.cam.ac.uk

Or search for Device Analyzer by dtg-android on the Android Market
Thanks to
Daniel Wagner, Andy Hopper,
Alastair Beresford, Simon Hay,
Google & Qualcomm

Computing for the Future of the Planet
http://www.cl.cam.ac.uk/research/dtg/planet
The distribution for the G1 phone splits into 3 parts

Dynamic Addressing

Google N1, Android 2.1, 100 trials / HTC G1 (or Magic), Android 1.1, 194 trials
The G1 histogram peaks are due to discontinuities in connection time
Caused by power control in radio?

HTC G1 (or Magic), Android 1.1, Dynamic
This power control is evident when sending data too.

Send 7K of data over TCP

Send 8K of data over TCP

HTC G1 (or Magic), Android 1.1
This effect has a big impact on energy cost

![Graph showing energy consumption per kilobyte over message size.]

- **Best case**: ≈ 0.005 Joules
- **Worst case**: ≈ 0.13 Joules

HTC G1 (or Magic), Android 1.1, 1120 Trials (HTC Hero, Android 1.5 is the same)
N1 energy performance

Best case: same
Worst case: much better

Best case ≈ 0.005 Joules
Worst case ≈ 0.04 Joules

Google N1, Android 2.1, 900 Trials
Programmer should make a different choice depending on the platform

- Using a G1 => send 7k chunks
- Using a Nexus One => the larger the better
- We see unexpected behaviour in both graphs
Measure sending costs by sending UDP packets

Nexus One
Send 4 packets
384ms interval
Android 2.2
Measure sending costs by sending UDP packets

Nexus One
Send 4 packets
224ms interval
Android 2.2
Measure sending costs by sending UDP packets

Nexus One
Send 4 packets
128ms interval
Android 2.2
Measure sending costs by sending UDP packets

Nexus One
Send 4 packets
8ms interval
Android 2.2
Co-scheduling packets between applications would save energy

- (Some) Applications already wait for opportunistic use of the network
- Operating system / library support needed to do better
TCP additionally needs to receive packets – more complex

DTIM=1

DTIM=10
2G consumes more idle power than 3G (in my office)

HTC G1 (or Magic) running Android 1.1
Bluetooth power consumption also shows this 'tail energy' effect

Assume that you want to make a connection to a known device

It has to listen periodically for you attempting to contact it

More frequent listening => quicker connection but more power
We can model fit these two modes as expected.