RadioJockey: Mining Program Execution to Optimize Cellular Radio Usage

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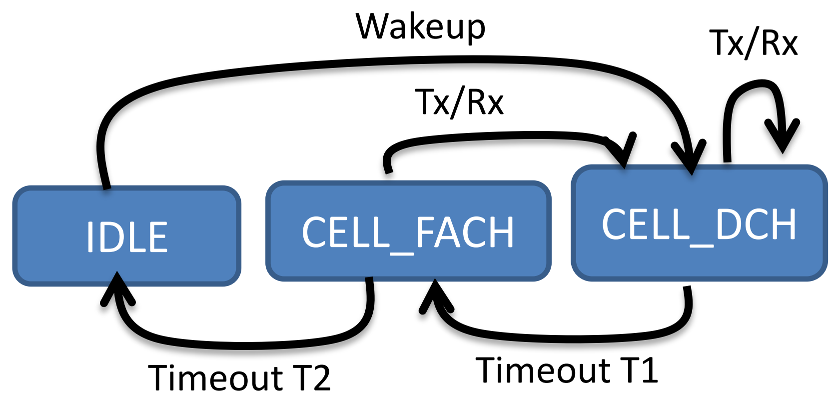
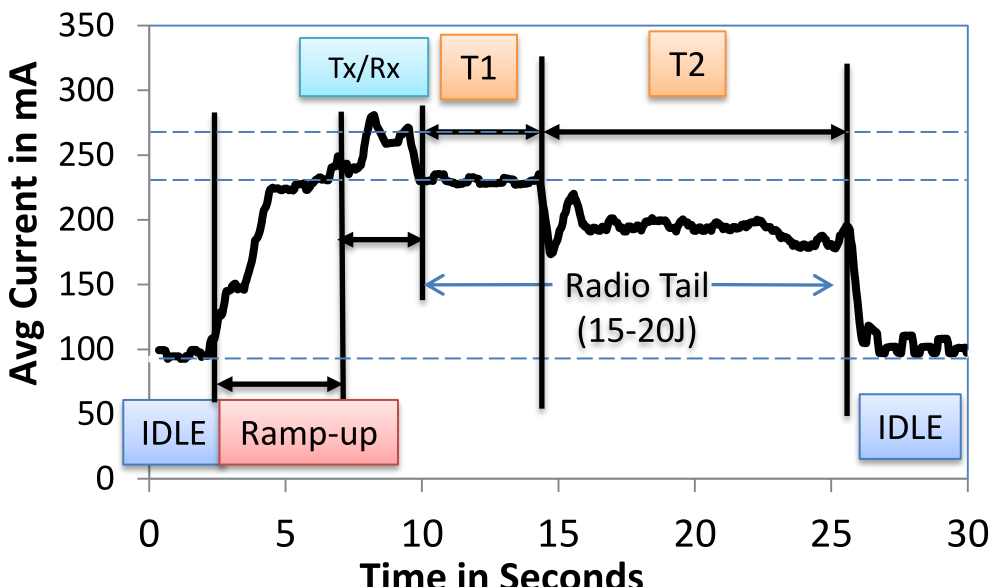
Problem Context: Overheads in Cellular Radio Usage

State transitions based on:
(1) traffic volume
(2) operator chosen timers



Power Consumption



Signaling

Transition	# control messages
IDLE → DCH	30
DCH → IDLE	2

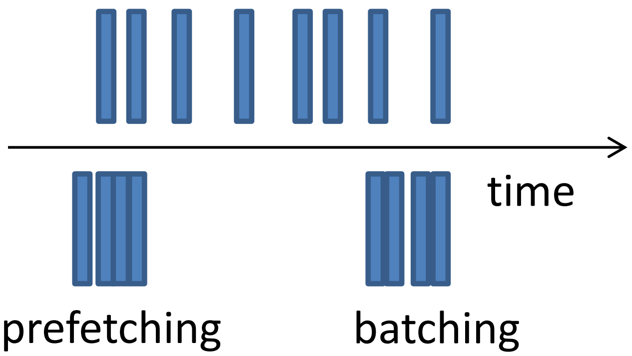
Latency

Transition	Secs
IDLE → DCH	2
DCH → IDLE	20

Existing Radio-tail Optimizations

1. Amortize tail overhead by shaping traffic

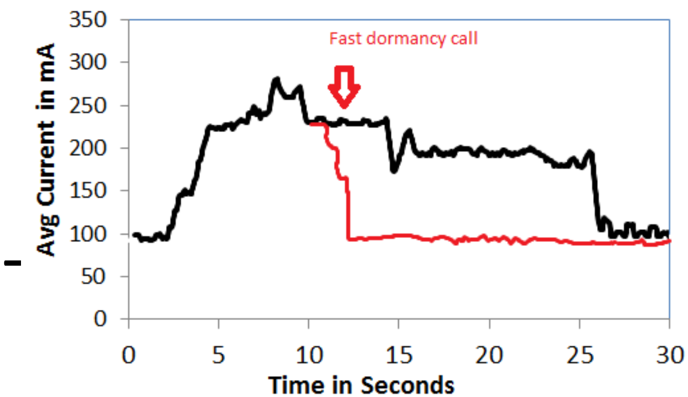
    a) TailEnder [IMC 09]



2. Adapt tail using Fast-dormancy

    a) Based on application hints – TOP [ICNP 10]

    b) Based on client-side idle timers - Falaki et al. [IMC 10]



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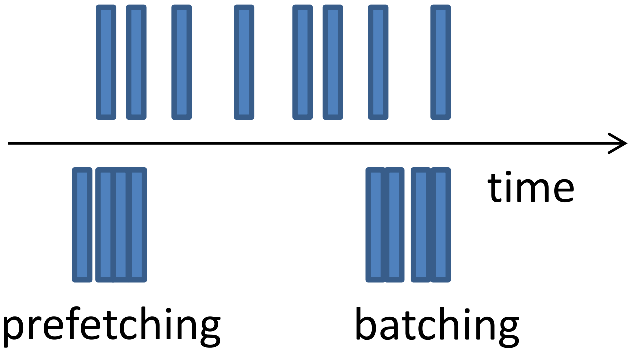


a) TailEnder [IMC 09]

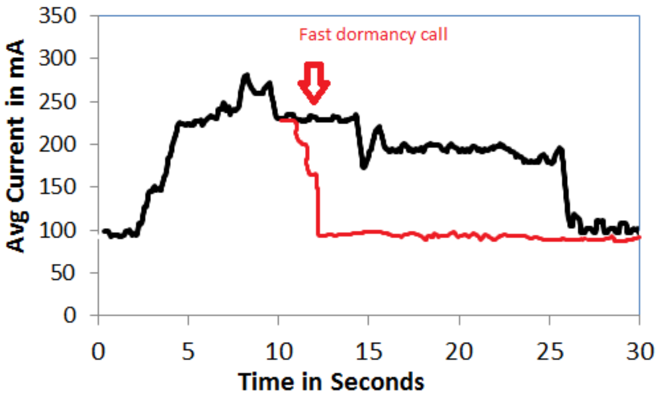
Requires app changes

2. Adapt tail using Fast-dormancy

a) Based on application hints –

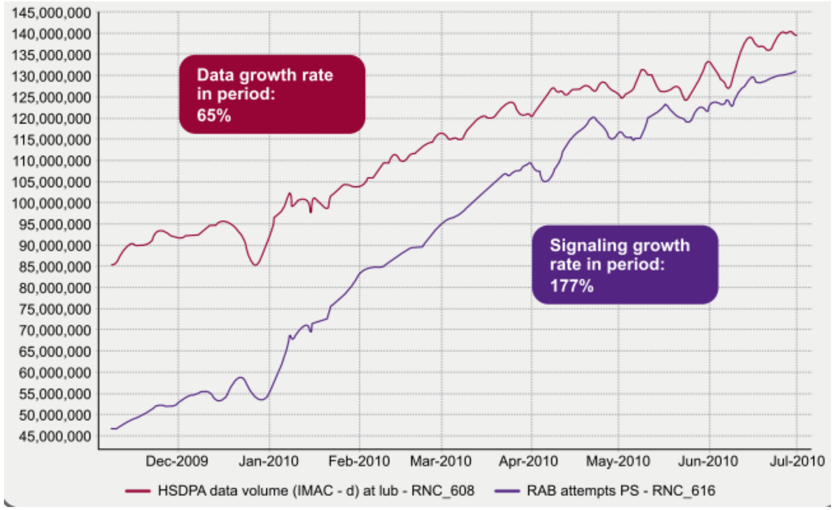
Requires app changes + developer awareness

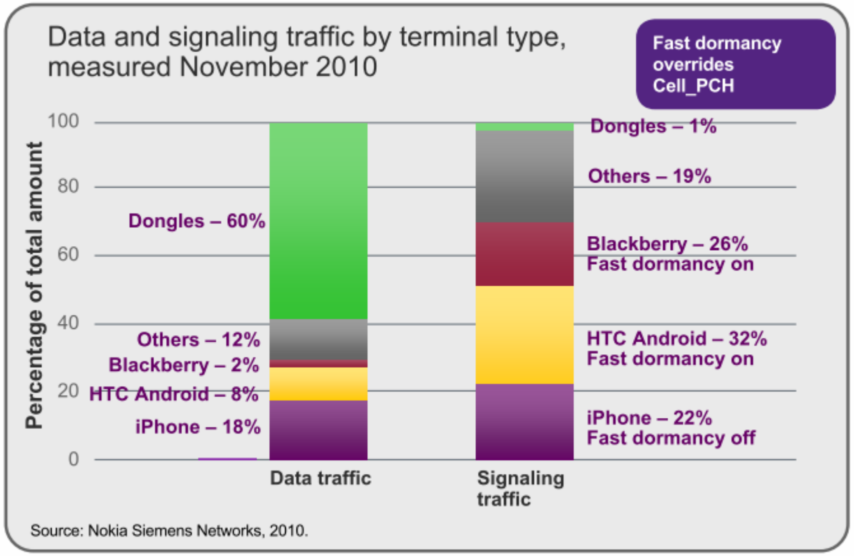
b) Based on client-side idle timers -



Commonly used in many smartphones (3-5 sec timers)

Fast Dormancy Woes

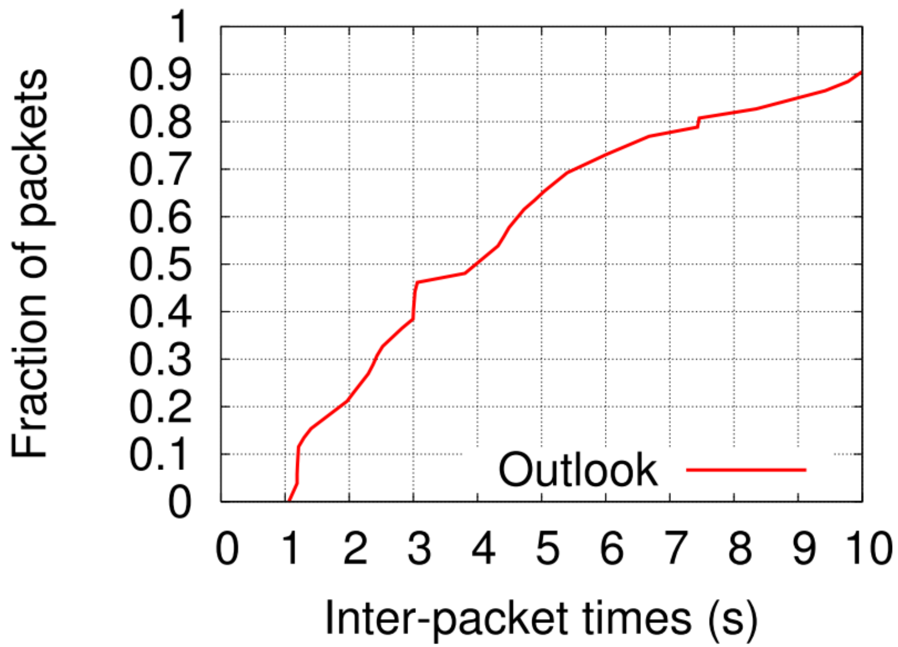




Disproportionate increase in signaling traffic caused due to increase in use of fast-dormancy

"Apple upset several operators last year when it implemented firmware 3.0 on the iPhone with a fast dormancy feature that prematurely requested a network release only to follow on with a request to connect back to the network or by a request to re-establish a connection with the network …"
[What's really causing the capacity crunch? - FierceWireless]()

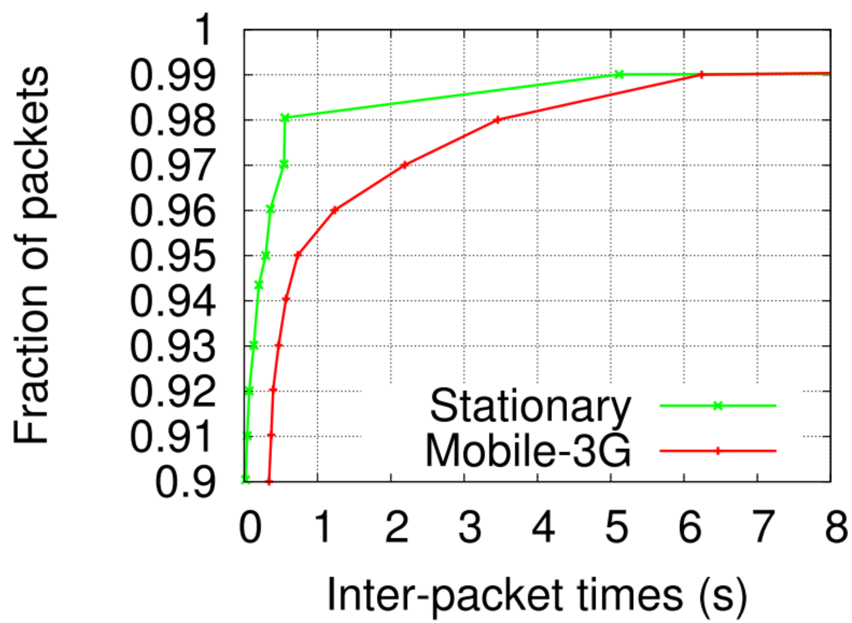
Problem #1: Chatty Background Apps



CDF of inter-packet times for Outlook application running in background

- No distinctive knee
- High mispredictions for fixed inactivity timer

Problem #2: Varying Network Conditions



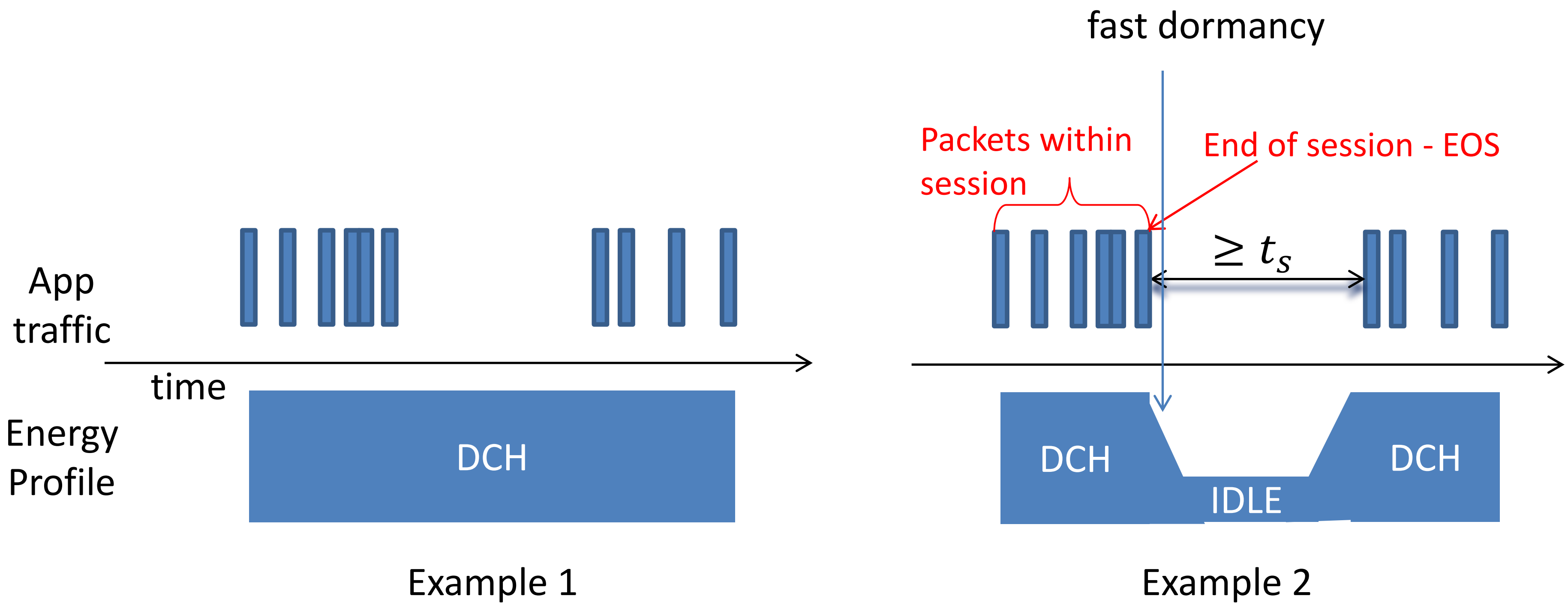
CDF of inter-packet times for Lync application for different network conditions

- Signal quality variations and handoffs cause sudden latency spikes
- Aggressive timers frequently misfire

Objectives

- Design a fast-dormancy policy for long-standing background apps which
  - Achieves energy savings
  - Without increasing signaling overhead
  - Without requiring app modifications

When to Invoke Fast Dormancy?



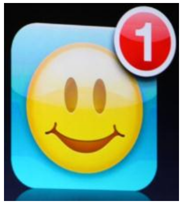
Energy savings when $t_s \geq 3\ sec$ and fast dormancy is invoked immediately after end of session

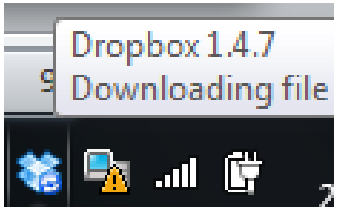
Problem: predict end of session (or onset of network inactivity)

Idea: exploit unique application characteristics (if any) at end of sessions

Typical operations performed:

- UI element update



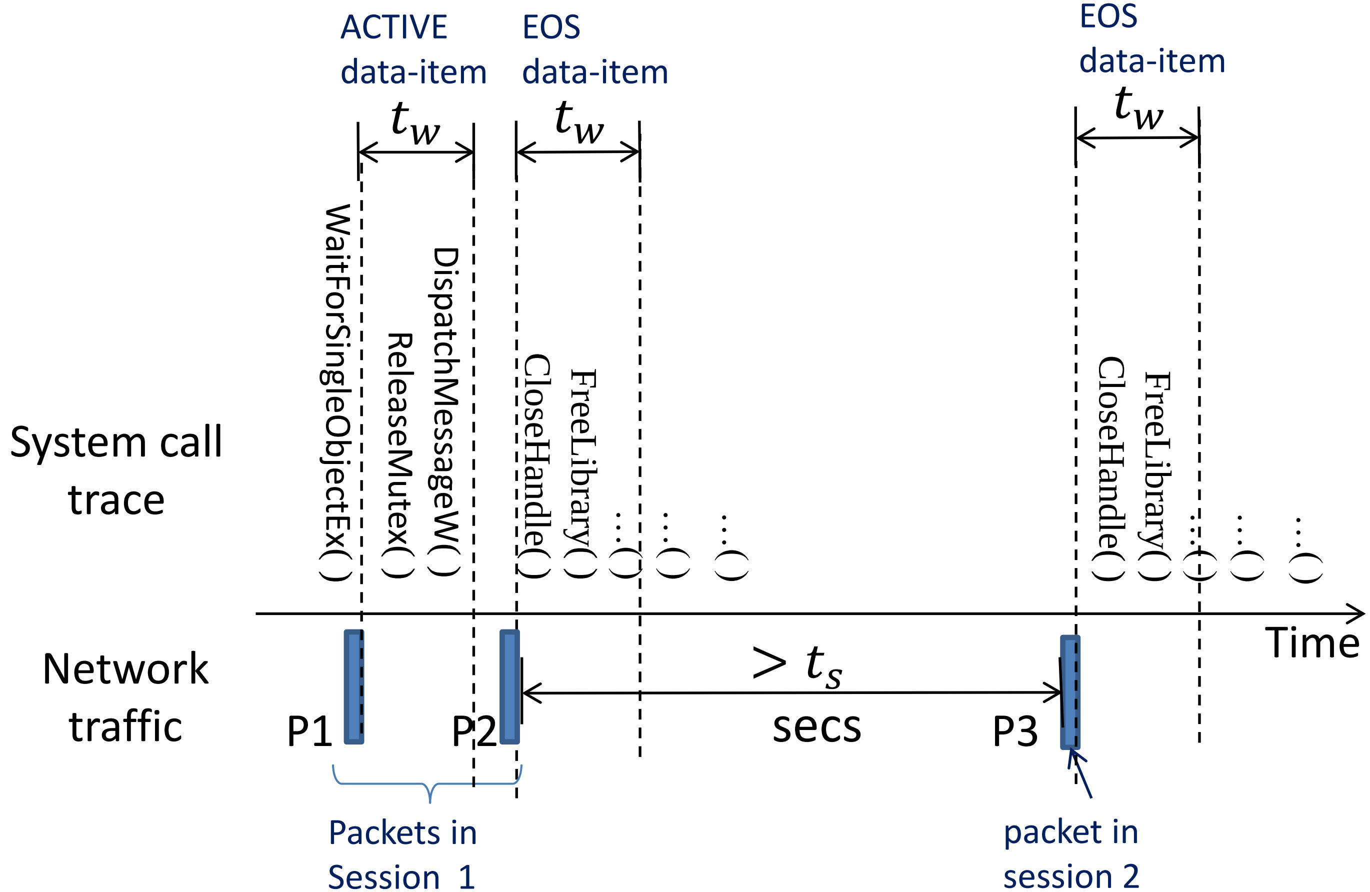


- Memory allocation or cleanup
- Processing received data

System calls invoked by an app can provide insights into the operations being performed

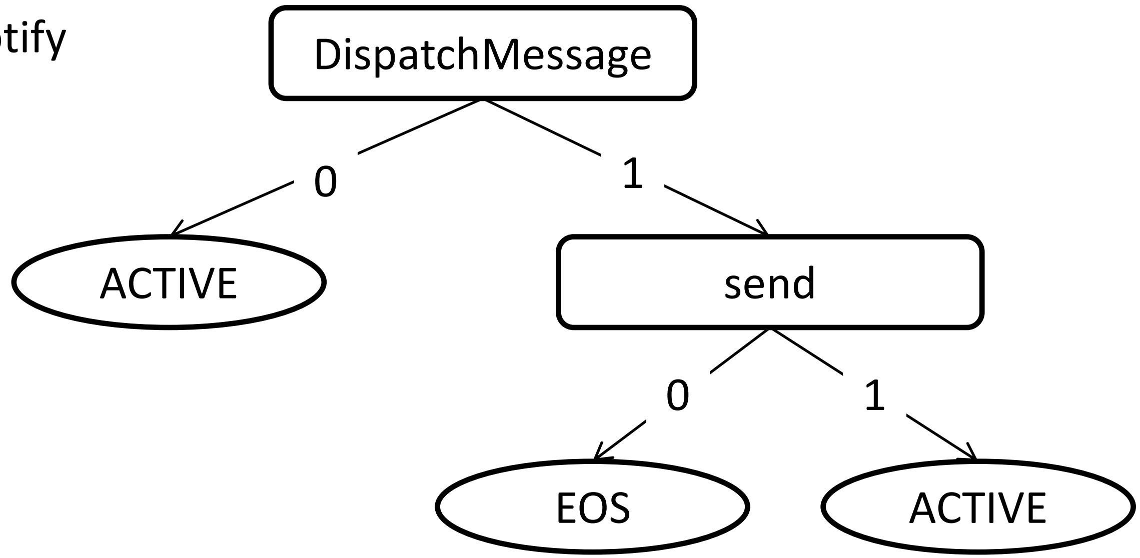
Predicting onset of network inactivity

- Technique: Supervised learning using C5.0 decision trees
- Data item: system calls observed immediately after a packet (encoded as bit-vector)
- Label: ACTIVE or EOS



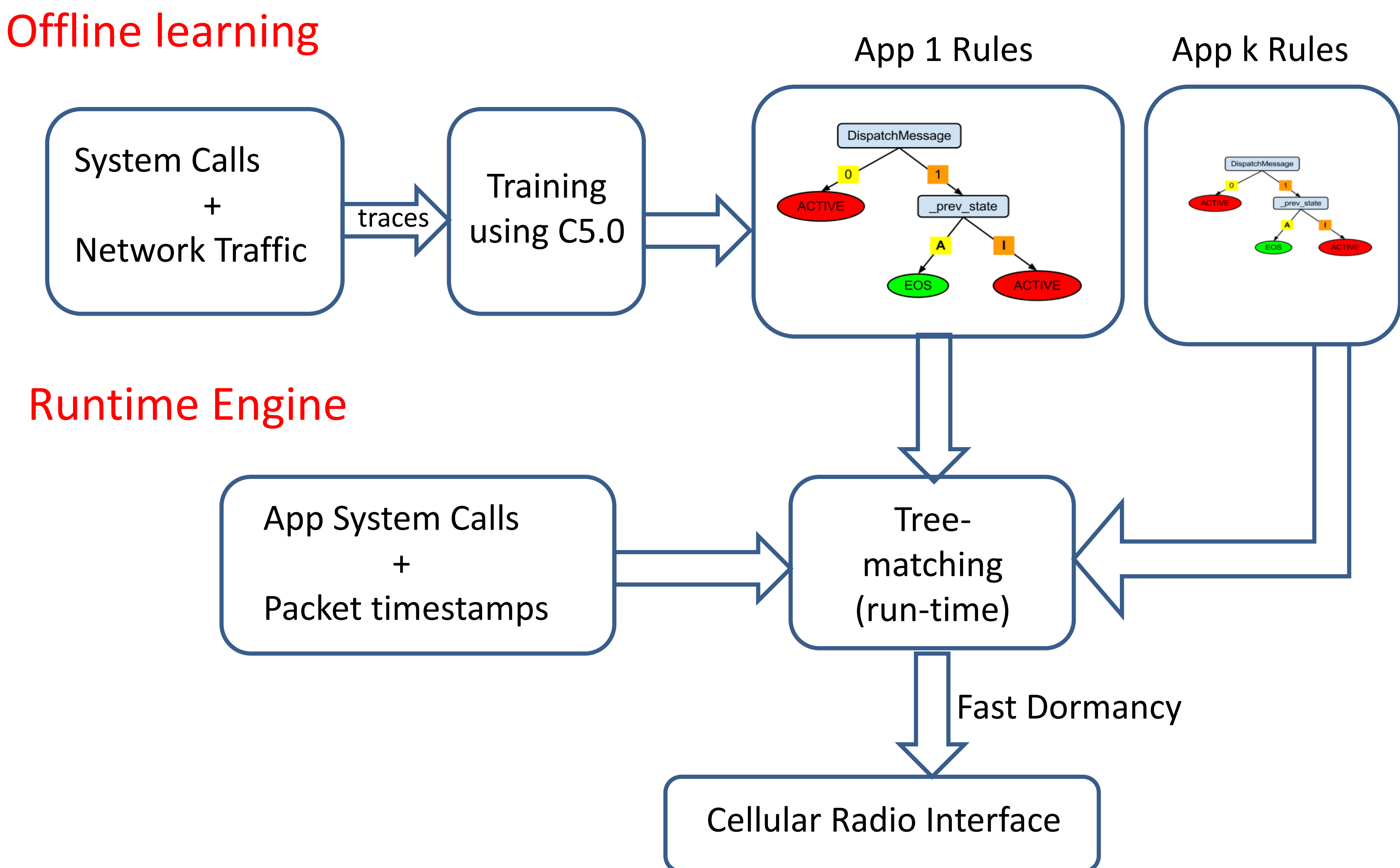
Decision tree example

Application: gnotify



Rules:
(DispatchMessage & ! send) => EOS
! DispathcMessage => ACTIVE
(DispatchMessage & send) => ACTIVE

RadioJockey System

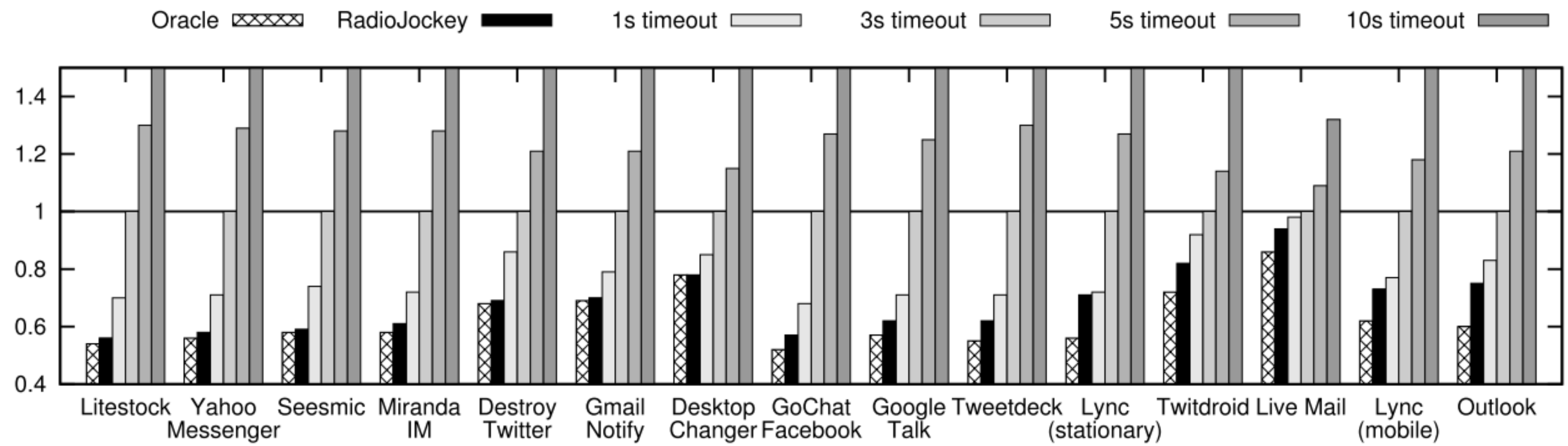


Evaluation Overview

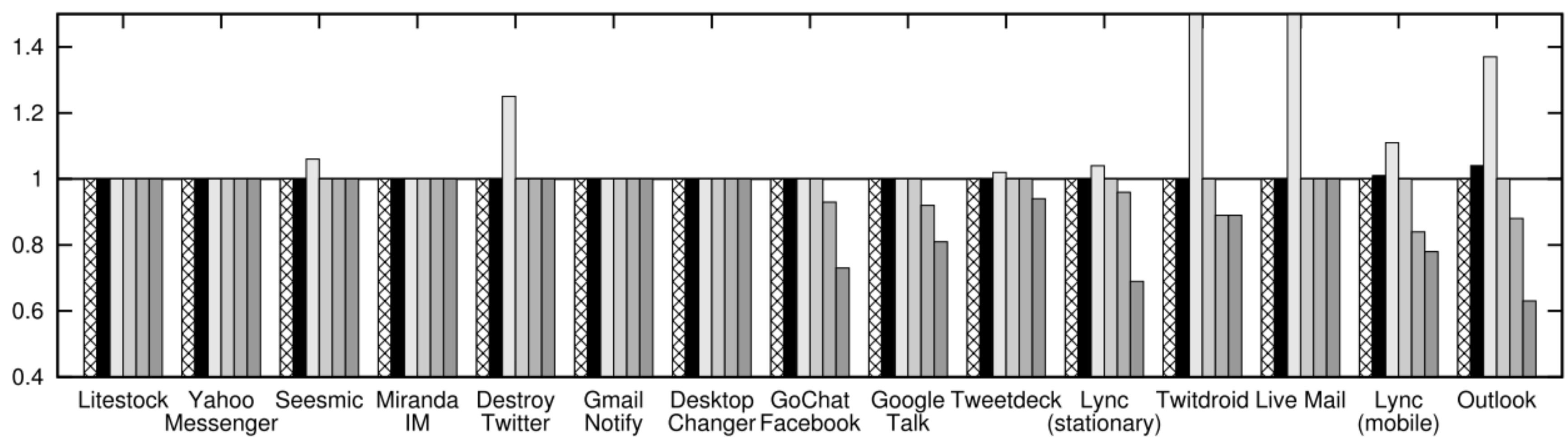
1. Trace driven simulations on traces from 14 applications (Windows and Android platform) on 3G network
   - Feature set evaluation for training
   - variable workloads and network characteristics
   - 20-40% energy savings and 1-4% increase in signaling over *3 sec idle timer*

2. Runtime evaluation on 3 concurrent background applications on Windows

Energy drain and signaling overhead



Energy consumed normalized to a 3-second idle timer approach



Signaling overhead normalized to a 3-second idle timer approach

Runtime Evaluation with Concurrent Background Applications

Applications	Energy Savings (%)	Signaling Overhead (%)
Outlook	24.03	4.47
GTalk	24.07	4.57
Lync	24.14	0
All	22.8	6.96

- 22-24% energy savings at a cost of 4-7 % signaling overhead
- Marginal increase in signaling due to variance in packet timestamps

Summary

- RadioJockey predicts onset of network inactivity using system calls invoked by background apps
- Requires no modifications to existing apps – legacy, native and managed apps
- Achieves energy savings of 20-40% with marginal increase in signaling overhead

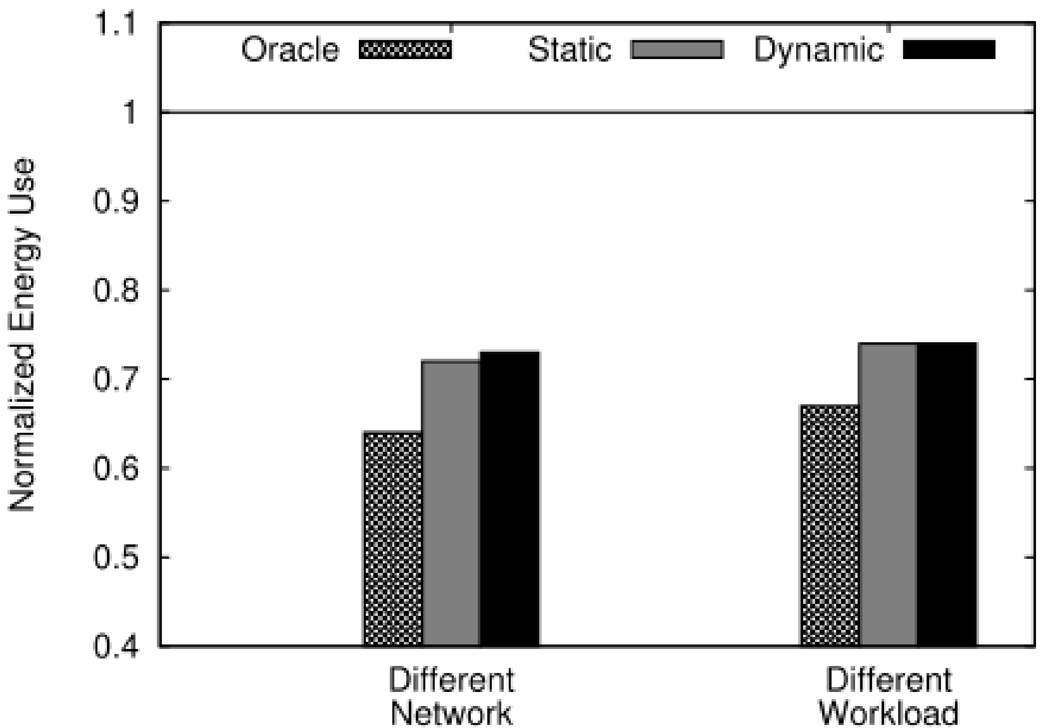
Backup Slides

Predict using only network features

- Features : IP, ports, TCP flags, HTTP headers

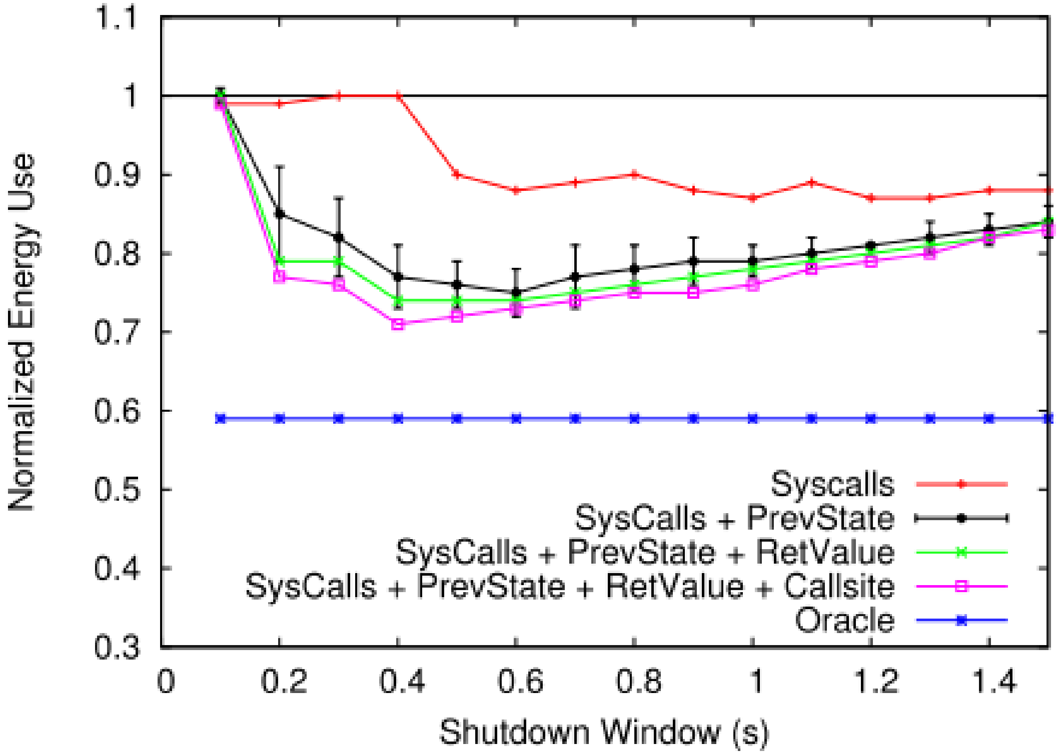
- Performance:
  - Energy savings only for simple apps
  - No good rules for complex apps(Outlook and Lync)
  - Cannot handle apps that use encryption

Varying networks and workloads



Energy consumed normalized to a 3-second idle timer approach

Feature Space Exploration and Choice of Window Size



- PrevState feature captures temporal state information
- Adding PrevState into learning boosted savings
- t_w of 0.5 seconds sufficient for most applications

Understanding Fast Dormancy Feature

- Client controlled
- Tail energy reduced to ~1.5J
- Without network support
  - RRC connection torn down
  - DCH/FACH to IDLE
  - Ramp-up costs up to 30 msgs
- With network support
  - Ramp-down to PCH instead of IDLE
  - Ramp-up to DCH incurs 12 msgs