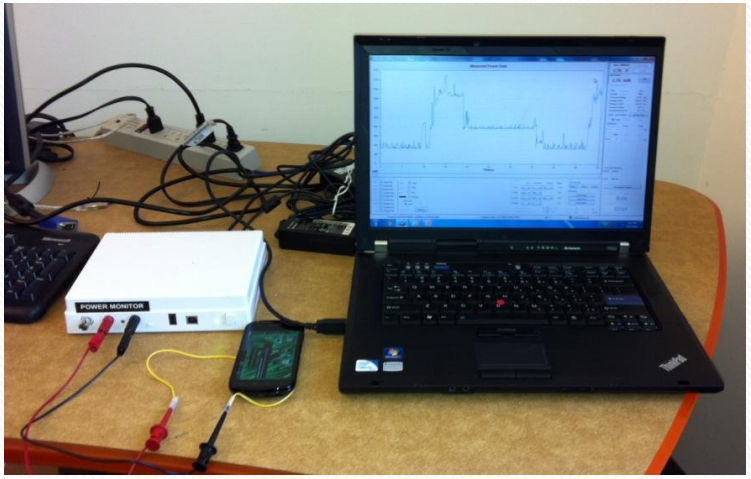
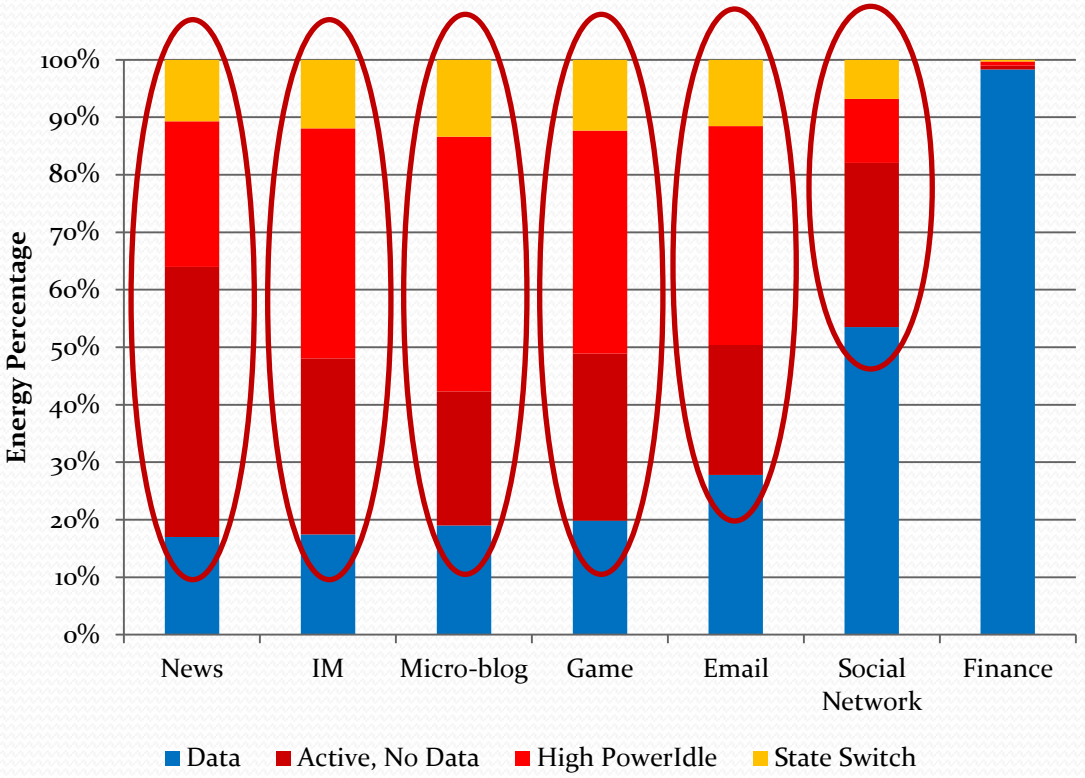
Traffic-Aware Techniques to Reduce 3G/LTE Energy Consumption

Shuo Deng, Hari Balakrishnan
MIT CSAIL

Problem: 3G/LTE is a battery hog

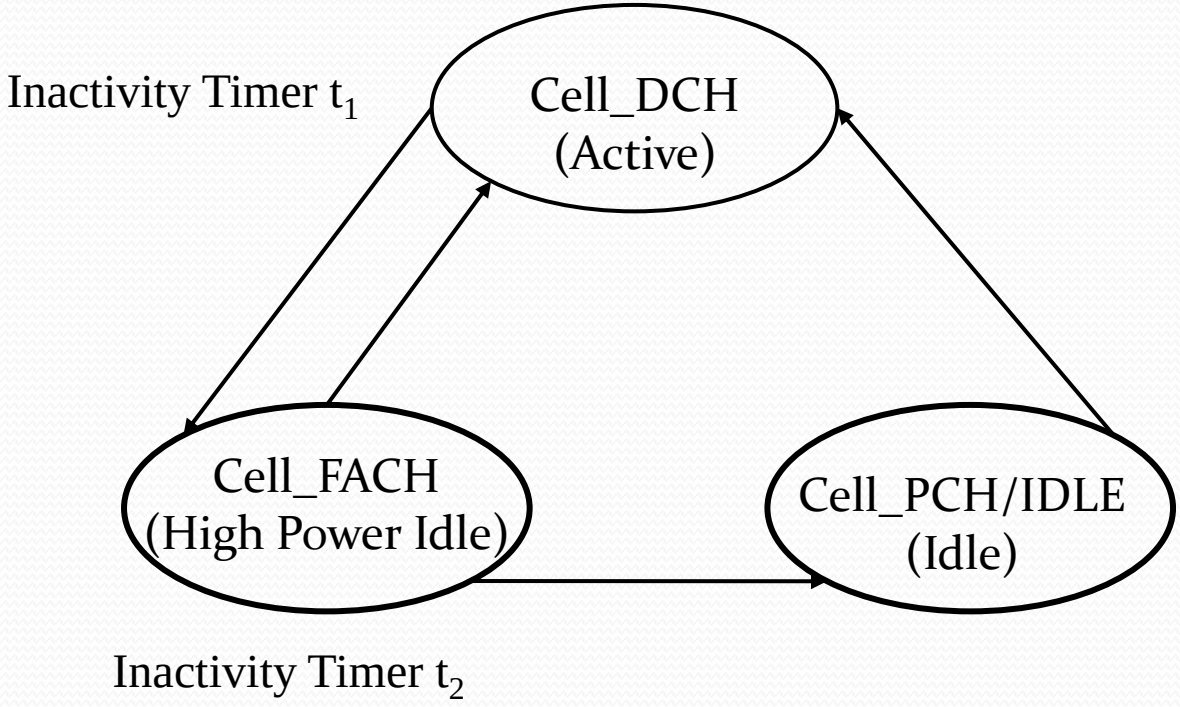
- "Up to 14 hours on 2G" ➡ "Up to 6.5 hours on 3G"

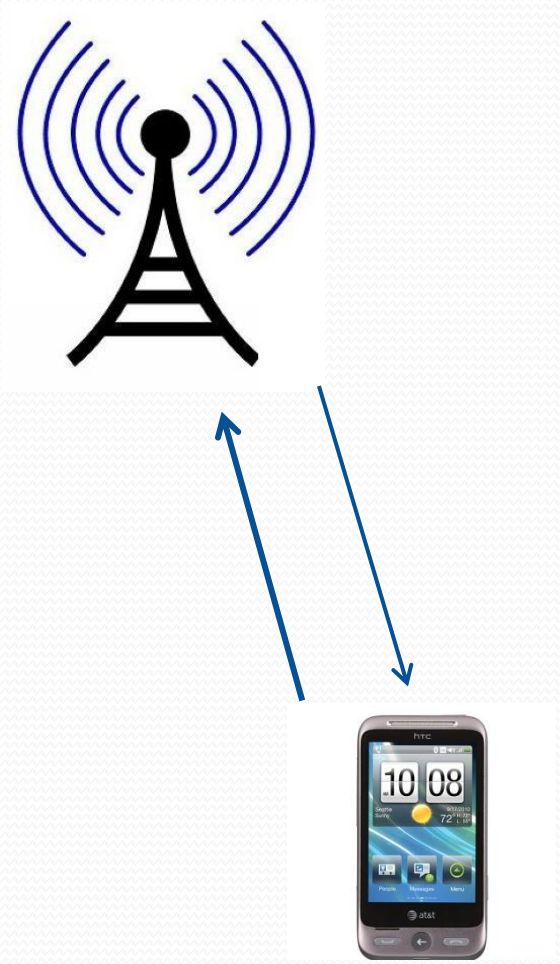




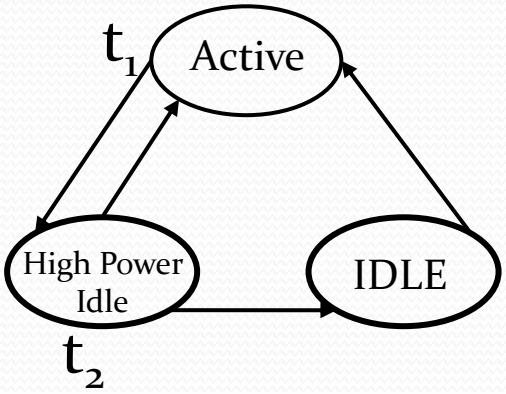
Goal: Reduce Energy Consumption

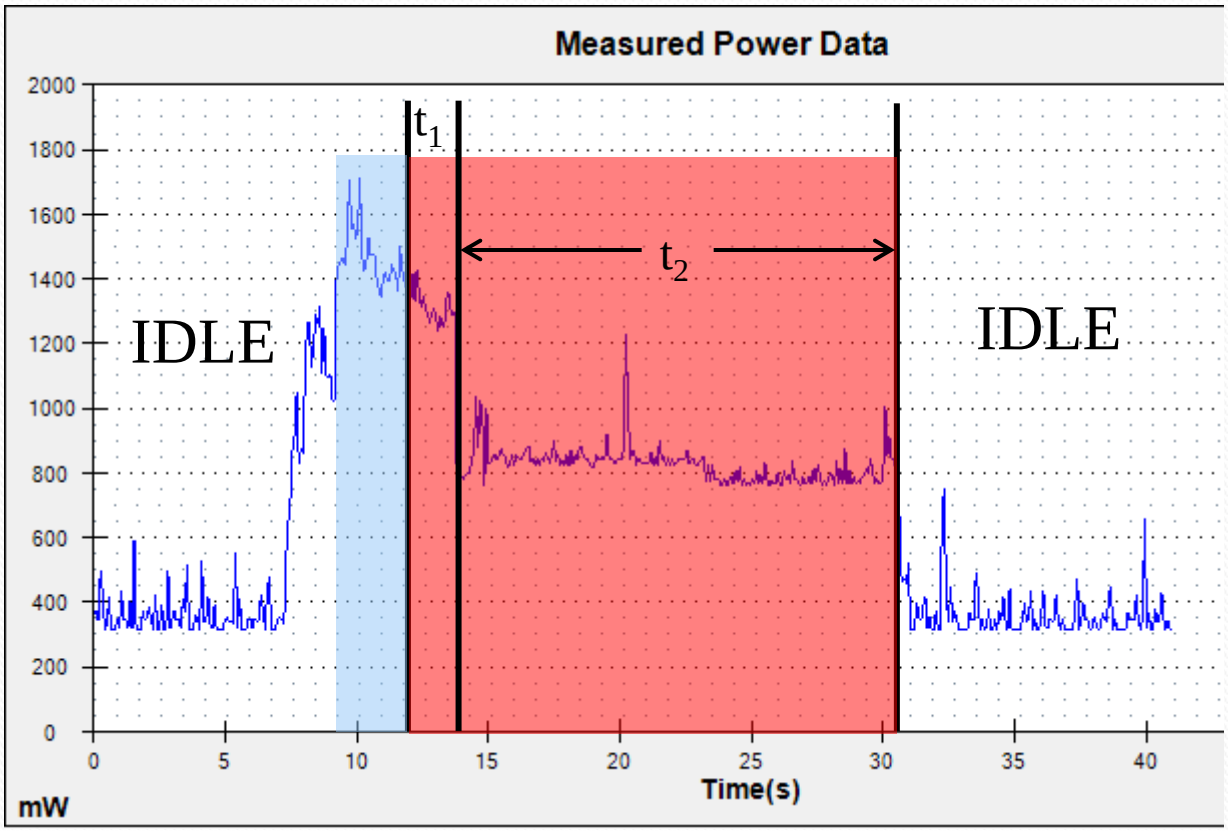
Context: Radio Resource Control



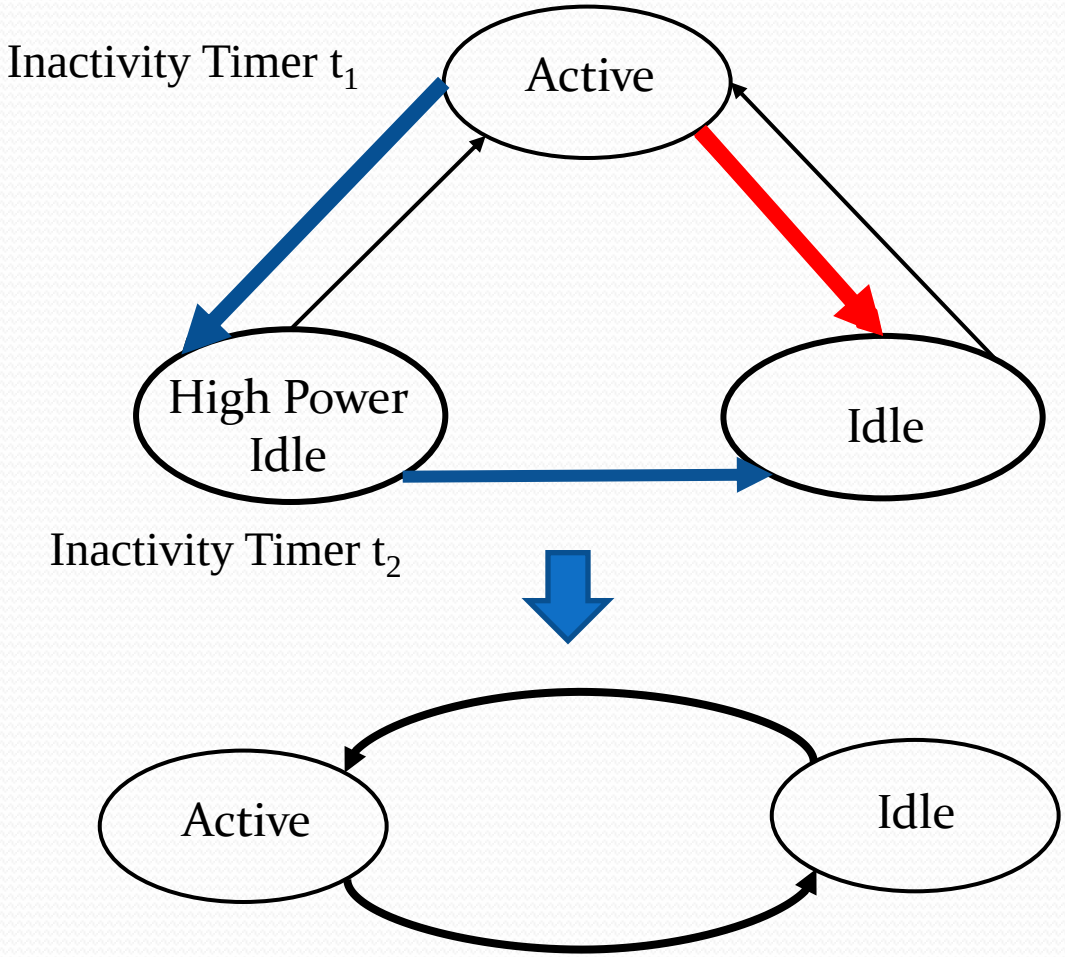


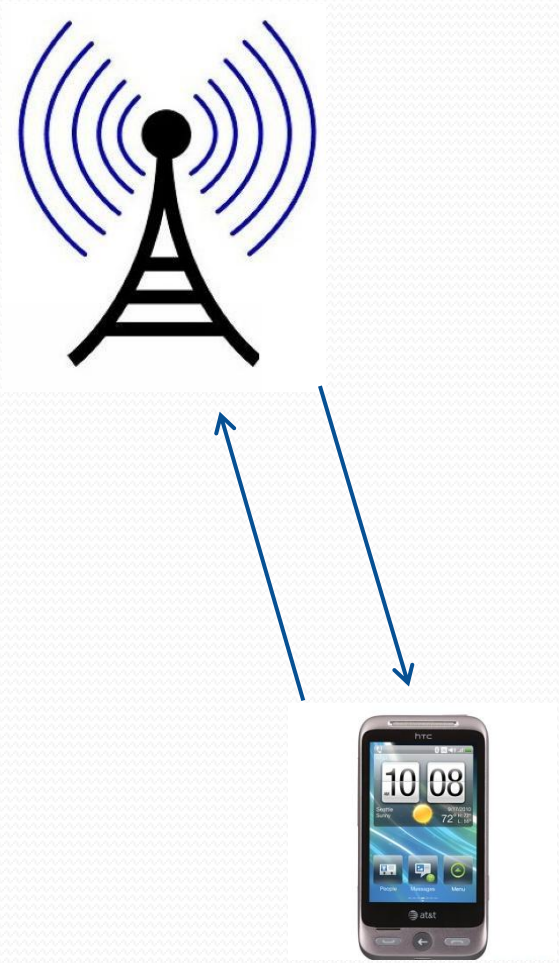
Power Consumption

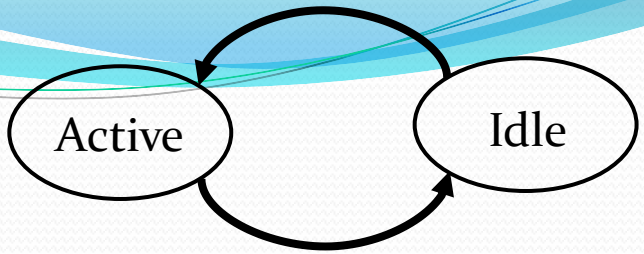




Fast Dormancy

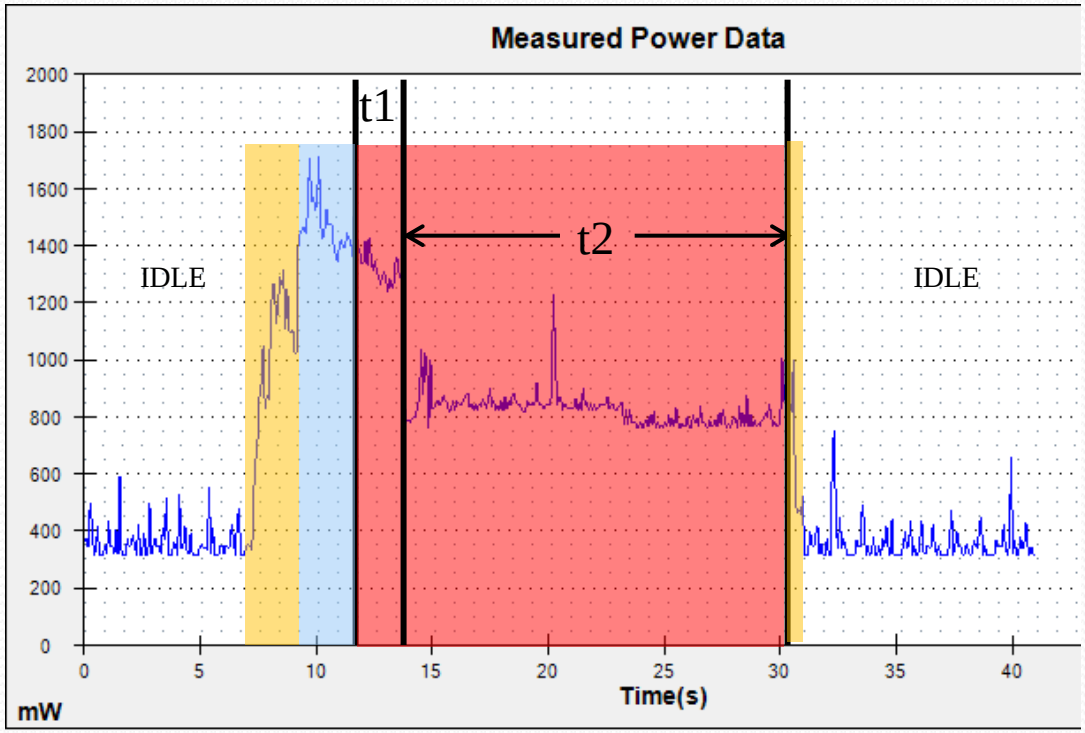






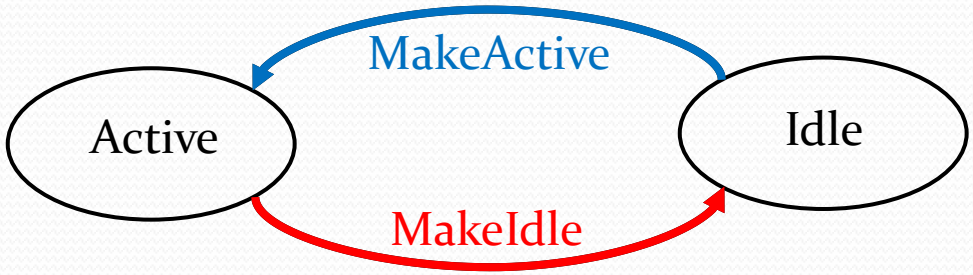
Challenges

- Switching between states takes time(1~3 seconds), and consumes energy
- Signaling overhead



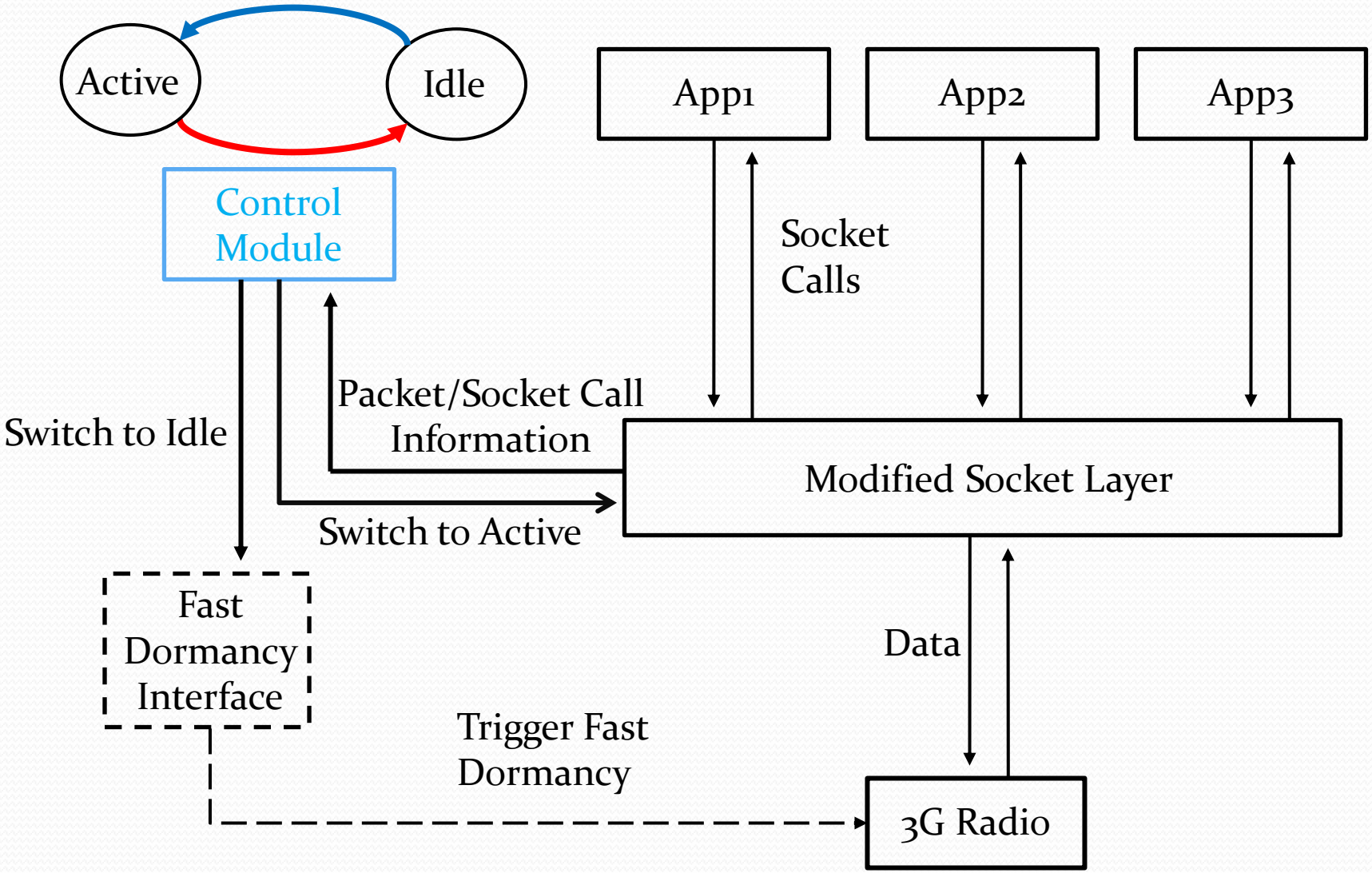
Contributions

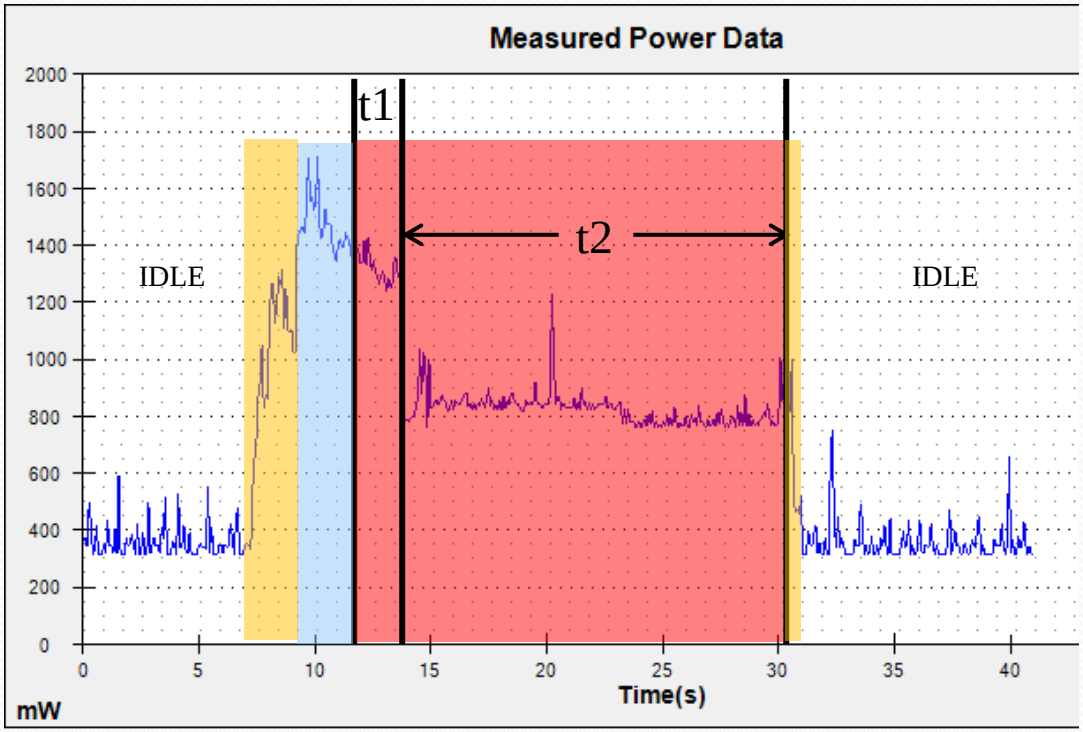
- A traffic-aware design to control radio state transitions to reduce energy consumption
  - MakeIdle: when to switch to Idle
  - MakeActive: when to switch to Active

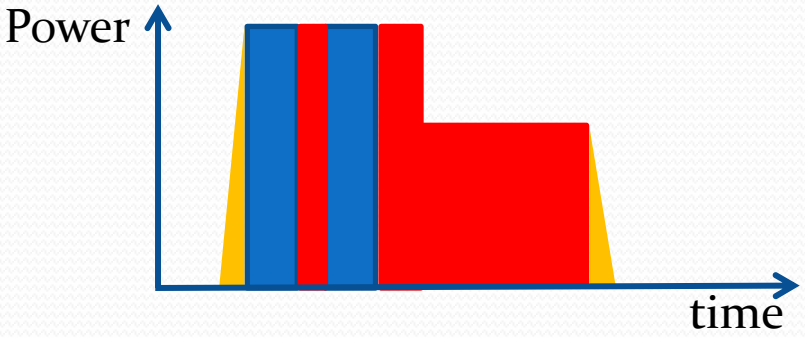


- Experimental evaluation on real usage data
  - Energy reduction up to 75% across different carriers

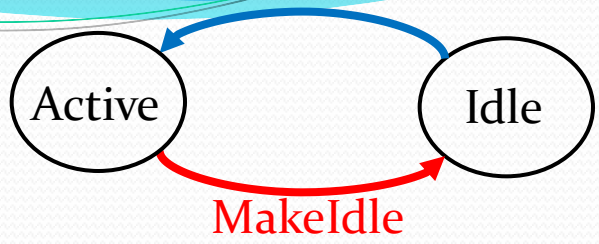
System Design

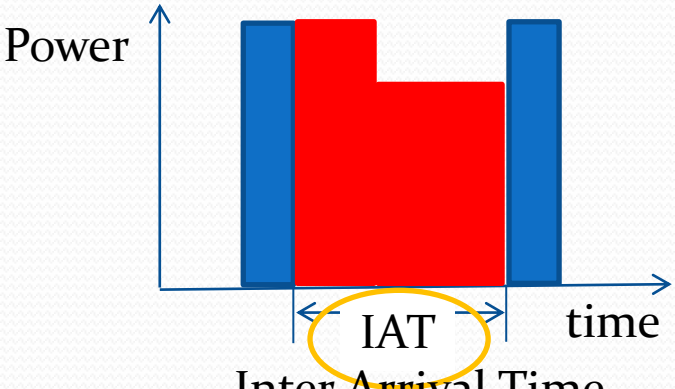


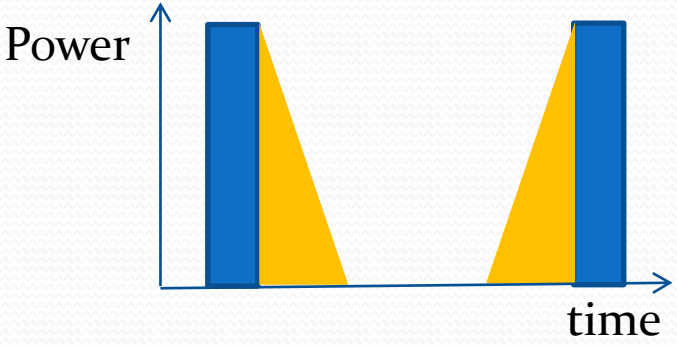

Measured Power Data
2000
1800
1600
1400
1200
1000
800
600
400
200
0
t1
t2
IDLE
IDLE
0
5
10
15
20
25
30
35
40
Time(s)
mW

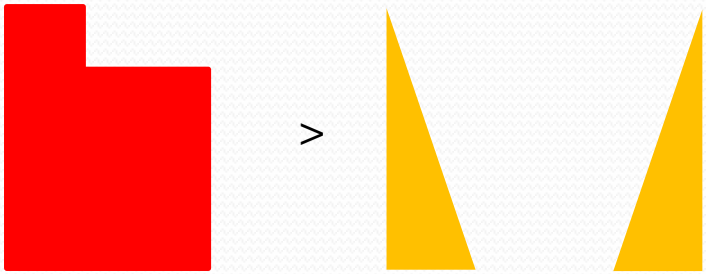

Power
time

MakeIdle Algorithm



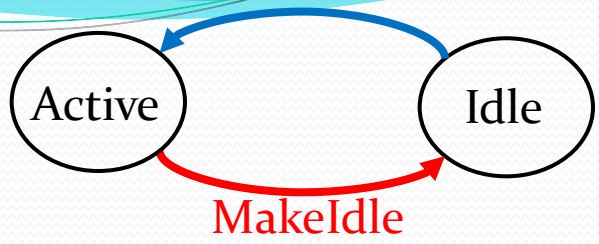




If  , should switch to Idle mode to minimize the energy consumption.

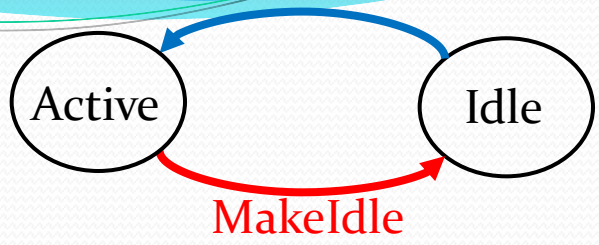
If *IAT* > *threshold*, should switch to Idle mode.

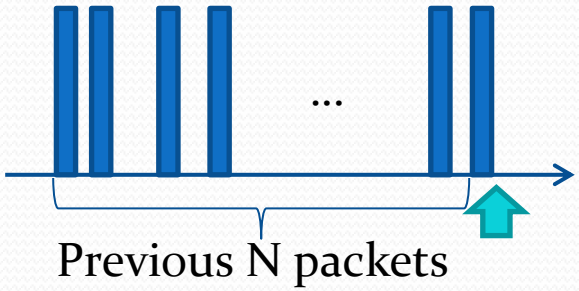
MakeIdle Algorithm



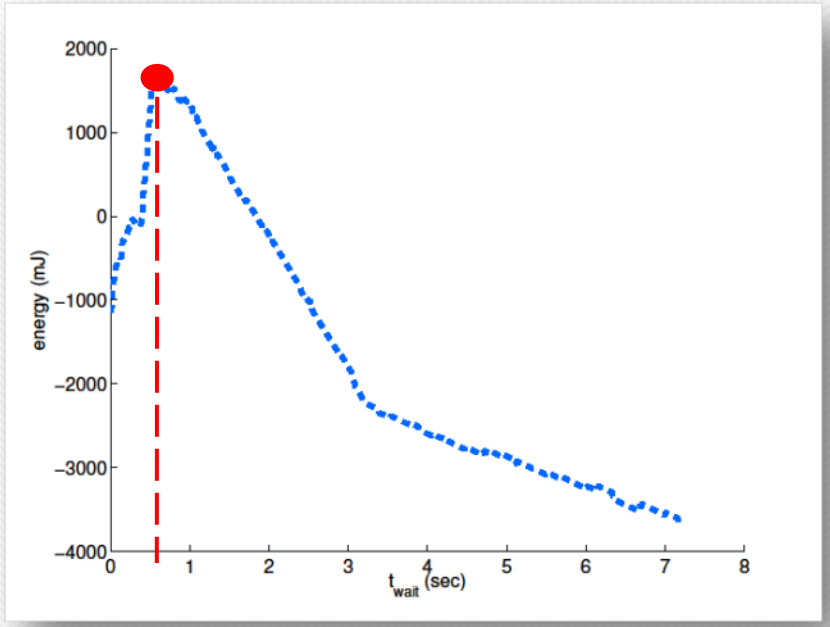
- Predict whether the IAT will be greater than *threshold*
- Wait for a short period of time t_{wait}, if no packet comes, then put the radio to Idle mode
- Why: the longer the network is idle, the longer it is likely to remain idle

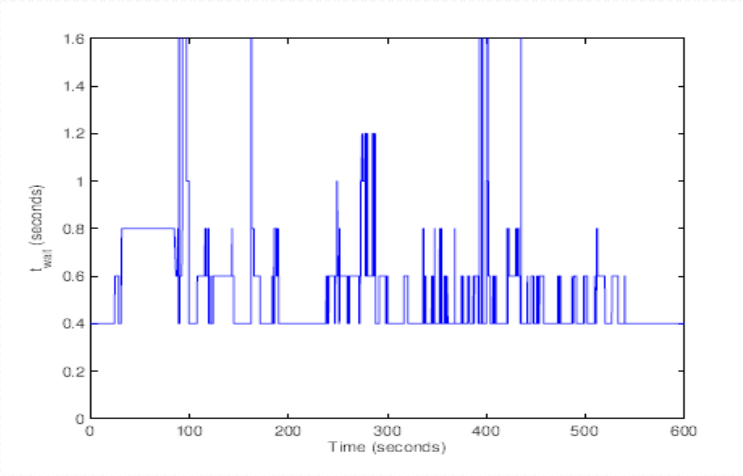
MakeIdle: Picking t_{wait}



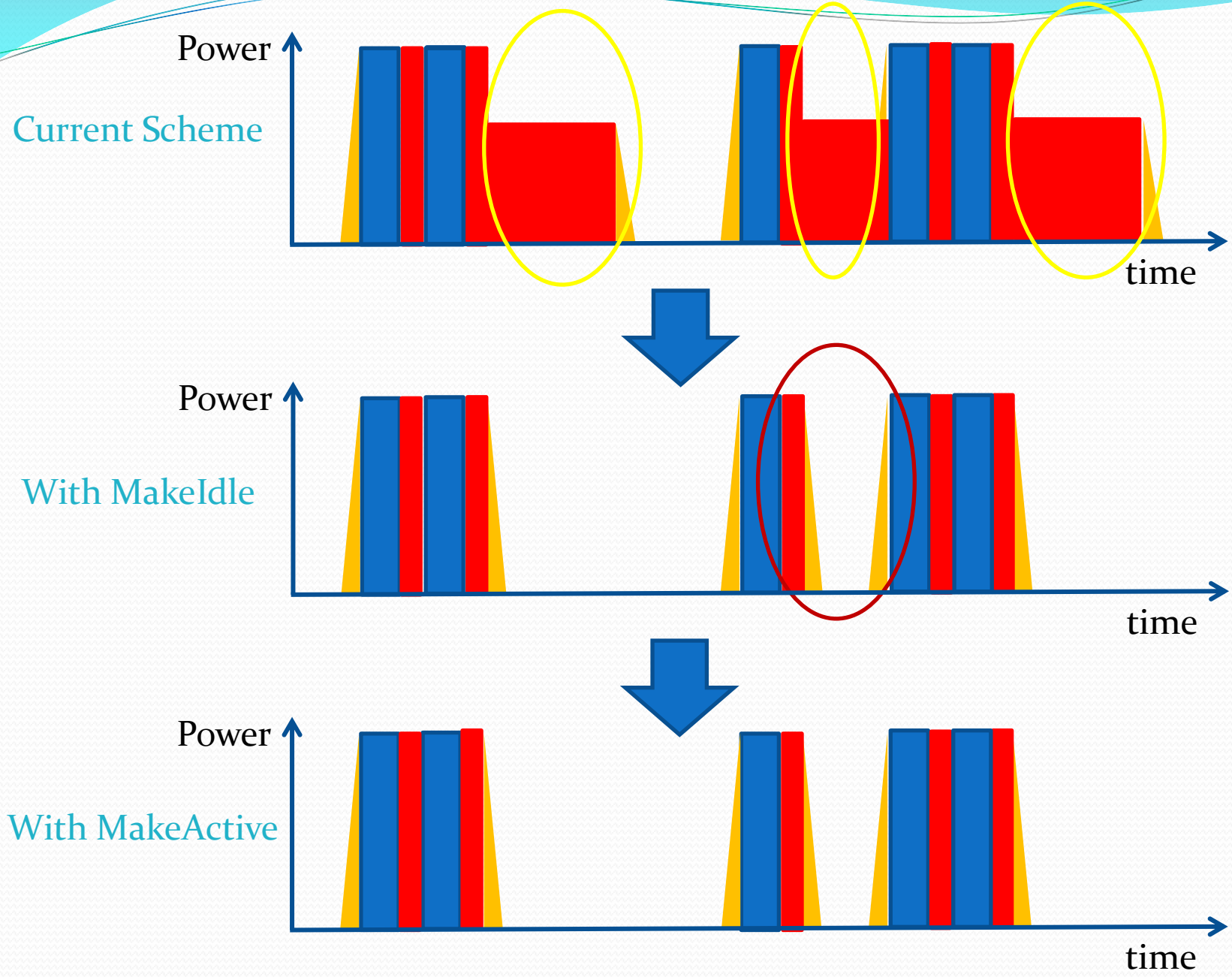


P(IAT>t+threshold | IAT>t)

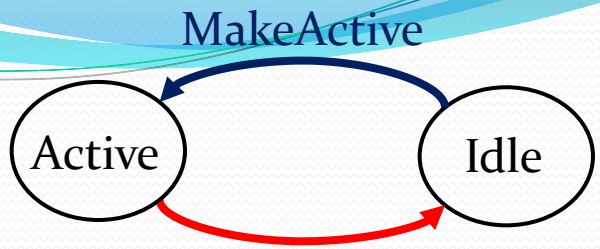




$$E(Energy_{state\_switch} - Energy_{no\_state\_switch})$$


Power
Current Scheme
time
Power
With MakeIdle
time
Power
With MakeActive
time

MakeActive Algorithm



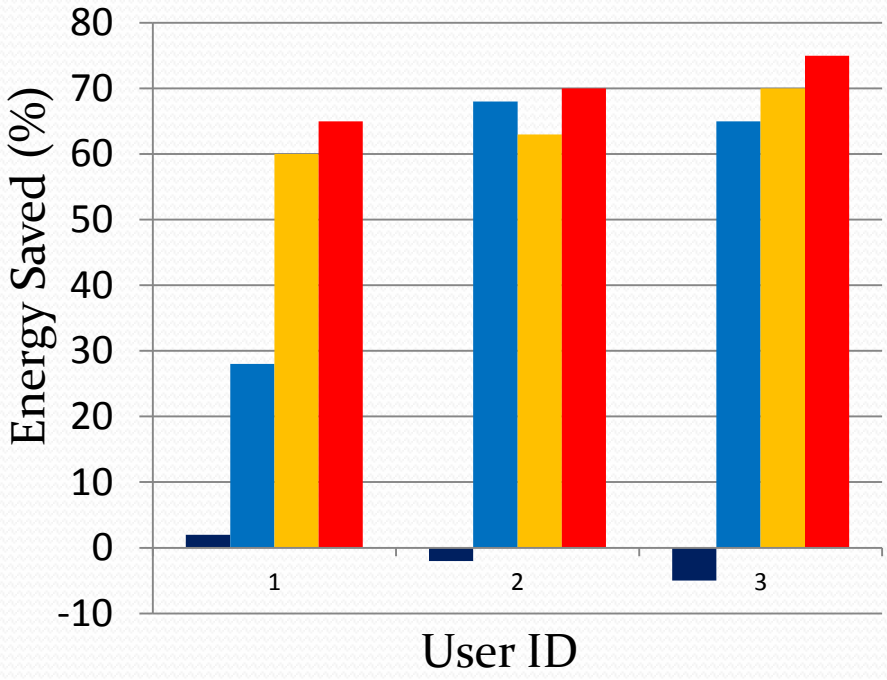
- Reduce the number of state switches by introducing a small delay when the radio is in Idle mode and data transmission requests come from the mobile device side

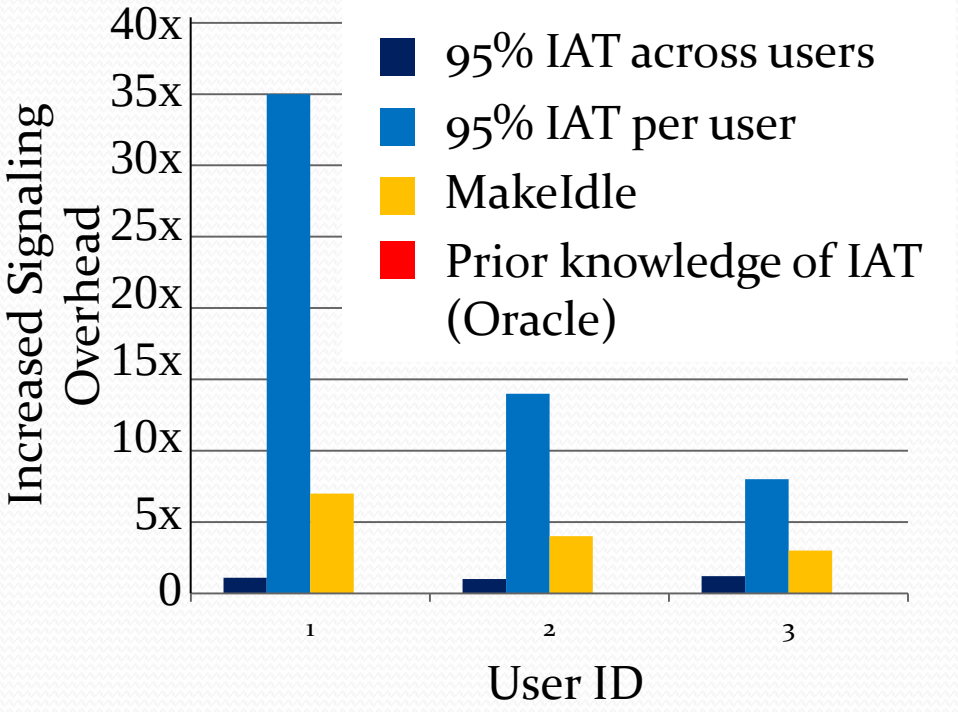
- How much delay for each request?
  - Fixed delay bound
  - Learning algorithm

Evaluation Setup

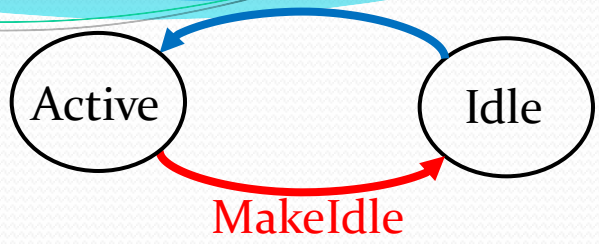
- Energy profiling
  - Power consumption profiles for 4 US major carriers: AT&T, Verizon, T-Mobile, Sprint
- Trace driven simulation
  - Tcpdump traces for real usage data, collected from 9 users, 28 days in total

Evaluation: MakeIdle

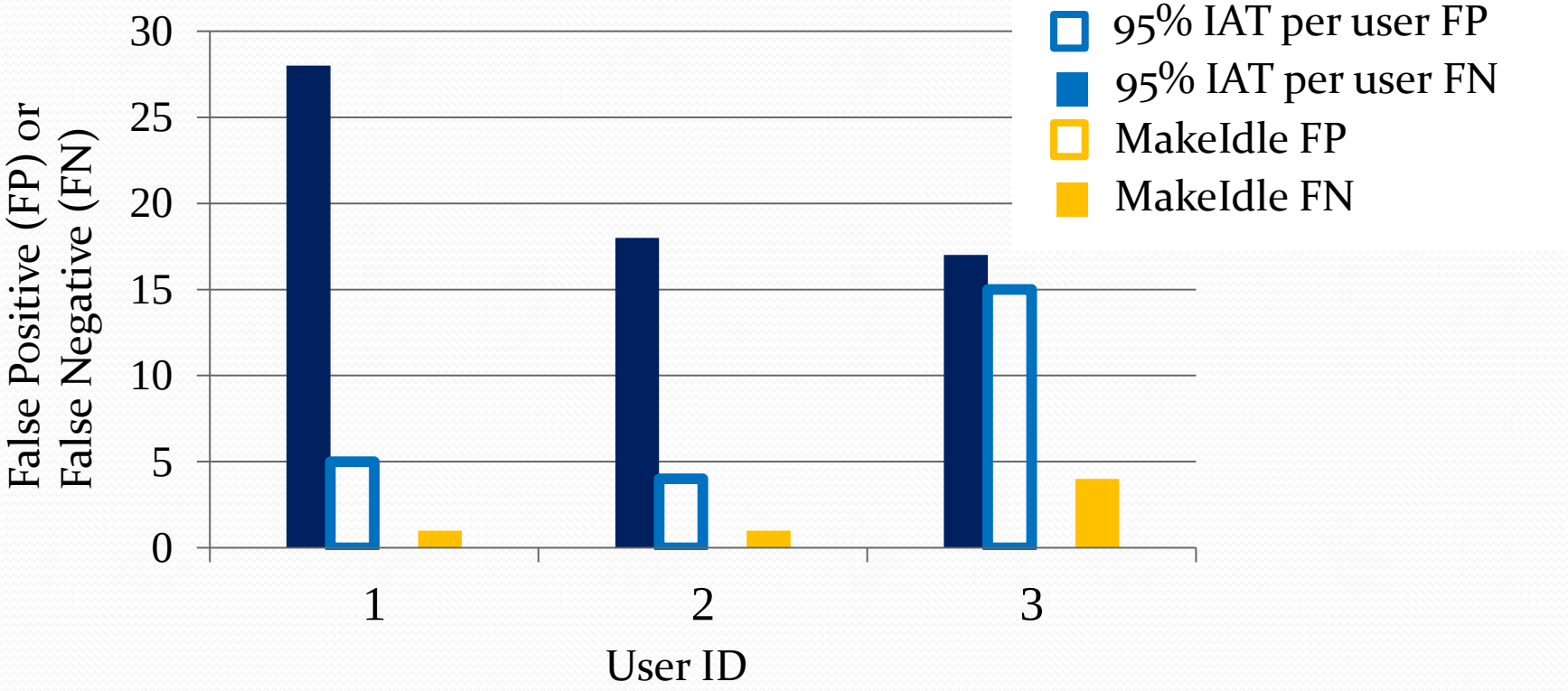




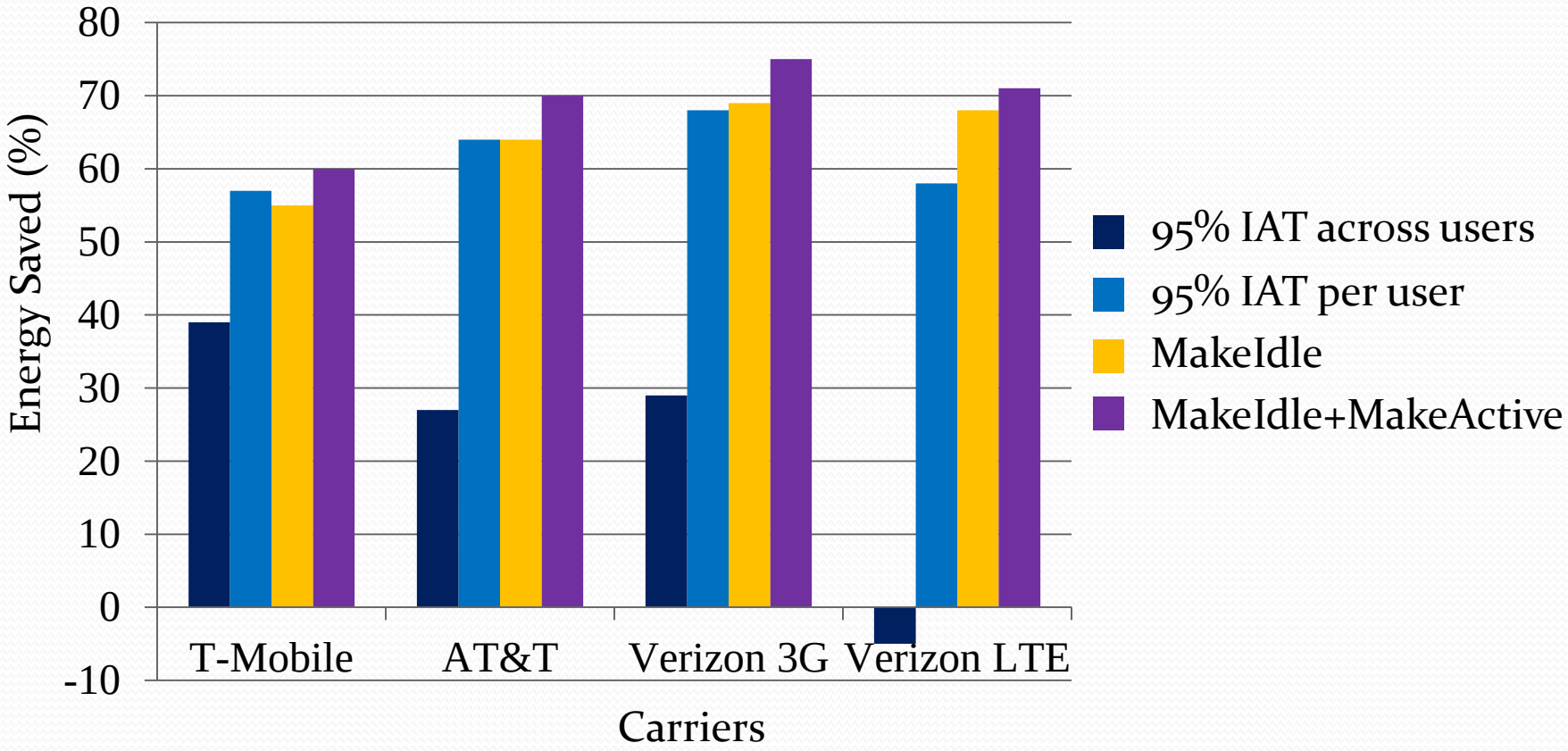
Evaluation: MakeIdle



- Prediction Accuracy



Evaluation: Different Carriers



Related Work

- Inactivity timer reconfiguration
  - Statistical method [Falaki et al, 2010]: 95 percentile packet inter arrival time
- Applications-Involved Design
  - *TailEnder* [Balasubramanian et al, 2009]: each application specifies its delay tolerance
  - *TOP* [Qian et al, 2010]: application predict the gap between its own traffic transmissions
  - *TailTheft* [Liu et al, 2011]: application specifies delay tolerance and predicts transmission duration

Conclusion

- A traffic-aware design to control state transitions of 3G/LTE radio to reduce energy consumption on mobile devices
- Require no modifications of the applications
- Save 3G/LTE energy consumption by up to 75% across different carriers