MAUI: Making Smartphones Last Longer With Code Offload

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Today’s Topics

➢ The Problem
➢ Motivation
➢ MAUI
➢ Evaluation
➢ Summary
The Problem

- Mobile devices are ubiquitous
- Wider range of applications
- Mobile Computation gets more intense
- Battery fails to keep up...
The Problem

- Cloud services are also ubiquitous
- Possess high computation capabilities
- Not limited by battery!
- Idea: mobile computation offloading to the cloud!
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Three questions quantify the need for remote offloading:

1. How Severe is the Energy Problem in Today’s Mobile Devices?

- Synthetic benchmark (bulk fetching+display) drained battery after 1.5 hours
- Synthetic, yet realistic scenario (Video streaming)
Three questions quantify the need for remote offloading:

2. How Energy Efficient is 3G for Code offloading?

- Researchers tested the uploading and downloading of 10/100KBs of code
- Energy(3G) is roughly 5x Energy(Wi-Fi)
- Battery drained after 2 hours of extensive use
- 3G might be impractical to use
Three questions quantify the need for remote offloading:

3. How Sensitive is the energy consumed to the Wi-Fi RTT?

- 10/100KB offloading on Wi-Fi
- Near linear energy growth w.r.t. RTT
- Cloud should strive to minimize offloading RTT
- Energy saving is significant for nearby servers (RTT~10ms)
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Main Challenges:

- **Partitioning** - what is the granularity of the code that is offloaded?
- **Amortizing costs** – what is the minimal “state” for offloading?
- **Detection** - how to detect offload candidates “on-the-fly”?
- **Programmability** - do not over-burden the programmer
The MAUI programming model:

- C# applications containing “remotable” methods (marked by the programmer)
- Methods that do not implement UI
- Methods that do not interact with mobile device’s IO devices (GPS etc.)
- Methods must be able to be re-executed (i.e. without irreversible side-effects)
The MAUI programming model:

- Methods are identified by attributes, server has matching messaging interface

// original interface
public interface IEnemy {
    [Remoteable] bool SelectEnemy(int x, int y);
    [Remoteable] void ShowHistory();
    void UpdateGUI();
}

// remote service interface
public interface IEnemyServer {
    MAUIMessage <AppState, bool> SelectEnemy(int x, int y);
    MAUIMessage <AppState, MauiVoid> ShowHistory();
}
The MAUI architecture:

- **Proxy** - handles control + data transfers
- **Profiler** - instruments the program
- **Solver** – ILP solver (elaborated later)
- **MAUI coordinator** – handles incoming requests, creates a partitioned application

- both device and server hold copies of the application (using CLR)
- Currently no support for multi-threaded applications 😞
The MAUI profiler

Instruments methods to predict offload profitability, depending on:

- The smartphone’s energy consumption
- Each method’s characteristics (e.g. run-time and resources needed)
- Network characteristics (RTT, BW latency, and packet loss rate)

Problem I: serializing entire state is time-consuming

Problem II: sending entire state wastes a lot of bandwidth

Heuristic Solution: app-state delta calculation
The MAUI profiler

Profiling policies

- **FullDiff** – serialize and calculate deltas on every call
- **FullSerial** – serialize on every call
- **LastDiff** – serialize on first call only, calculate deltas for each call
- **LastSerial** – serialize first call only
- **Oracle** – knows exactly which methods to offload without calculation
The MAUI solver: attempts to solve the offload decision problem

- Reaching the optimal solution requires a global view of the program
- Formal problem definition: $G(V,E) \forall = \text{call stack method } e=(u,v) \rightarrow u \text{ invokes } v$

\[
\begin{align*}
\text{maximize} & \quad \text{Total offloaded energy} \\
\text{such that:} & \quad \text{Total energy of state transmission} \\
& \quad \text{The time that takes to run both remotable and local methods} \\
& \quad \text{The time taken by state transmission} \\
& \quad \leq L \quad \text{and} \quad \text{we’re not offloading non-remotable methods}
\end{align*}
\]
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Evaluation

- Methodology:
  - 3 micro-benchmarks are evaluated (Face recognition, chess moves, video)
  - 6 configurations: smartphone only, MAUI + 4 WiFi RTTs, MAUI* + 3G

![Graphs of energy consumption for different benchmarks and configurations.](image-url)
Methodology:

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Summary

- Combines two approaches:
  - Fine-grained partitioning (offload strategies are defined by the programmer)
  - Process and VM migration (limited choice for offloading, all done by the OS)
- Use of CLR: same copy of the application on the device and server
  - Provides architecture-independent execution (translation overhead?)
  - Idea: maybe MAUI server should run a VM simulating mobile device?
- Might provide benefits beyond energy savings
  - Can offloading improve performance?
  - Applications that could not run on mobile devices run on the cloud
Conservative approach: relying on entire objects as AppState

- WIP: static analysis tool check which vars are referenced by remotable methods

In the MAUI solver section they only formulate the problem...

- How does it really solve the problem? Does it really solve an ILP?

Tested on three micro-benchmarks

- What about other applications?
- How much of the presented gain came from programming effort?

Does the fact that 3G is wasteful make MAUI impractical?
Summary

- Timeliness ≠ Performance
Summary

Thank you!