

Performance vs. Energy on Smartphones

Can we have both?

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- **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

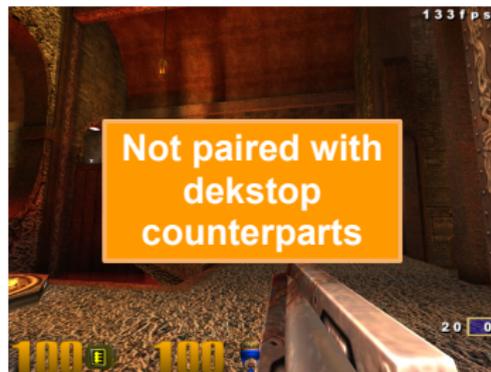


- CPU performance during same period – **246x**
- Solving the battery problem seems unlikely

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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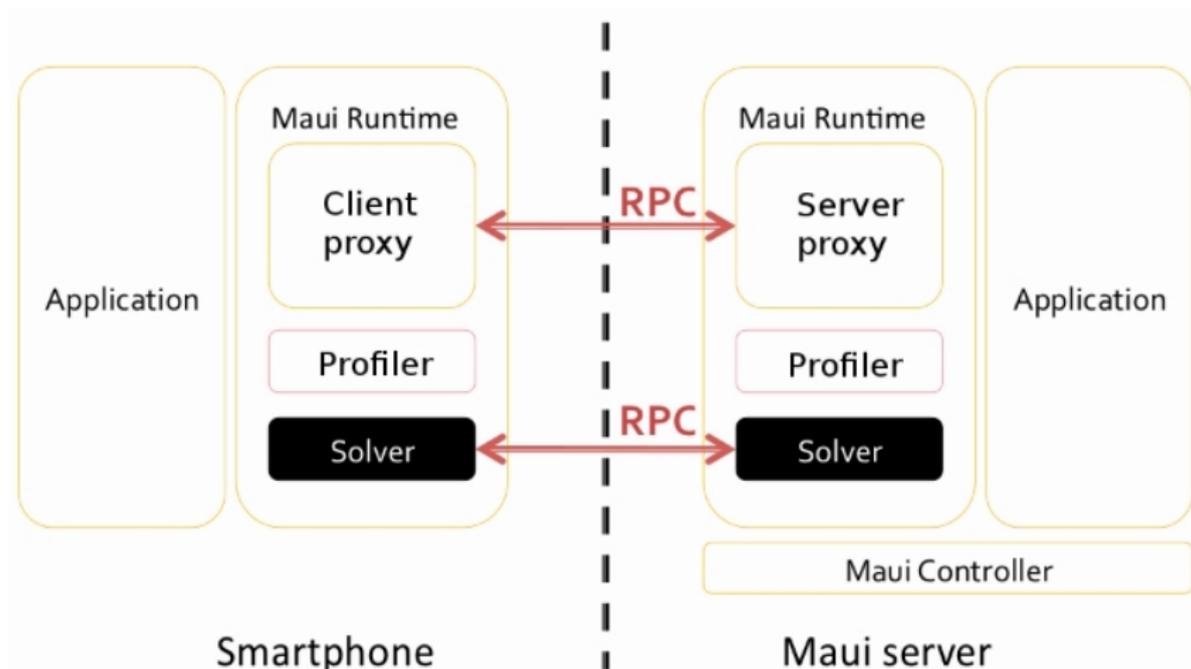
Remote execution can reduce energy consumption



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



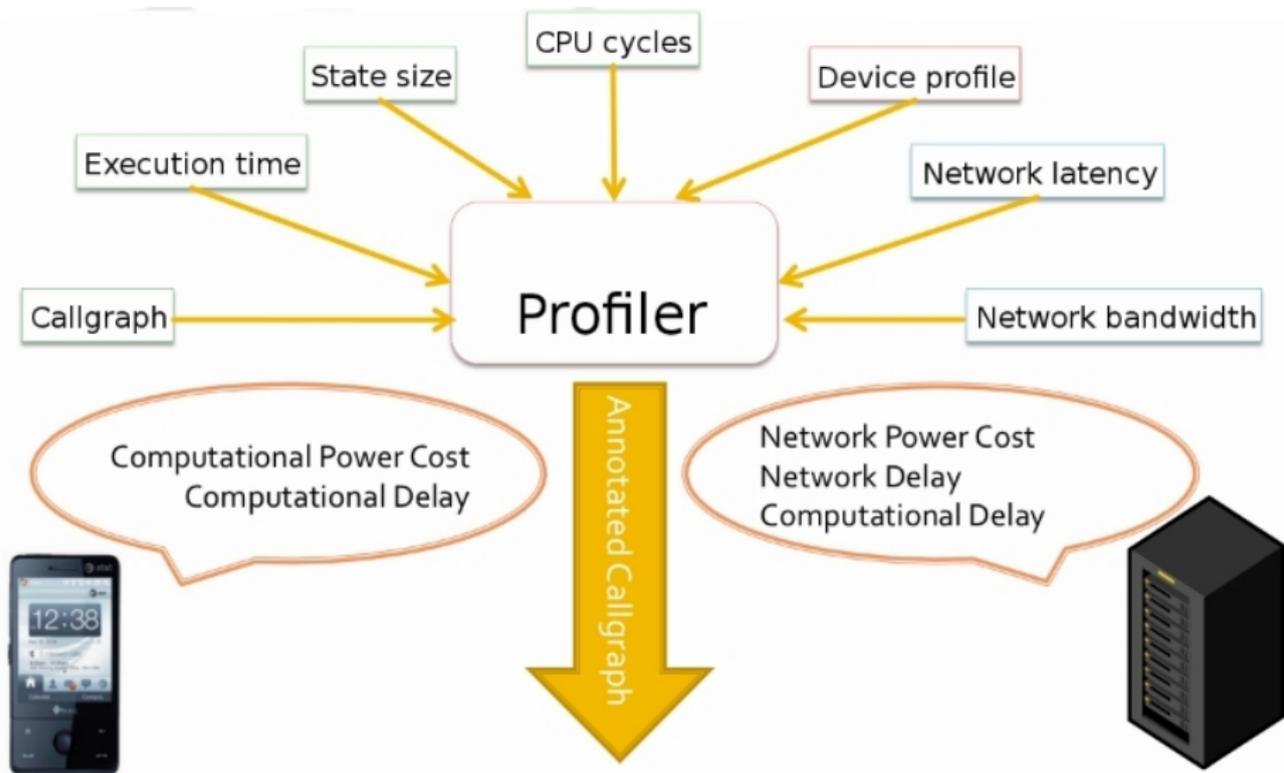
MAUI: How does the programmer use it?

As a programmer, you ...

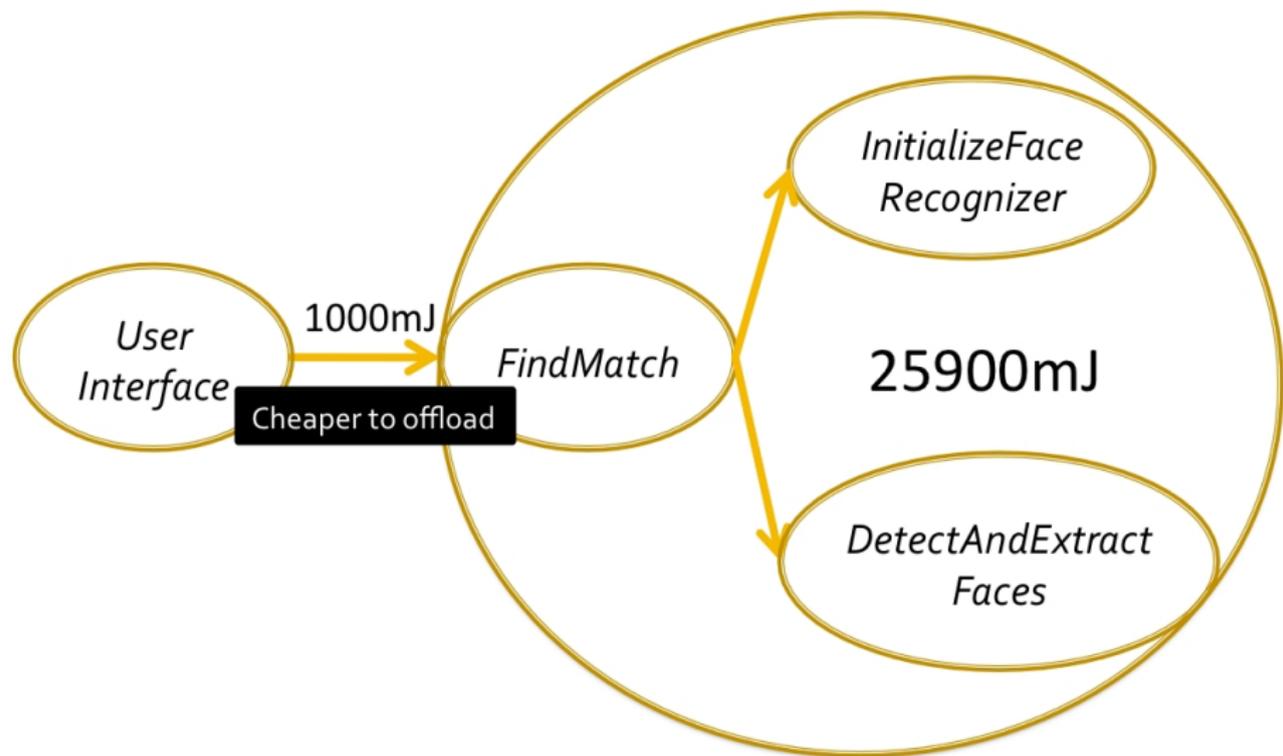
- build apps as stand-alone phone apps
- add .NET **Remoteable** attribute
- Language run-time support for partitioning



MAUI: Profiler



MAUI: Solver



MAUI: Adapt to changing conditions?

- Adapt to
 - Network bandwidth / latency changes
 - Application computational requirements

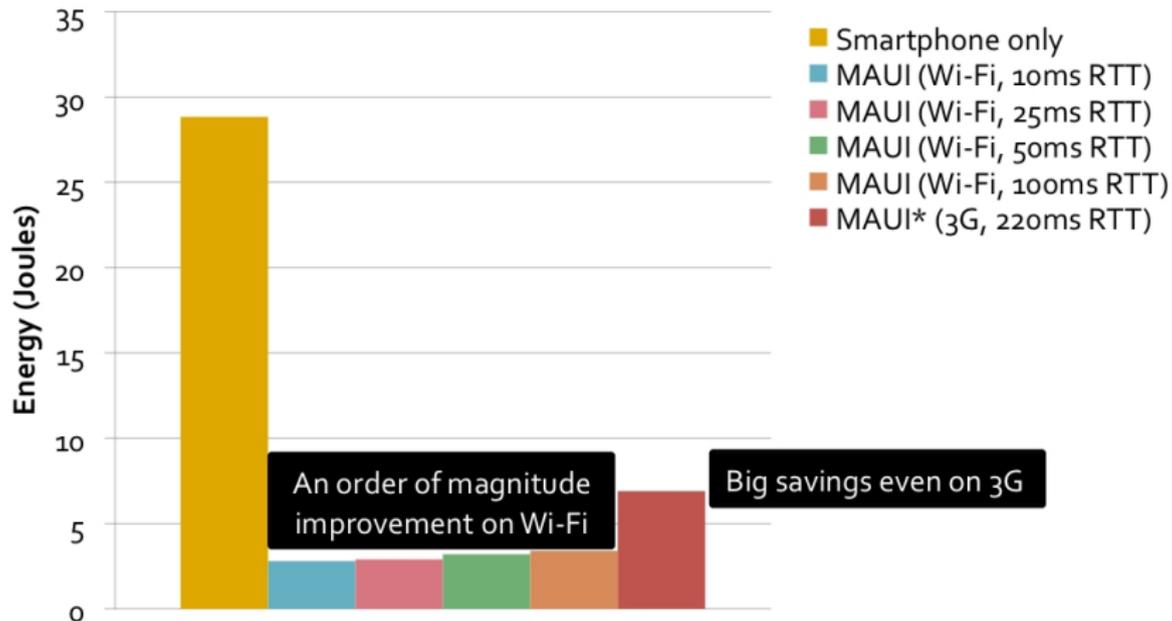
- Applications
 - Chess
 - Face recognition
 - Arcade game
 - Voice-based translator

- HTC Fuze
- Monsoon power monitor



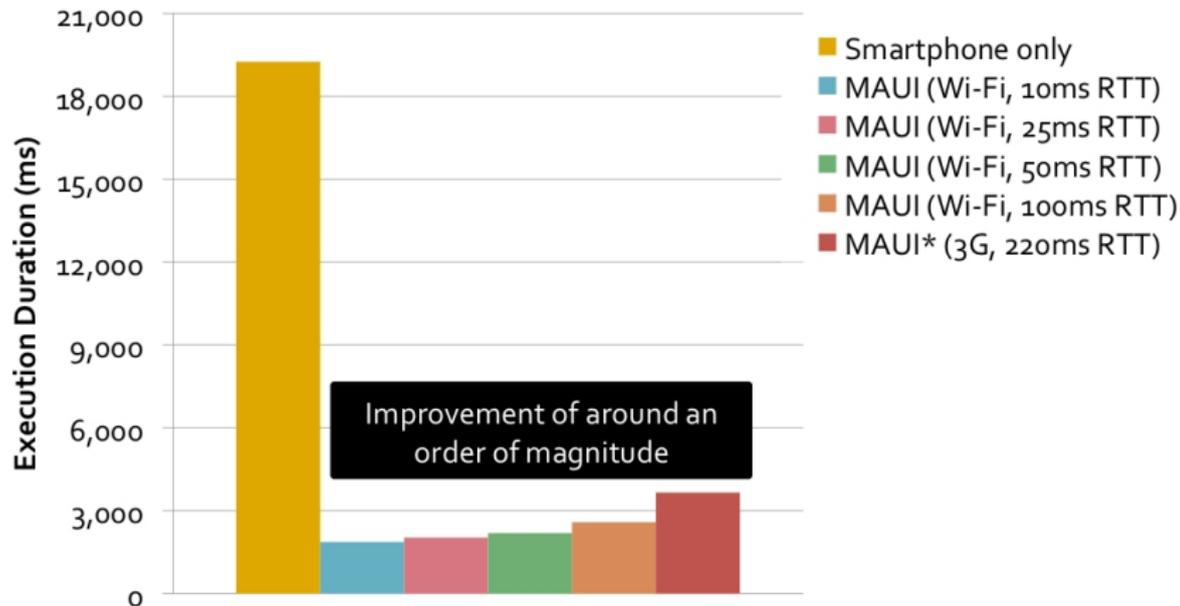
MAUI: Reducing energy consumption

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)

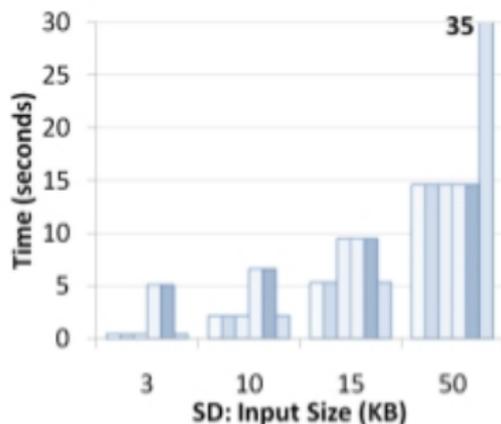
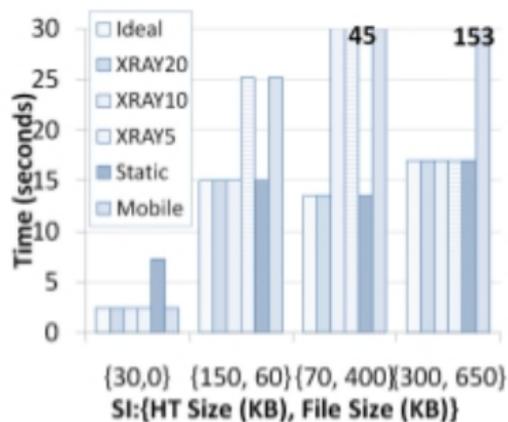


XRay: Automatic app partitioning and offloading

- 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!

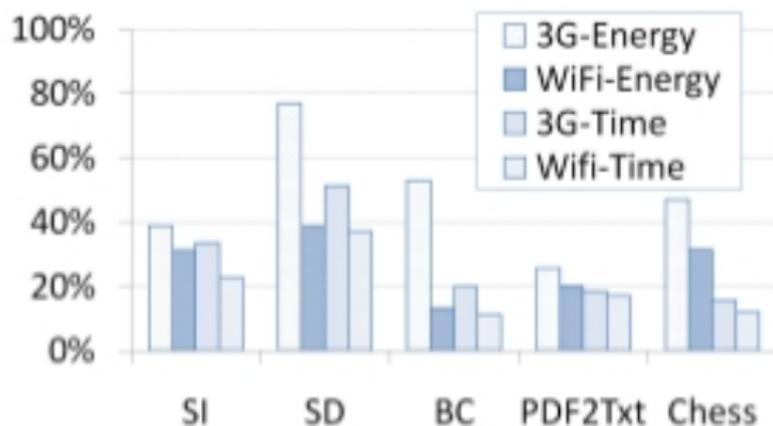
XRay: Adapting to user inputs

- 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



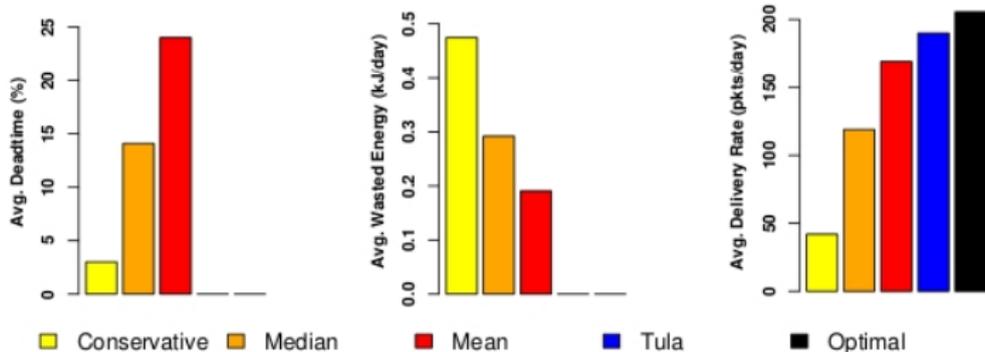
- Monitoring with mobile systems
 - Balance sensing and communication (routing)
 - Balance energy allocation between
 - sensing
 - routing the node's own data
 - routing data for other nodes
 - Constraint optimization problem
 - Coordinate sensing and routing activities by resource allocation



- 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?