

MAUI: Making Smartphone Last Longer with Code Offload

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MAUI: Mobile Assistance Using Infrastructure

- MobiSys '10
- <https://www.sigmobile.org/mobisys/2021/>

Overview

- Introduction
- Remote Execution
- MAUI's System Architecture
- Evaluation
- Conclusion

Introduction

- Consumption of energy
- Remote execution
- Rely on the programmer: Large energy savings
- Full VM migration: Reduces burden on programmers
- Where MAUI comes in!

Introduction - MAUI

- Code Portability
- Programming Reflection and Type Safety
- Serialization
- Offers a dynamic system

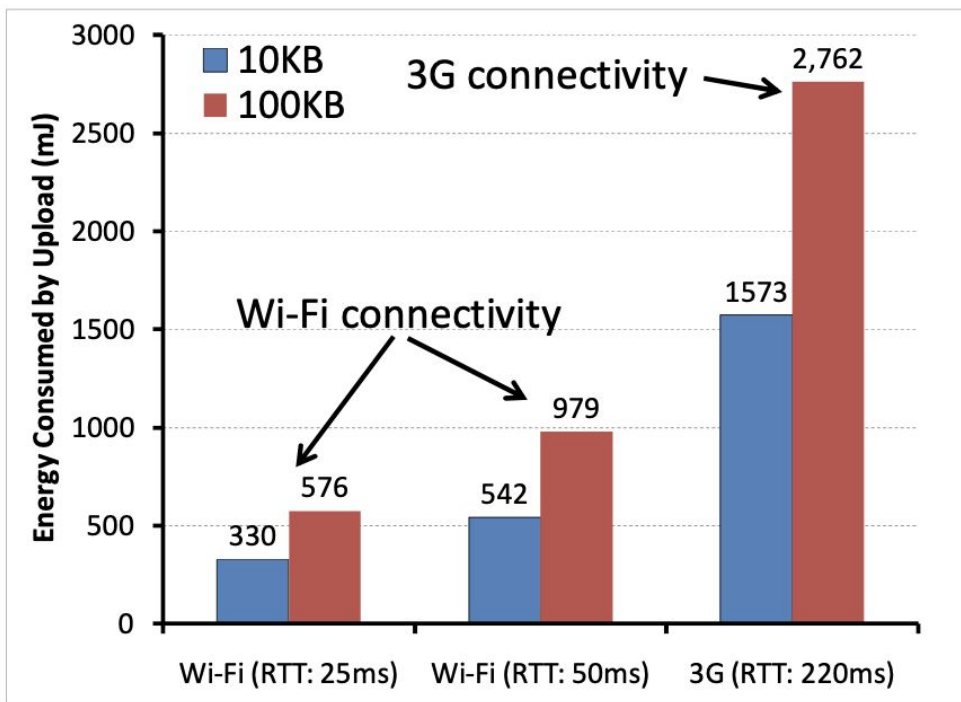
Remote Execution

- How severe is the energy problem on today's handheld devices?
- How energy efficient is using 3G for code offloading?
- How sensitive is the energy consumption of code offloading to the round trip times (RTTs) to the remote server?

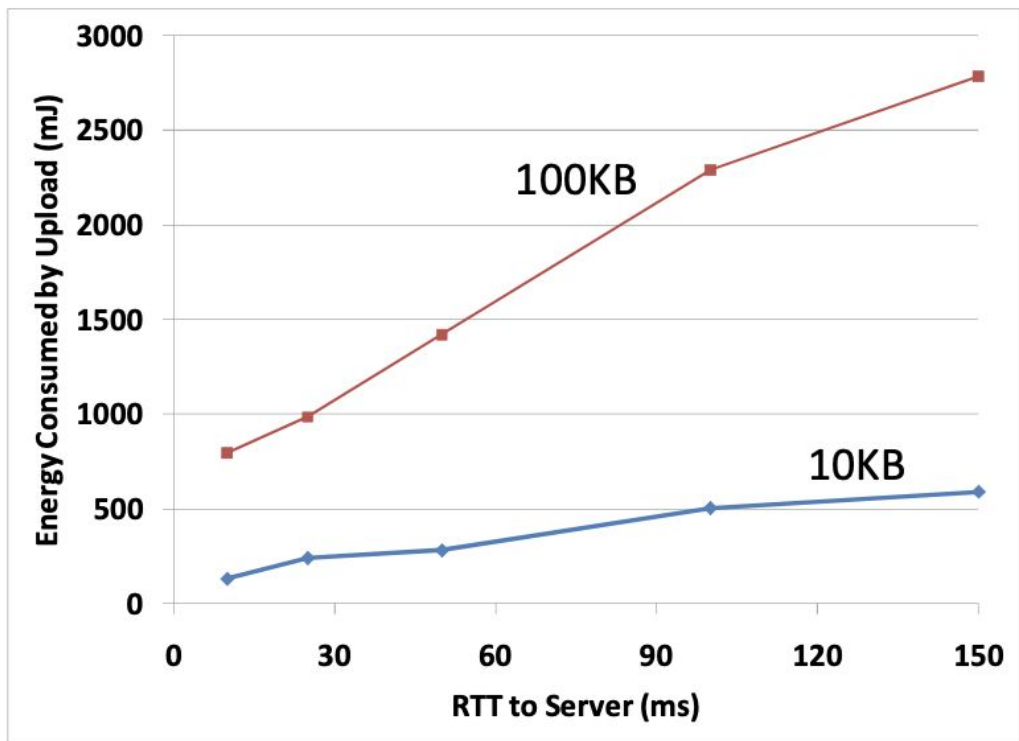
How severe is the energy problem on today's handheld devices?

- Limited Battery Capacity
- Energy Hungry Applications
- $\frac{1}{3}$ iPhone users accessed Youtube
- 400% increase of uploads in the first 6 days after iPhone 3GS
- Newer chemicals? Fuel cells?

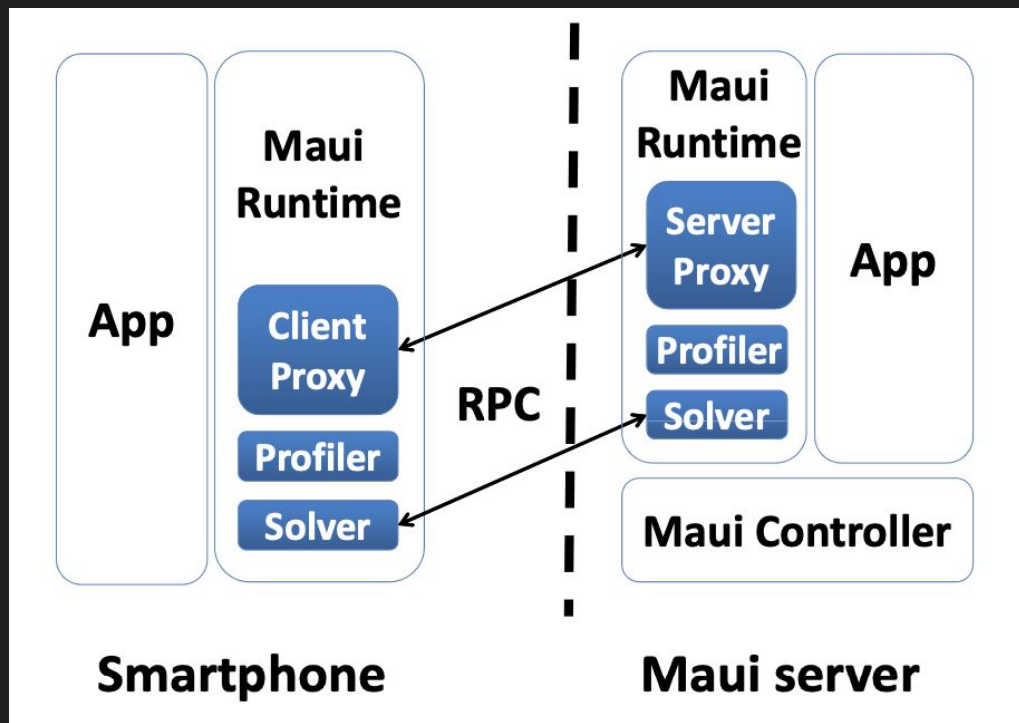
How energy efficient is using 3G for code offloading?



How sensitive is the energy consumption of code offloading to the round trip times (RTTs) to the remote server?



MAUI System Architecture



MAUI System Architecture

- Program Partitioning
- Different CPU architectures
- Identify which methods are marked remoteable
- Identify and migrate necessary program state from one machine to another
- Local or remotely on current environment
- Detect and tolerate failures

Different CPU Architectures

- Only supports Microsoft .NET Common Language Runtime
- MAUI application written in C#
- Must ensure that MAUI server has copies
- Directly from smartphone
- MAUI runtime on smartphone can send signature to the MAUI server

Marked Remote Methods and States Needed for Remote

- .NET Reflection API
- Simply looks for tag
[Remoteable]
- MAUI generates a wrapper
- Adds one additional input
parameter and one return value

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

//remote service interface
public interface IEnemyService {
    MAUIMessage<AppState, bool> SelectEnemy (AppState state, int x, int y);
    MAUIMessage<AppState, MauiVoid> ShowHistory(AppState state);
}
```

Running Locally or Remotely

- Two proxies
- Implements MAUI decisions from solver
- Solver get input from MAUI profiler
- Single threaded application

Detect and Tolerating Failures

- Timeout mechanism
- Reinvoke method locally
- Find new MAUI server

MAUI Profiler

- Smartphone's energy consumption
- Program characteristics
- Network characteristics

Device Profiling



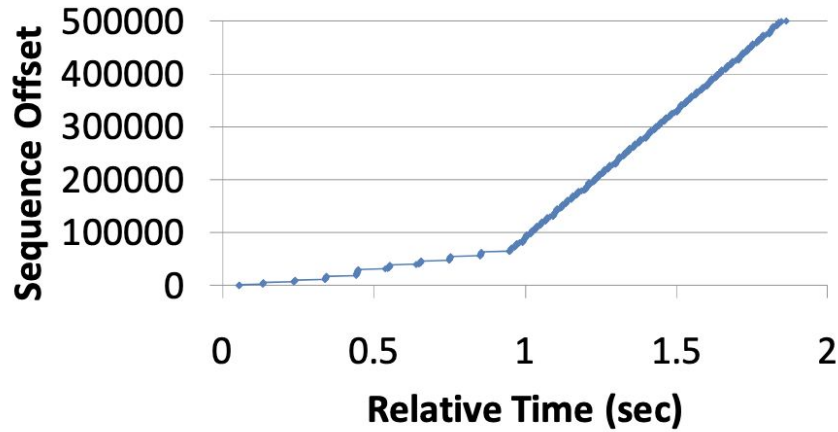
Program Profiling

- MAUI using methods duration and CPU cycles
- Applications are not deterministic
- Smartphones scale CPU's voltage dynamically

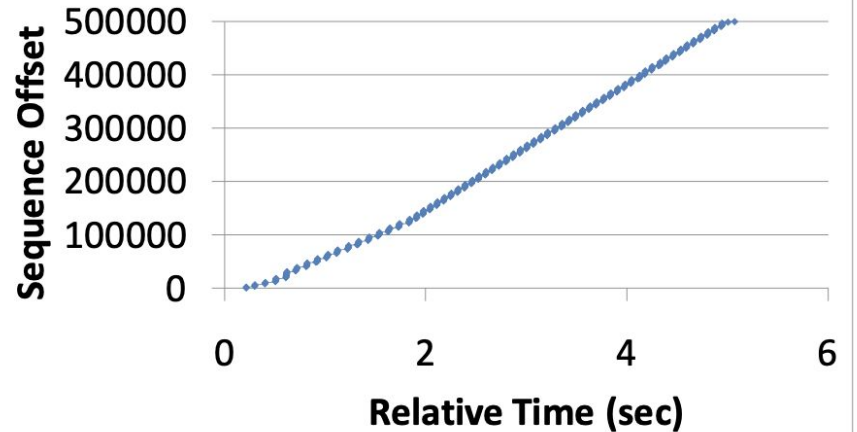
Network Profiling

- Power save mode with Wi-Fi hurts battery life
- Had to leave power save mode off during implementation
- Gathered data by TCP byte offsets vs time

Network Profiling



RTT: 25ms

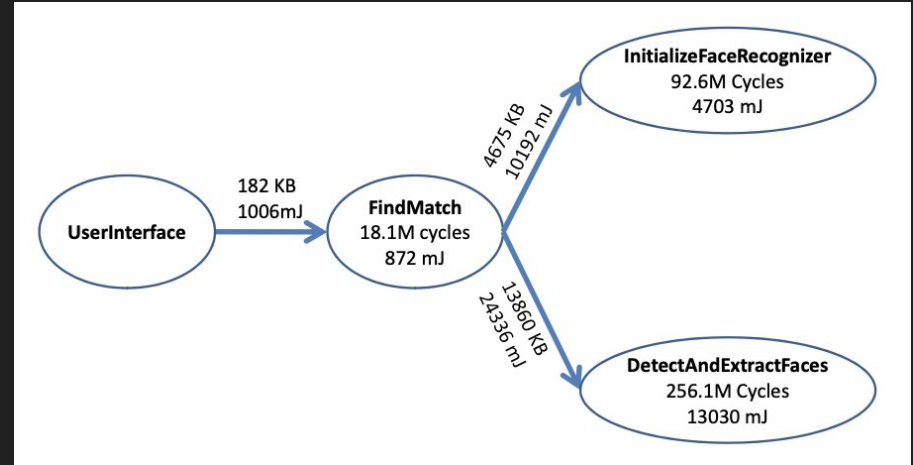


RTT: 75ms

Figure 7: The dynamics of a 500 KB TCP transfer with PSM disabled over a two links, one with a 25 ms RTT and one with 75 ms RTT. *During slow-start, for small sender window sizes, the sender goes to sleep after finishing sending its window causing the RTT of the transfer to effectively become 100 ms. As the size gets larger, the senders starts receiving TCP ACKs before finishing sending its window worth of segments. The discrepancy between these two regions of a transfer is less pronounced as the link's RTT increases.*

MAUI Solver

- Find program partitioning strategy that minimizes smartphone's energy consumption



MAUI Solver

- Formally, an 0-1 integer linear programming problem

v, u = method in call stack

E = energy consumption

I = indicator variable

C = cost of transferring

$$\text{maximize } \sum_{v \in V} I_v \times E_v^l - \sum_{(u,v) \in E} |I_u - I_v| \times C_{u,v}$$

$$\text{such that: } \sum_{v \in V} ((1 - I_v) \times T_v^l) + (I_v \times T_v^r)$$

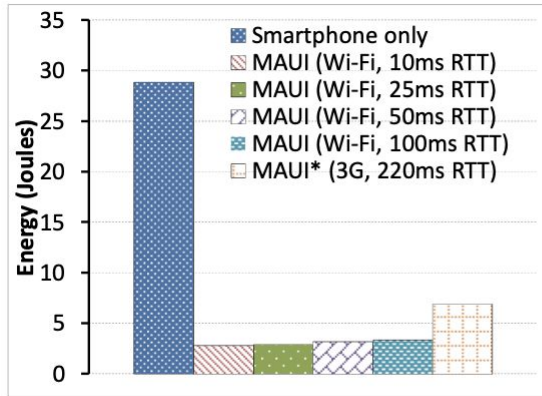
$$+ \sum_{(u,v) \in E} (|I_u - I_v| \times B_{u,v}) \leq L$$

$$\text{and } I_v \leq r_v, \forall v \in V$$

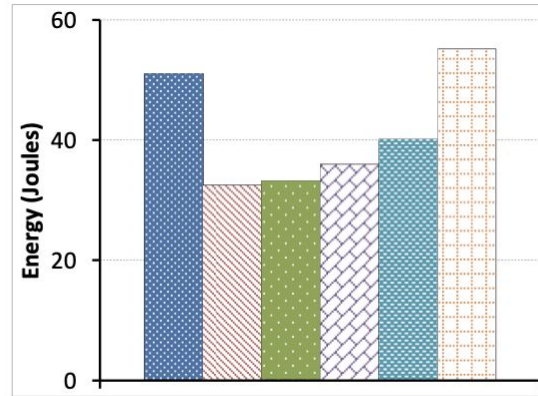
Evaluations

- Used HTC Fuze
- How much does MAUI reduce energy consumption of mobile applications?
- How much does MAUI improve the performance of mobile applications?
- Can MAUI run resource intensive applications?
- One run face recognition, 400 frames of video games, 30 move chess games

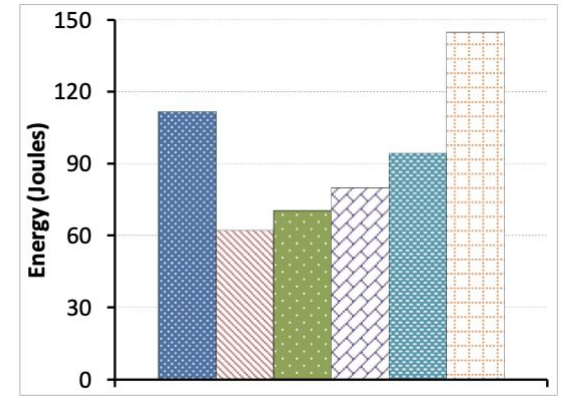
Evaluations - Energy Consumption



ONE RUN FACE RECOGNITION

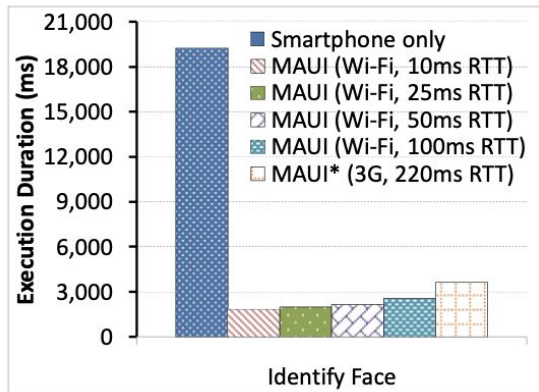


400 FRAMES of VIDEO GAME

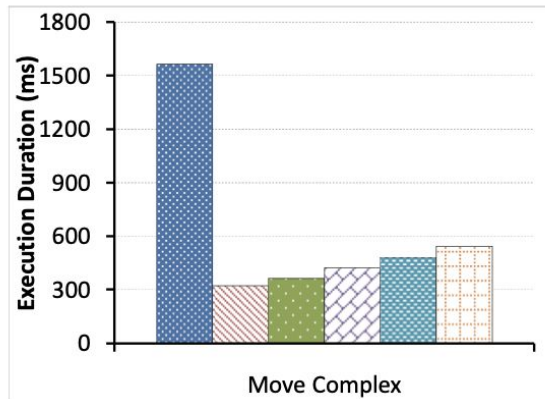


30 MOVE CHESS GAME

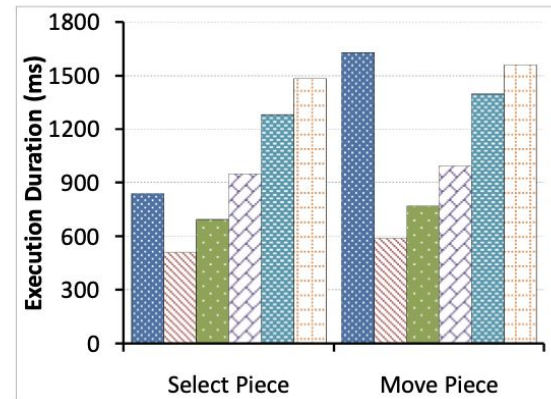
Evaluations - Performance



ONE RUN FACE RECOGNITION

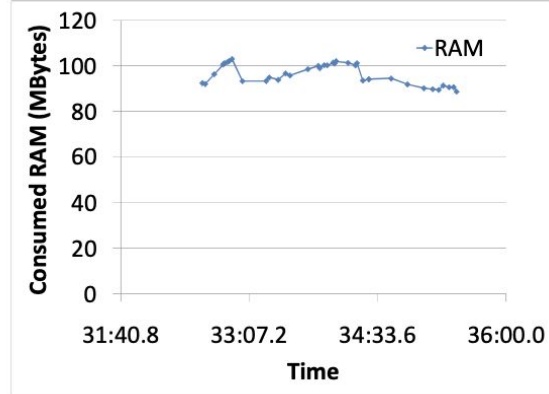
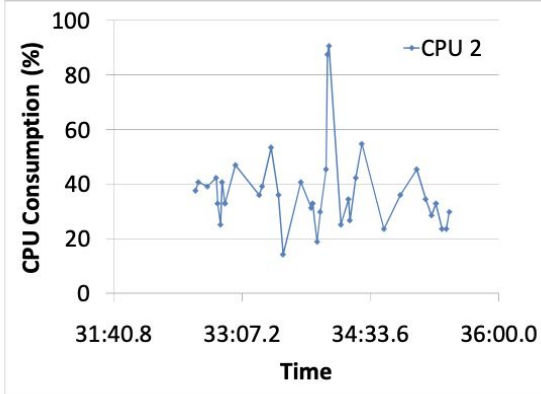
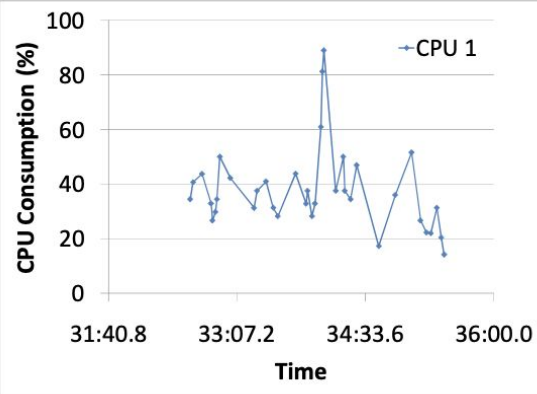


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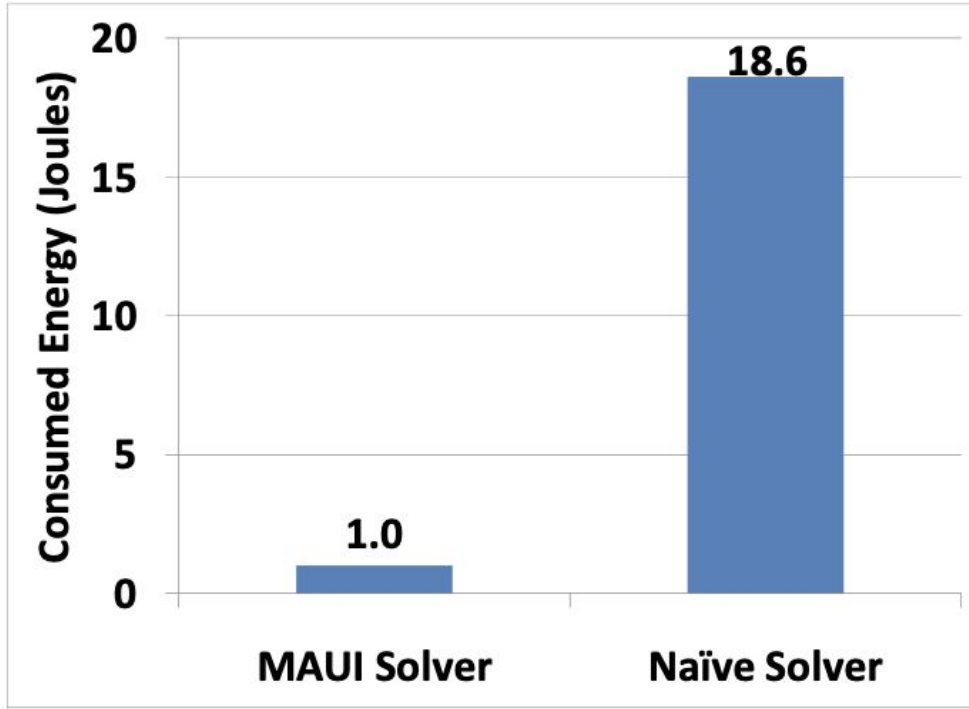


30 MOVE CHESS GAME

Evaluations - Speech Recognition



Evaluations - Misc.



Conclusion

- MAUI
- Need for remote execution
- MAUI's system architecture
- Evaluations

Questions?

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