Energy Consumption in Mobile Phones: A Measurement Study and Implications for Network Applications (IMC09)

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Adapted from Original Slides
Outline

- Motivation
- Contribution
- Measurement
- TailEnder Protocol
- Evaluation
- Conclusion & Discussion
Motivation

- Network application increasingly popular in mobile phones:
  - 50% phones sold in US are 3G/2.5G enabled
  - 60% of smart phones worldwide are WiFi enabled
- Network application are huge power drain and considerably reduce battery life.

How can we reduce the phone's energy cost?
Contributions

- Measurement study on 3G and 2.5G
  - Energy depends on traffic pattern, not just data size
  - 3G incurs a disproportionately large overhead
- Design TailEnder protocol to amortize energy overhead
  - Traffic shaping
  - Energy reduced by 40% for common applications including email and web search based on 3G
Measurement

- 3G/2.5G Power Consumption Components
- Measurement Goals
- Measurement Results
3G/2.5G Power consumption

Power profile of transmitting one data

- Ramp
  - create dedicated channel
- Transfer
  - Data Transmission
- Tail
  - reduce signaling overhead and latency

How to improve the energy cost efficiency???
Try to put more data transmission here

Not So Simple!
More on the Tail Time

- Alleviates the delay incurred in moving to the high power state from the idle state.
- It reduces the signaling overhead incurred due to channel allocation and release during state transitions.

Tail time is the trade-off between latency and energy.

- The tail time is set by the operator to reduce latency. Devices do not have control over it.
Measurement Goals

- What fraction of energy is consumed for data transmission instead of other overheads?

- How does energy consumption vary with application workloads and traffic patterns for cellular network?
3G Energy Distribution for a 100K download

Total energy = 14.8J

Tail time = 13s

Tail energy = 7.3J

Data Transfer (32%)

Ramp (14%)

Tail (52%)
100K download: GSM

- GSM (2.5G)
  - Data transfer = 74%
  - Tail energy= 25%
More analysis of the 3G Tail

Over varied data sizes, days and network conditions

Experiments over three days

At different locations

(c) Geographical variation
3G: Varying inter-transfer time

Decreasing inter transfer time reduce energy!
Sending more data requires less energy!

Why?
TailEnder Protocol

• **Observations:** Several applications can
  - Tolerate delays: Email
  - Prefetch: Web search

• **Implication:** Exploiting prefetching and delay tolerance can decrease time between transfers

Traffic Shaping!
TailEnder Design

- Application that are delay tolerant
- Application that can benefit from prefetching
Exploiting delay tolerance

How can we schedule requests such that the time in the high power state is minimized?
TailEnder scheduling

- Online problem: No knowledge of future requests
TailEnder algorithm

- If the request arrives within $\rho.T$ from the previous deadline, send immediately.
  $0 \leq \rho \leq 1$

- Else, defer until earliest deadline.

Why we need $\rho$?
How to set $\rho$'s value?

1. TailEnder is within $2x$ of the optimal offline algorithm
2. No online algorithm can do better than $1.62x$
TailEnder Design

- Application that are delay tolerant
- Application that can benefit from prefetching
TailEnder for web search

Current web search model

Idea: Prefetch web pages.

Challenge: Prefetching is not free!
How many web pages to prefetch?

- Analyzed web logs of 8 million queries

TailEnder prefetches the top 10 web pages per query
Evaluation

• Methodology
  - Application traces-based simulation
  - Emulation on the phones

• Baseline
  - Default algorithm that schedules every request when it arrives
Evaluation: Email

With delay tolerance = 10 minutes

For increasing delay tolerance

TailEnder nearly halves the energy consumption for a 15 minute delay tolerance. (Over GSM, improvement is 25%)
Evaluation: Web search

% energy improvement

Wireless technology

3G

GSM
## Web search emulation on phone

**Metrics:** Number of queries processed before the phone runs out of battery

<table>
<thead>
<tr>
<th></th>
<th>Default</th>
<th>TailEnder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queries</td>
<td>622</td>
<td>1011</td>
</tr>
<tr>
<td>Web pages retrieved</td>
<td>864</td>
<td>10110</td>
</tr>
<tr>
<td>Latency (seconds)</td>
<td>1.7</td>
<td>1.2</td>
</tr>
</tbody>
</table>

TailEnder retrieves more data, consumes less energy and enjoys lower latency!
Conclusions & Discussion

- Large overhead in 3G has non-intuitive implications for application design.

- TailEnder amortizes 3G overhead to significantly reduce energy for common applications

- Competitive analysis for $\rho$
  - The $\rho$'s value depends on the competitive analysis (how we choose the adversary). Is the value claimed in the paper the optimal?
  - Try to make schedules based on the prediction of requests' arrivals?
  - How to schedule transmission among different applications?