Performance vs. Energy on Smartphones

Can we have both?

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Roadmap

- **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
- Too CPU intensive
- Not paired with desktop counterparts
MAUI: Unleash app potential by code offloading
MAUI: Unleash app potential by code offloading
Remote execution can reduce energy consumption
MAUI: Remote execution

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

The diagram illustrates the MAUI architecture, featuring the interplay between the Smartphone and the Maui server, facilitated by the Maui Runtime and its components. The diagram includes:

- **Application**
- **Maui Runtime**
  - Client proxy
  - Profiler
  - Solver
- **RPC**
- **Server proxy**
- **Profiler**
- **Solver**
- **Maui Controller**

The interaction is mediated by RPC (Remote Procedure Call) to ensure efficient communication and data exchange between the Smartphone and the Maui server.
As a programmer, you ...

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

- Profiler
- Callgraph
- State size
- CPU cycles
- Device profile
- Network latency
- Network bandwidth
- Execution time
- Computational Power Cost
  Computational Delay
- Annotated Callgraph
- Network Power Cost
  Network Delay
  Computational Delay
MAUI: Solver

User Interface 1000mJ Cheaper to offload

FindMatch

InitializeFace Recognizer

25900mJ

DetectAndExtract Faces
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

- Smartphone only
- MAUI (Wi-Fi, 10ms RTT)
- MAUI (Wi-Fi, 25ms RTT)
- MAUI (Wi-Fi, 50ms RTT)
- MAUI (Wi-Fi, 100ms RTT)
- MAUI* (3G, 220ms RTT)

Energy (Joules)

An order of magnitude improvement on Wi-Fi

Big savings even on 3G
MAUI: Improving app performance

Face Recognizer

Execution Duration (ms)

- Smartphone only
- MAUI (Wi-Fi, 10ms RTT)
- MAUI (Wi-Fi, 25ms RTT)
- MAUI (Wi-Fi, 50ms RTT)
- MAUI (Wi-Fi, 100ms RTT)
- MAUI* (3G, 220ms RTT)

Improvement of around an order of magnitude
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)
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
Reducing execution time reduces energy consumption
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
Tula: TurtleNet

- 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?