

# Performance vs. Energy on Smartphones

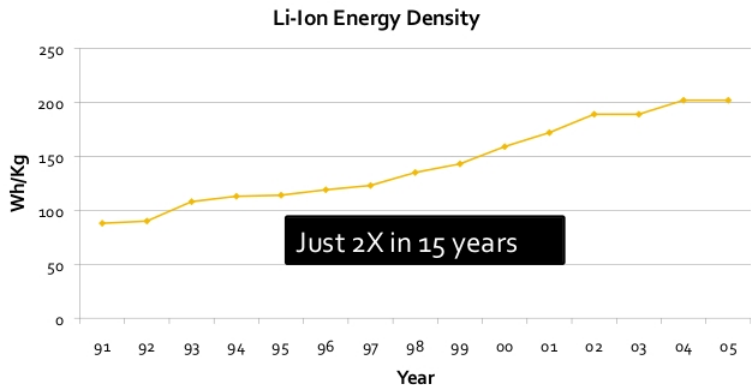
Can we have both?

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May 15<sup>th</sup> 2012

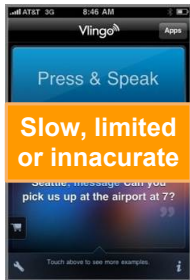
- **MAUI (Mobile Assistance Using Infrastructure)**
  - ... making smartphones last longer with code offload
  
- **XRay**
  - ... automatic offloading of resource-constrained smartphone applications
  
- **Tula**
  - ... balancing energy for sensing and communication

# MAUI: Battery is a scarce resource



- CPU performance during same period – **246x**
- Solving the battery problem seems unlikely

# MAUI: Apps can't reach their full potential



**Slow, limited  
or inaccurate**



**Not paired with  
desktop  
counterparts**



**Too CPU  
intensive**

# MAUI: Unleash app potential by code offloading



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**Remote execution can reduce energy consumption**

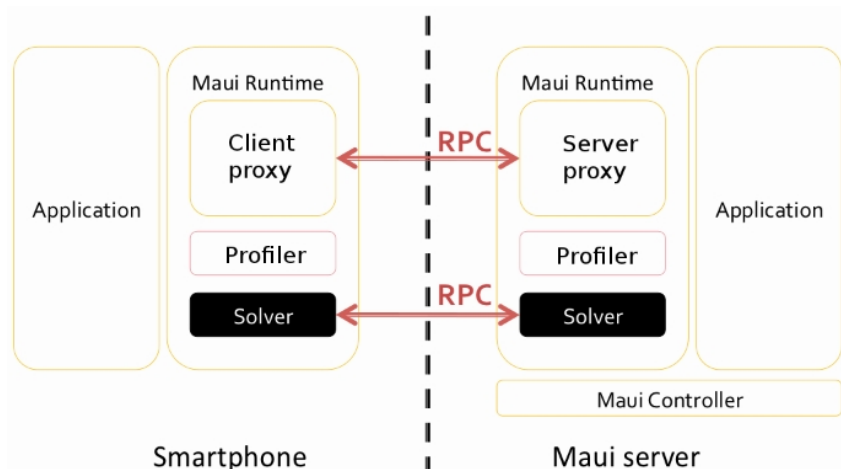




## Challenges

- What should be offloaded?
  - How to dynamically decide when to offload?
  - How to minimize the programmer effort?
- 
- **Extensive profiling + solver**
    - Dynamic offload decisions
    - Optimize for energy reduction
    - Profile device, network and application
  - **Leverage modern language runtime**
    - Simplify program partitioning

# MAUI: Architecture



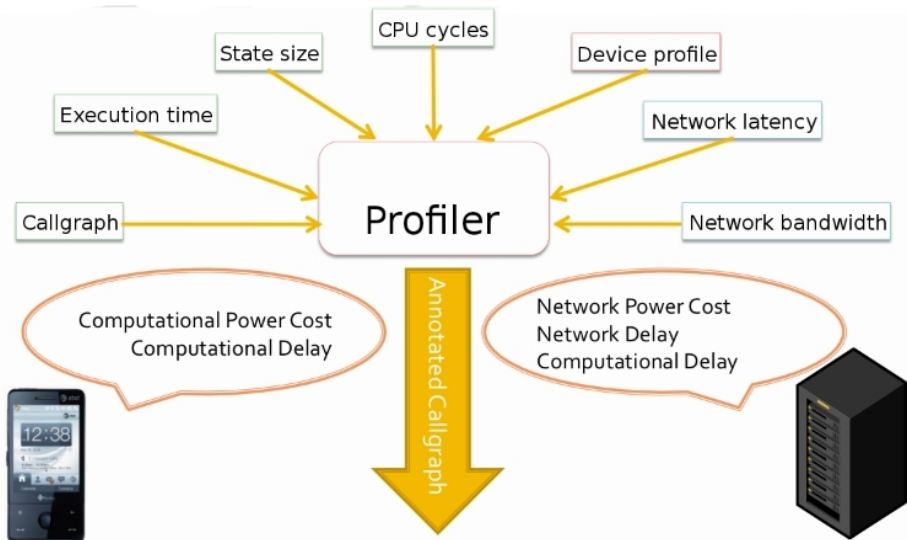
# MAUI: How does the programmer use it?

## As a programmer, you ...

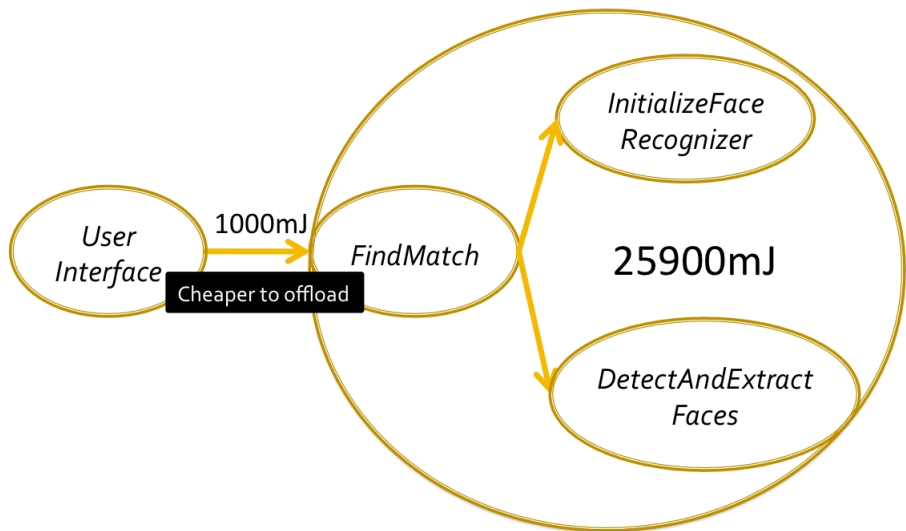
- build apps as stand-alone phone apps
- add .NET **Remoteable** attribute
- Language run-time support for partitioning



# MAUI: Profiler



# MAUI: Solver



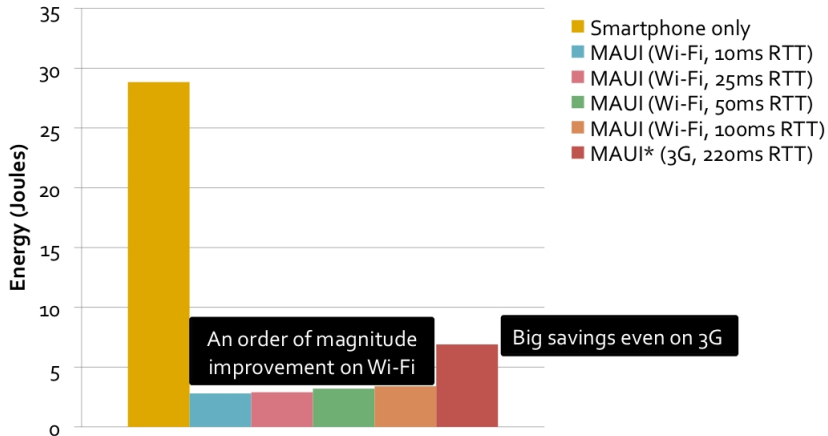
# MAUI: Adapt to changing conditions?

- Adapt to
  - Network bandwidth / latency changes
  - Application computational requirements
  
- Applications
  - Chess
  - Face recognition
  - Arcade game
  - Voice-based translator
  
- HTC Fuze
- Monsoon power monitor



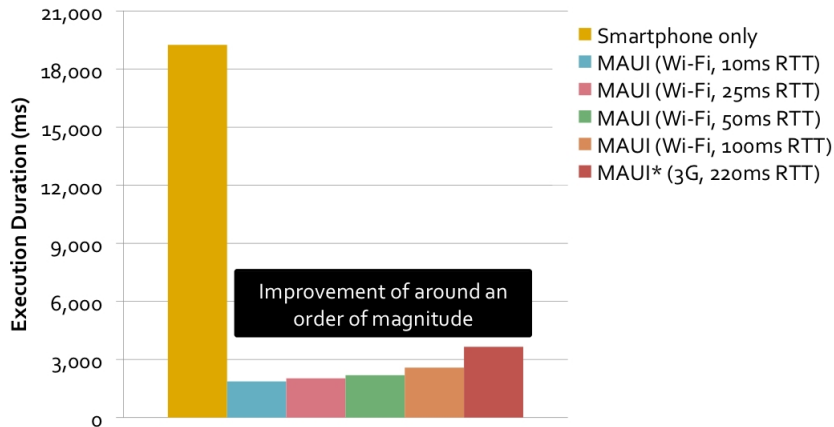
# MAUI: Reducing energy consumption

## Face Recognizer



# MAUI: Improving app performance

## Face Recognizer





# MAUI: So let's remember... what does it achieve?

- Bypass the limitations of handheld devices
- Simple program annotations
- Adapts to network conditions and app CPU demands
- Can reduce energy consumption by an order of magnitude (10x)

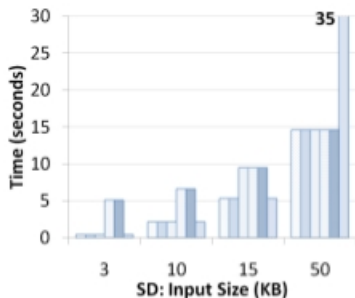
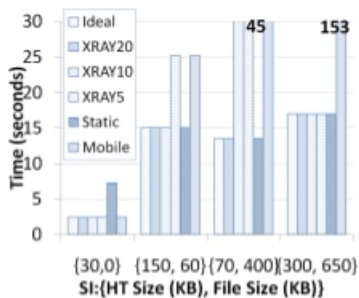


# XRay: Automatic app partitioning and offloading

- MAUI assumed programmer support for application partitioning
  - **Cumbersome!**
  - **Limitations in practice!**
- How about **automatic partitioning**?
  - Trace all system- and app-level events
  - Classify them into **local** and **remotable**
  - Identify **remotable methods**
- Model based on **performance**
  - **Regression** → adapt to user inputs!

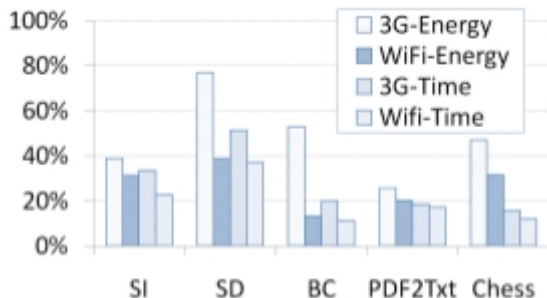
# XRay: Adapting to user inputs

- 6 alternatives
  - Mobile
  - Static (XRay with 1 profiling run)
  - XRay 5/10/20
  - Ideal



# XRay: Energy savings

- Reducing execution time reduces energy consumption



# Tula: Balancing energy



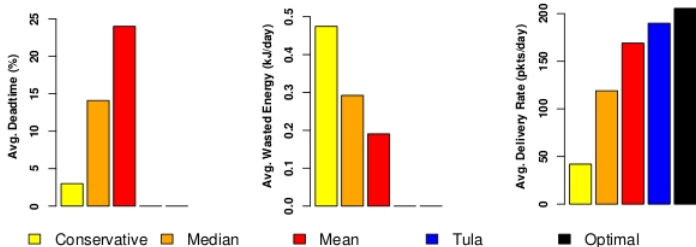
- Monitoring with mobile systems
  - Balance sensing and communication (routing)
  - Balance energy allocation between
    - sensing
    - routing the node's own data
    - routing data for other nodes
  - Constraint optimization problem
    - Coordinate sensing and routing activities by resource allocation



- Mobile sensor network deployed to study Gopher turtles
- 17 tracking devices
  - Temperature, GPS coordinates, battery level, solar energy, energy consumption
  - Exchange data on opportunistic connections

# Tula: What sensing rate ...

- ... to assign to nodes?
- Compare between **optimal**, **conservative (90%)**, **median (50%)**, **mean (25%)** and **Tula**
- **Dead time, wasted energy and delivery rate**



# Conclusions and reviews

- MAUI and XRay

- Code offloading makes smartphones happy
- **Score = 2.33**
- Original, interesting, well-written, good evaluation, good explanations
- Rather long, repetitive, 1 phone + 1 OS for evaluation, 3G results
- **Multi-threading?**
- **For what apps does it make sense to use MAUI?**
- **What is MAUI's overhead on the smartphone?**
- **What about EDGE?**
- **Porting to Android?**
- **What are the security risks?**
- **How does MAUI handle failures and unstable network?**
- **How to incorporate routines to drive energy savings?**

- Tula

- How well does it adapt to mobility oscillations?