

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

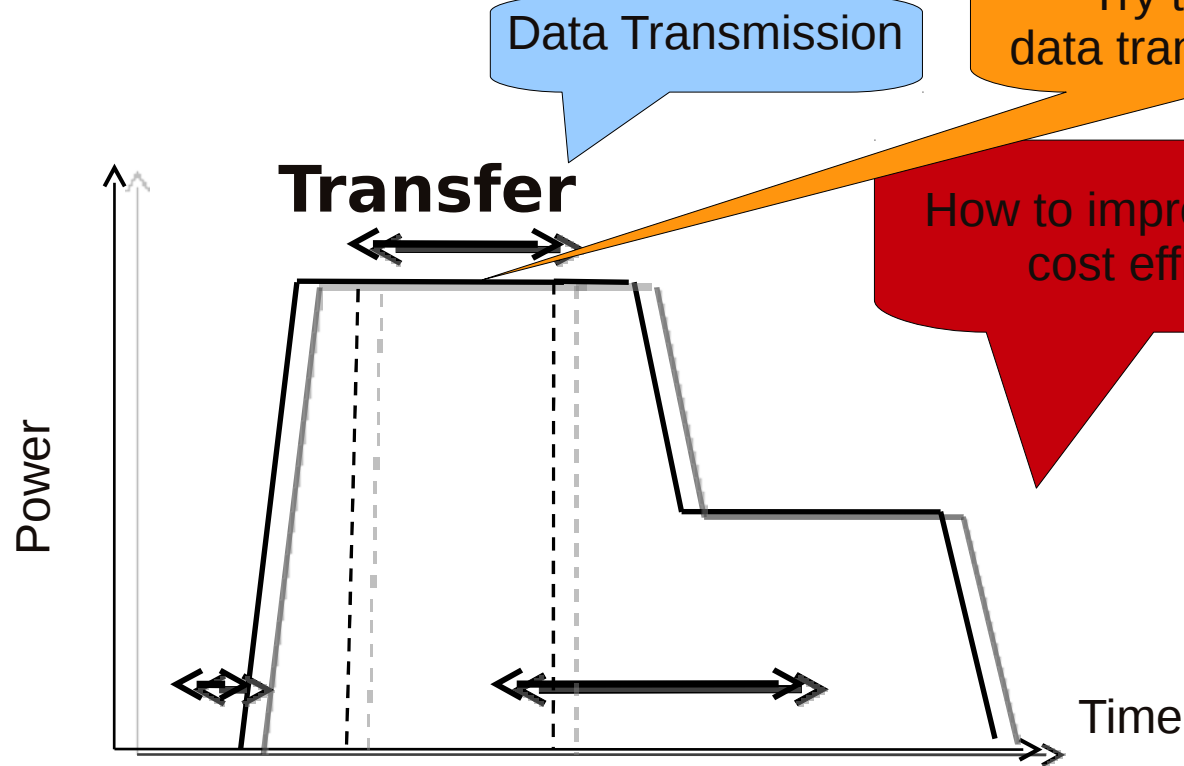
Measurement

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

3G/2.5G Power consumption

Not So Simple!

Power profile of transmitting one data



Ramp

create dedicated channel

Tail

reduce signaling overhead and latency

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

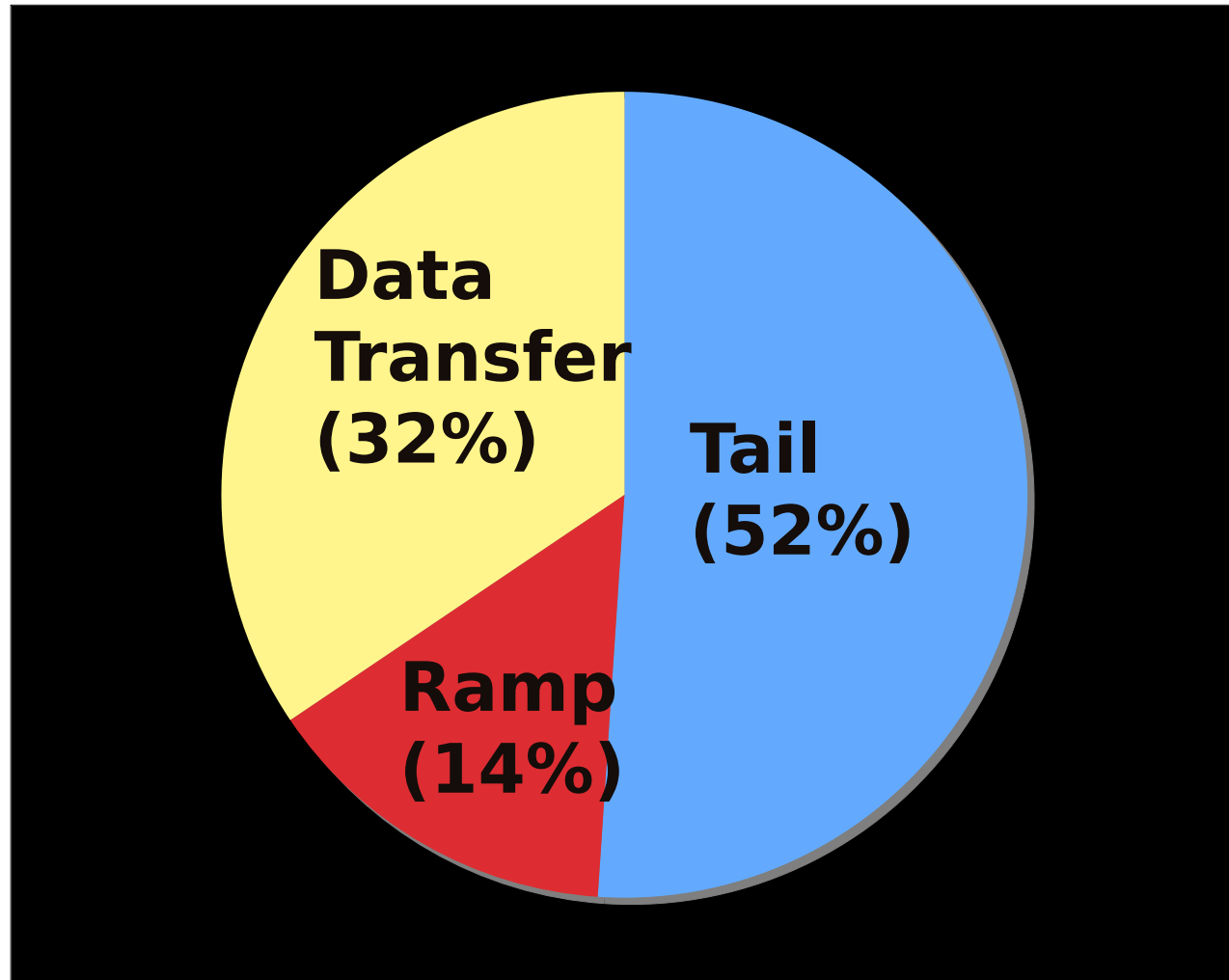
- The tail time is set by the operator to reduce latency. Devices do not have control over it.

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

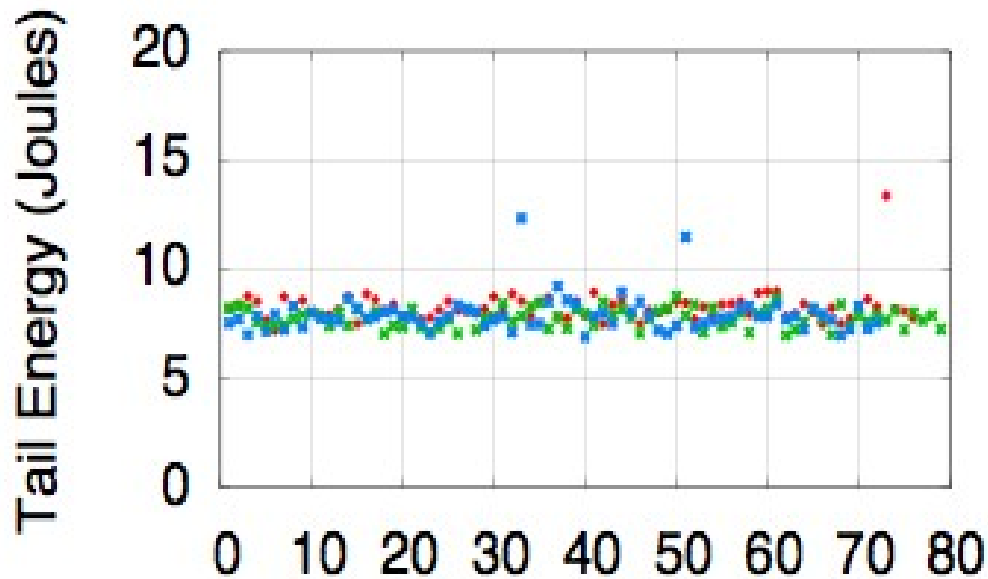
Tail energy = 7.3J

100K download: GSM

- GSM (2.5G)
 - Data transfer = 74%
 - Tail energy = 25%

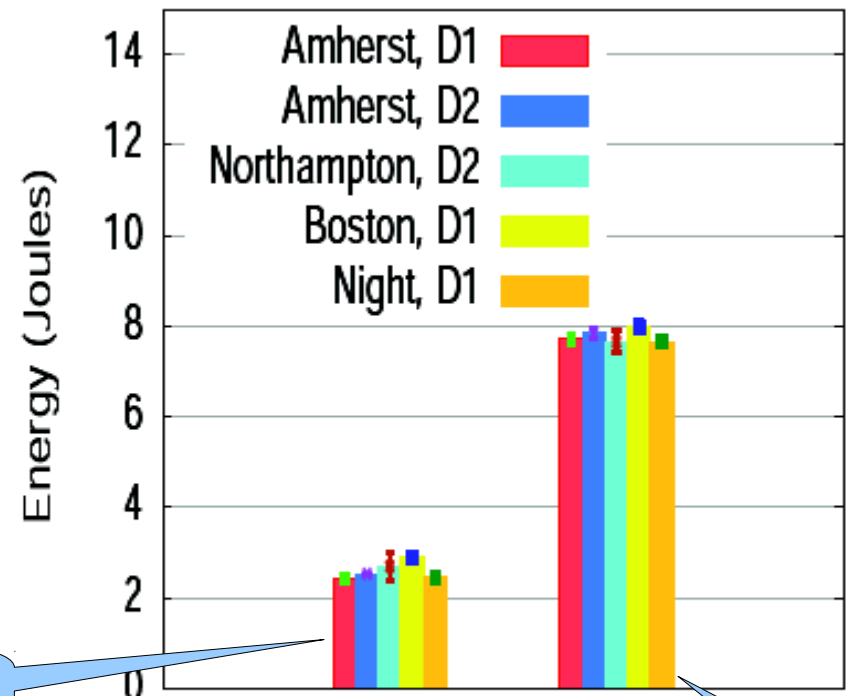
More analysis of the 3G Tail

Over varied data sizes, days
and network conditions



Experiments over three days

At different
locations

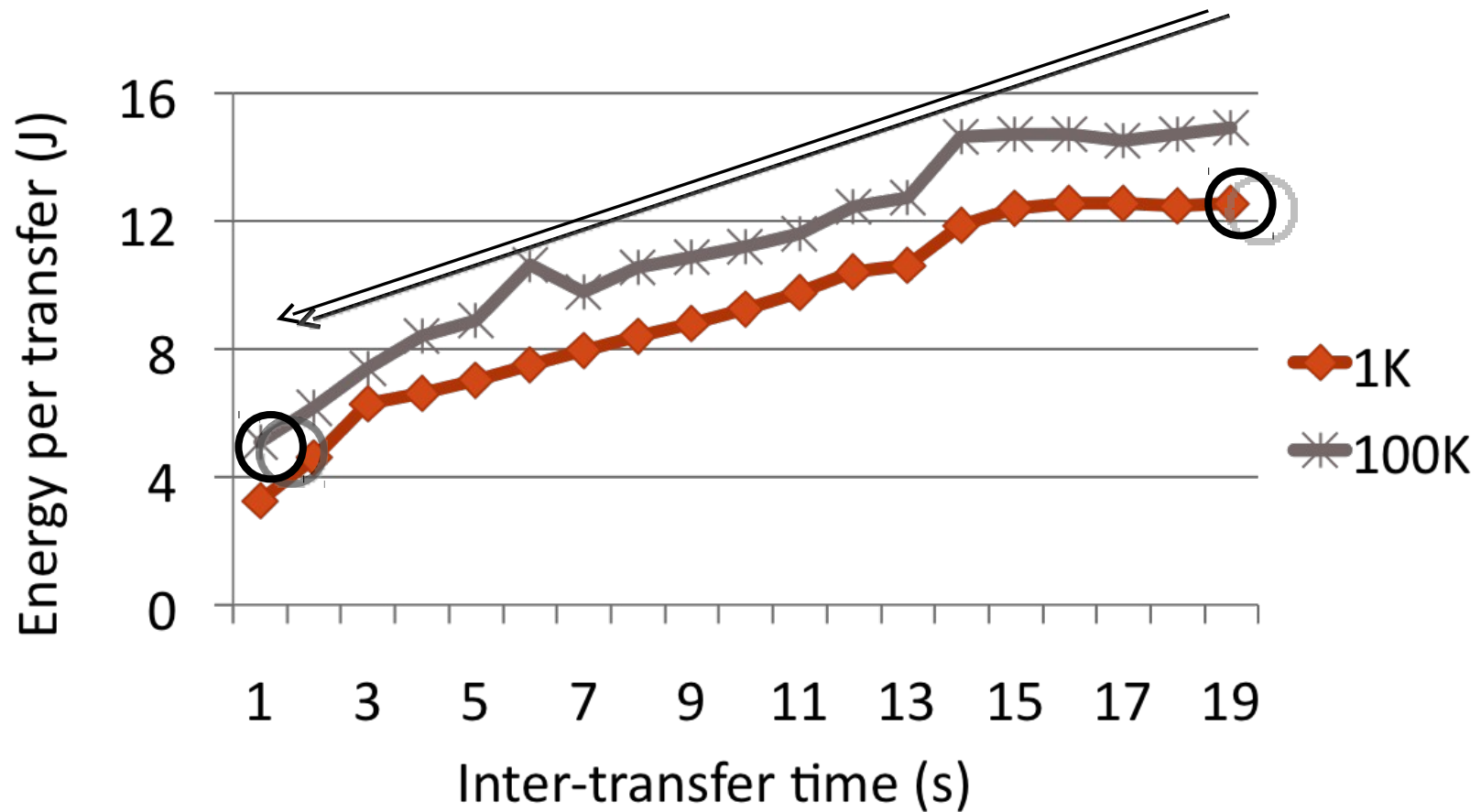


Ramp

(c) Geographical variation

Tail

3G: Varying inter-transfer time



Decreasing inter transfer time reduce energy!

Sending more data requires less energy!

Why?

TailEnd Protocol

- **Observations:** Several applications can
 - Tolerate delays: Email
 - Prefetch: Web search
- **Implication:** Exploiting prefetching and delay tolerance can decrease time between transfers

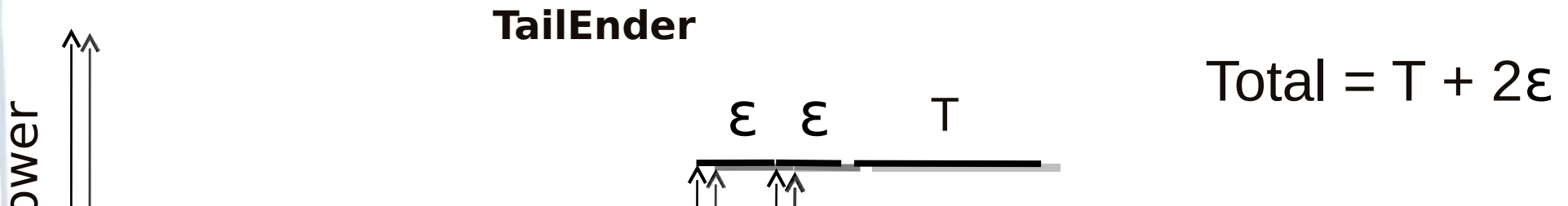
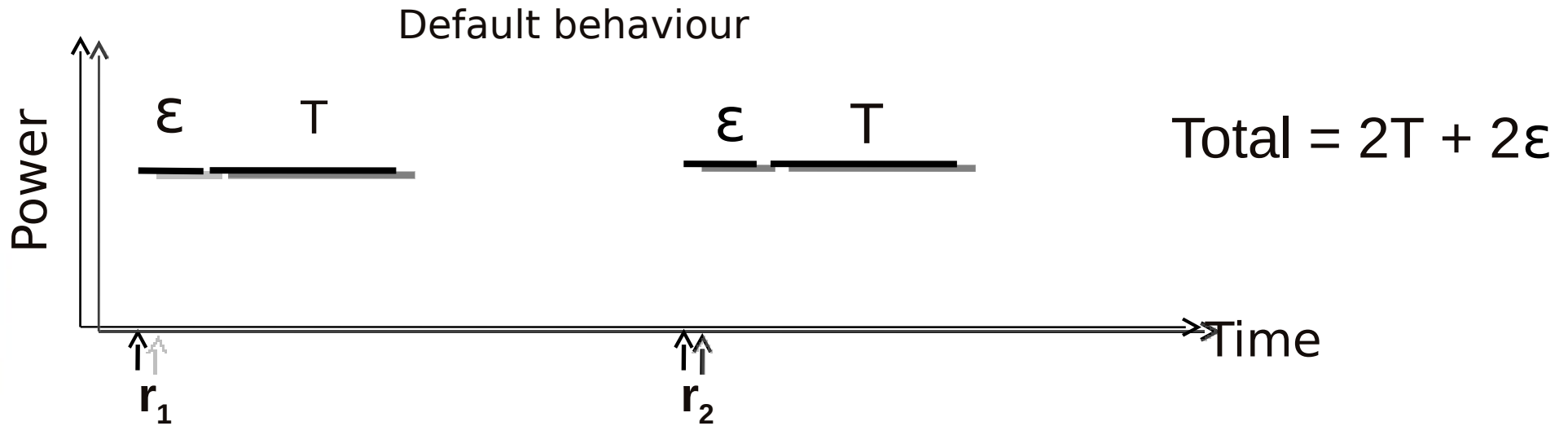


Traffic Shaping!

TailEnd Design

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

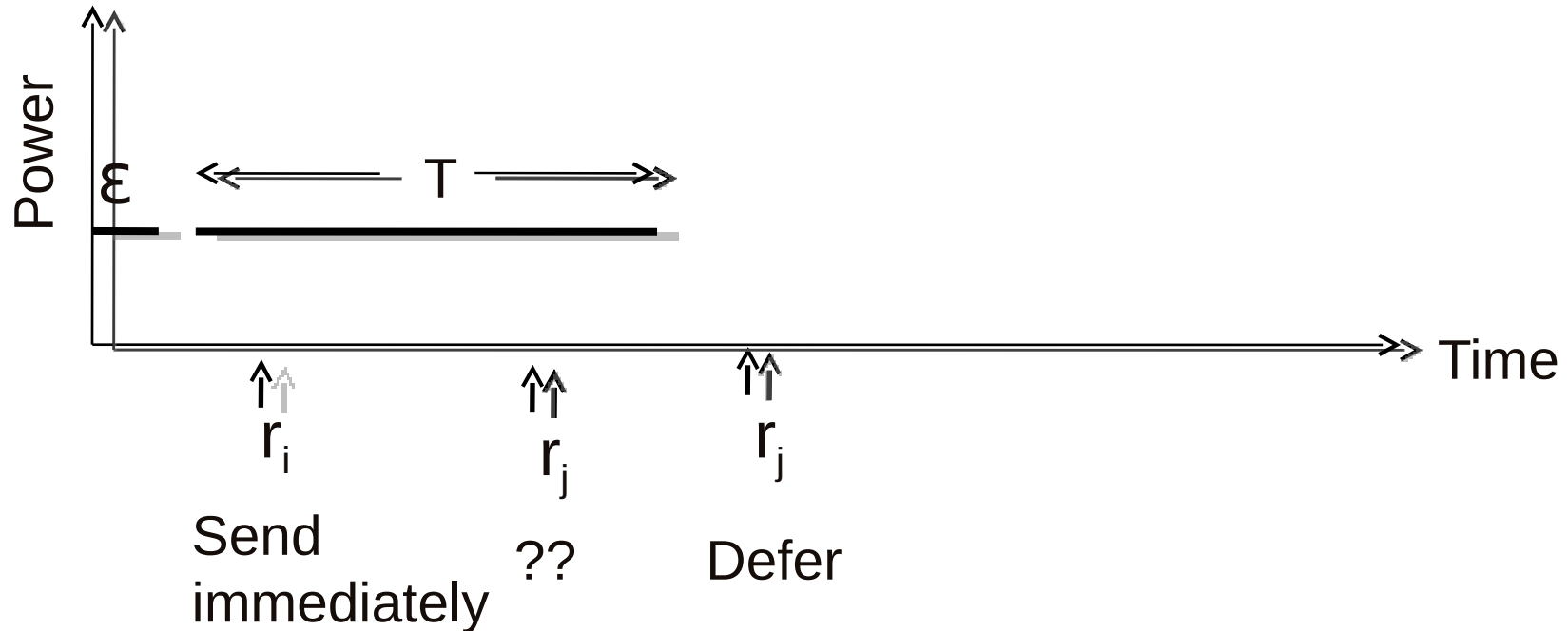
Exploiting delay tolerance



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 $\rho \cdot T$ from the previous deadline, *send immediately*

$$0 \leq \rho \leq 1$$

Tail time

- Else, *defer until earliest deadline.*

Why we need ρ ?
How to set ρ 's value?

Competitive
Analysis

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

TailEndr for web search

Current web search model

Nokia N95

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The **Nokia N95** (N95-1, internally known as RM-159) is a smartphone produced by **Nokia** as part of their Nseries line of portable devices. The **N95** runs Symbian OS v9.2, with a S60 3rd ...
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The **Nokia N95** (N95-1, internally known as F The N95 runs [Symbian OS v9.2](#), with a [S60](#) to access either media playback buttons or a Its capabilities include^{[1][2]}: a [Global Position camera with Carl Zeiss optics](#), flash, video re Bluetooth; a portable media player with the a

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It's what computers have become

- connect to the world faster
- get clearer photos and videos
- navigate quickly and easily

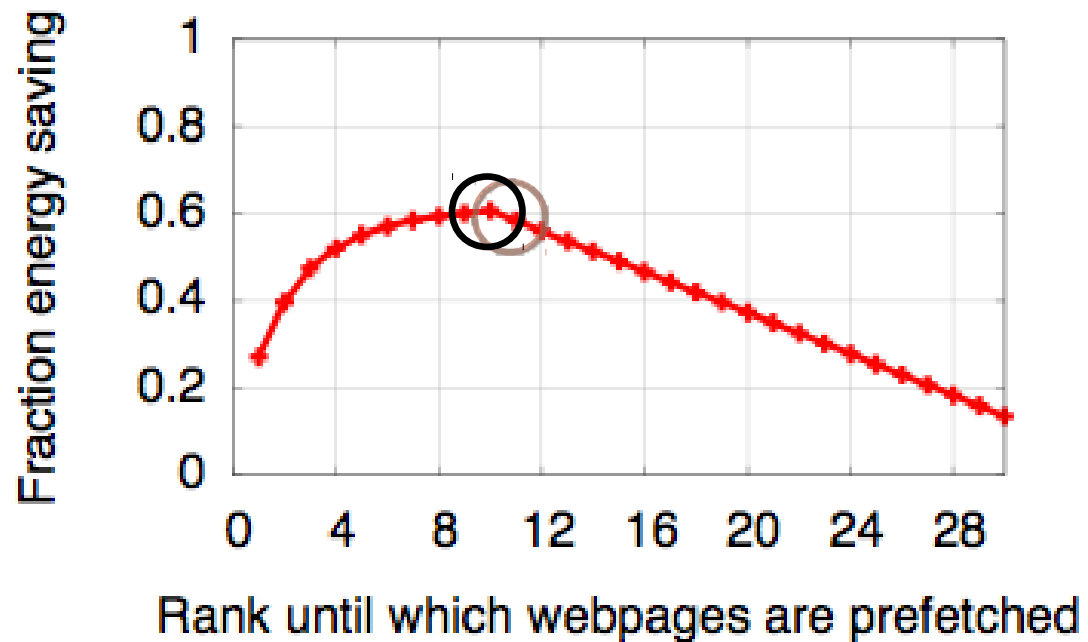
Idea: Prefetch web pages.

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



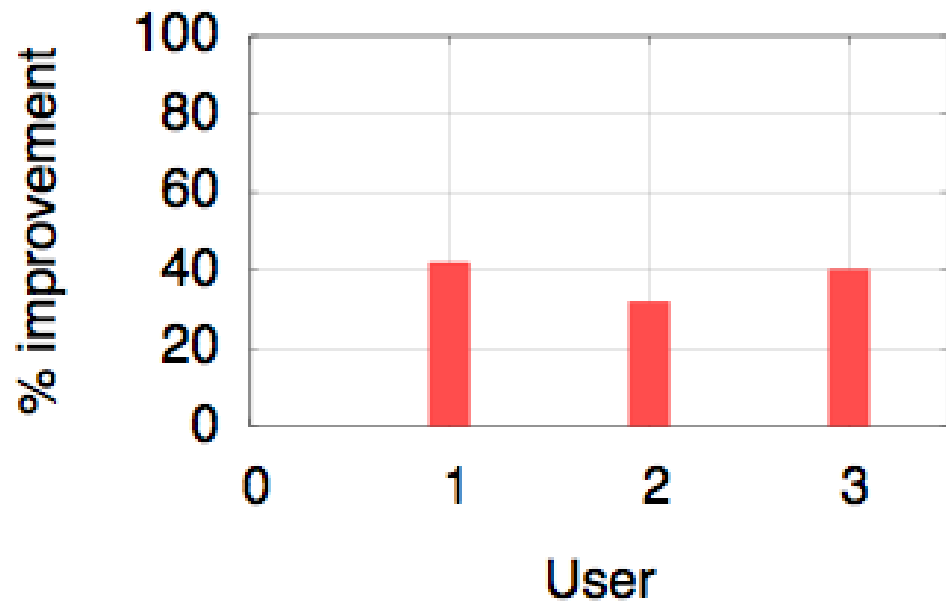
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Evaluation

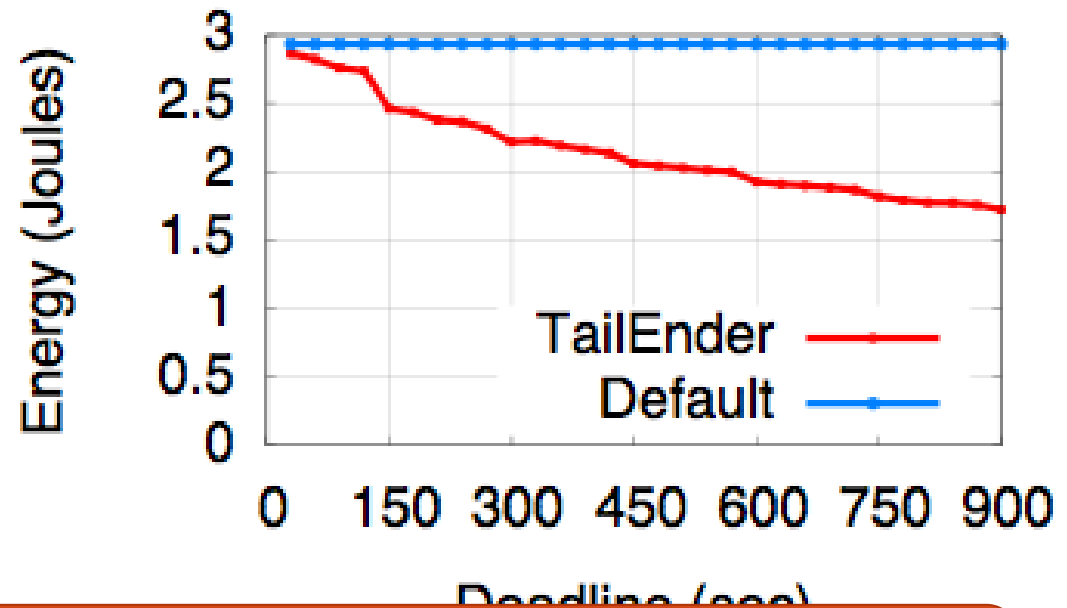
- Methodology
 - Application traces-based simulation
 - Emulation on the phones
- Baseline
 - Default algorithm that schedules every requests when it arrives

Evaluation: Email

With delay tolerance = 10 minutes

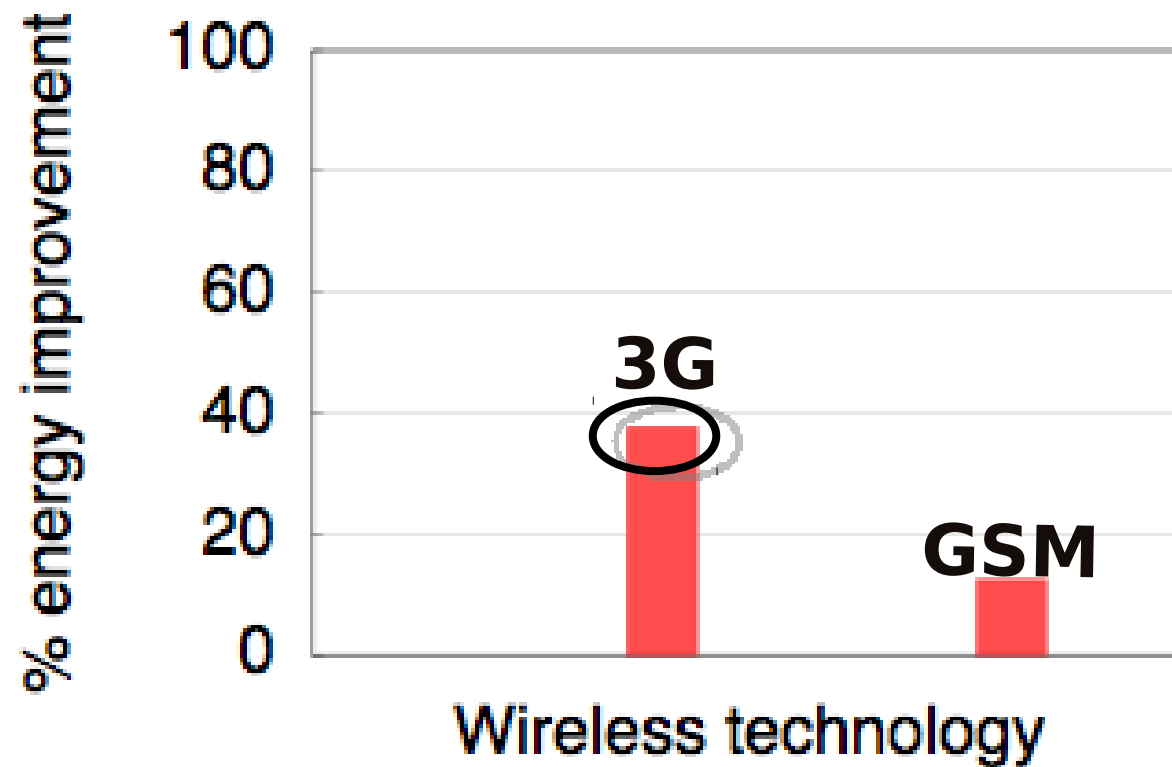


For increasing delay tolerance



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

Evaluation: Web search



Web search emulation on phone

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

	Default	TailEnder
Queries	622	1011
Web pages retrieved	864	10110
Latency (seconds)	1.7	1.2

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 ρ
- The ρ '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?