An Investigation into Energy-Saving Programming Practices for Android Smartphone App Development

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Motivation

- Usability of mobile apps is constrained by limited battery energy
- Energy consumption is an important, but informal, quality metric for mobile app developers
- Can influence users' ratings of applications
- No guidelines for app developers

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Current State of the Art

- Many techniques have been developed
  - Energy measurement
  - Energy estimation
- Connection between usage and areas for improvement is not straightforward
- Developer blog tips are generally unsupported by any empirical evaluation or evidence

Goal of the Study

1. Identify set of recommended best practices, conventional wisdom, and suggested tips
2. Quantitatively evaluate each to determine its effectiveness at reducing the energy consumption of a mobile app

Focus of the Study

1. Network usage
2. Memory usage
3. Performance oriented tips
   a) Loop iteration
   b) Direct access of fields
   c) Static method invocation

Why Network Usage?

- Informally, network communication is known as an energy expensive operation
- Accessing the Internet is one of the most popular activities performed on a smartphone
- HTTP packet usage underlies most of this communication
- **Known:** Larger data packet sizes are better than smaller data packets for throughput

Does this hold for energy usage as well?

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Why Memory Usage?

- Commonly used and in large quantities
- **Widely assumed**: higher memory usage leads to more energy consumption

What is the cost of memory usage?

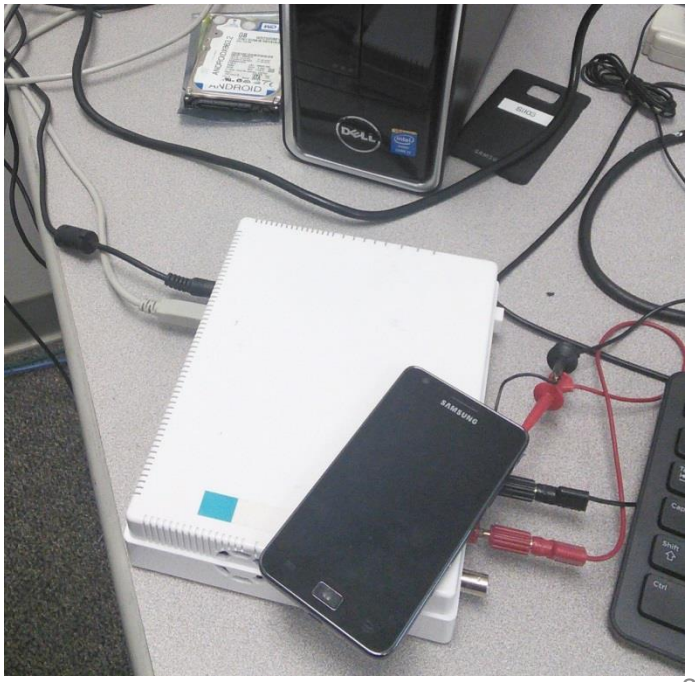
Why Performance Tips?

- Performance generally focuses on runtime speed
- Runtime is more readily noticed than other metrics
- Many app developers care a lot about runtime
- As a result, there are many “speed up” tips

Do these help reduce energy consumption as well?

Experiment Equipment

- Smartphone: Samsung Galaxy II AT&T version
  - Running Samsung official Android 4.2.2.
- Power Measurement platform: Monsoon
- Controller: Dell XPS 8100
  - Intel 3GHz i5 processor
  - 8GB memory



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Network Usage: Experiment

RQ: Could bundling of small HTTP requests save energy?

Network Usage: Experiment

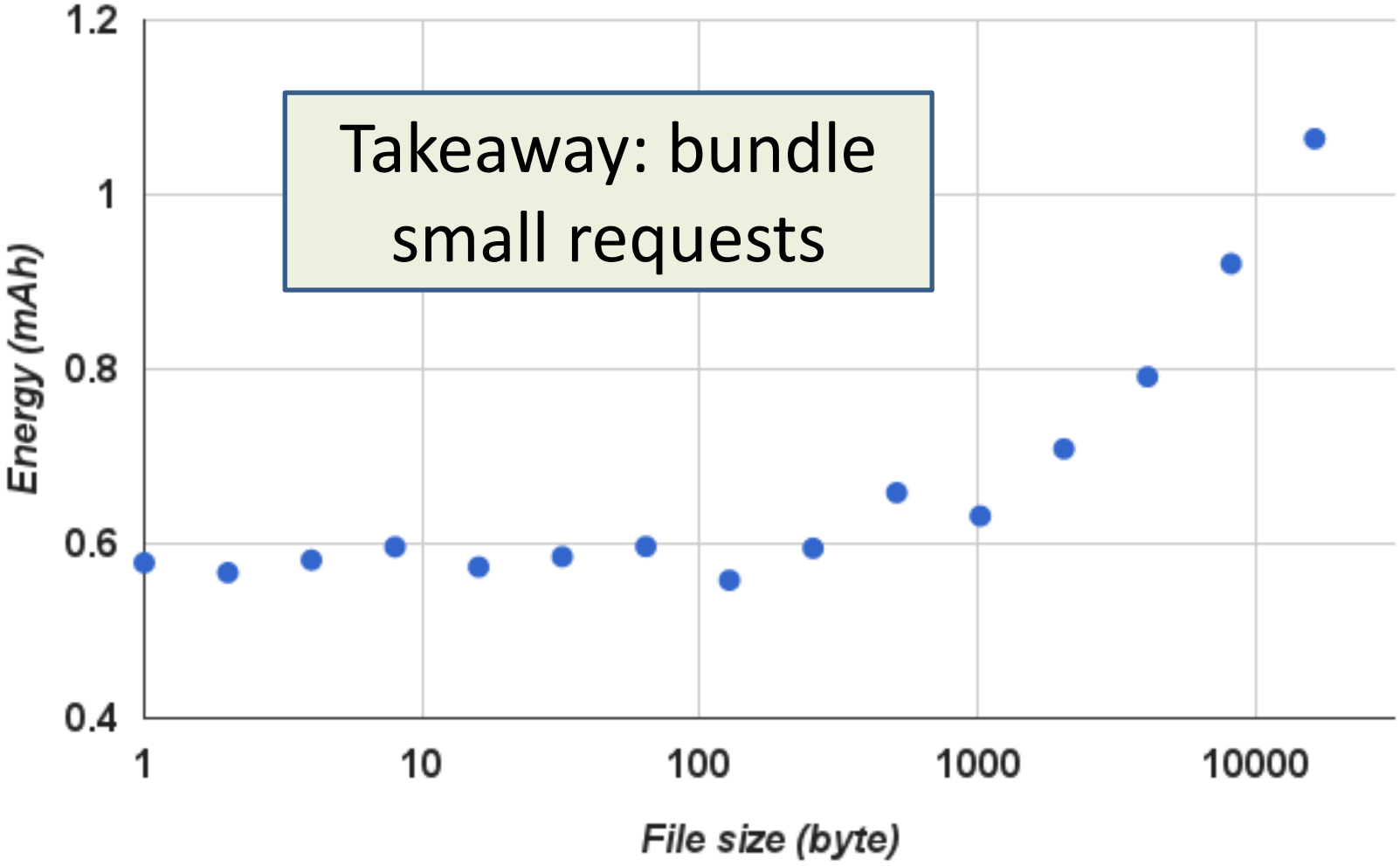
```
1  protected void onCreate(Bundle savedInstanceState) {
2      super.onCreate(savedInstanceState);
3      setContentView(R.layout.activity_main);
4      URL url = new URL(resourcelink);
5      for(int i=0;i<N;i++)
6      {
7        URLConnection urlConn = url.openConnection();
8        InputStream in = new BufferedInputStream(urlConn.
                 getInputStream());
9        try {
10           readStream(in);
11       finally {
12           in.close();
13       }
14     }
15     finish();
16 }
```

Vary size of remote file

Network Usage: Experiment Details

- Measure the energy of empty loop
  - As background/baseline energy
- Download test file from our server
  - Use the GET method
  - Measure the energy of the program
  - Repeat 1000 times (N)
- Subtract the energy of the empty loop

Network Usage: Result



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Memory Usage

- RQ: Does high memory usage make the application consume more energy?

Memory Usage

```
1  protected void onCreate(Bundle savedInstanceState) {
2      super.onCreate(savedInstanceState);
3      setContentView(R.layout.activity_main);
4      int[] array=new int[size];
5      for(int k=0;k<N;k++)
6          for(int i=0;i<size;i++)
7          {
8              array[i]=1;
9           }
10 }
```

Vary size

Memory Usage: Experiment

- Array size: 512 - 5,120,000 bytes
- Iterate N = 100,000 times
- Subtract the energy of empty loop
- Report $AE = \frac{E}{N*size}$
  - E: the energy consumption of the program minus empty loop energy
  - AE is the average energy of accessing each unit in the array

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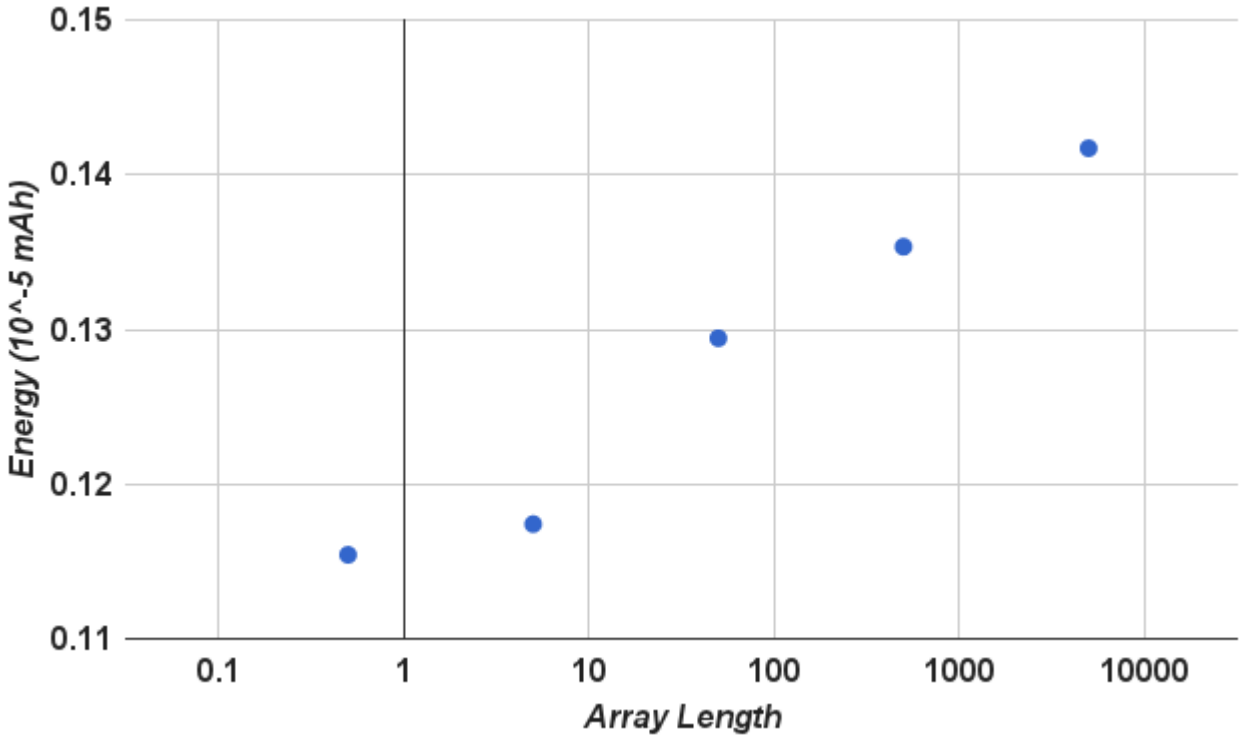
Memory Usage: Result



- Memory cost increases very slowly
- **Tradeoff:** use memory when it can help save energy for other components. (e.g., network buffers)

Performance Tips

```
1    Object[] array;
2    int l=array.length;
3    for(int i=0;i<l;i++)
4    {
5        array[i]=null;
6    }
```

```
1    Object[] array;
2    for(int i=0;i<array.length;i++)
3    {
4        array[i]=null;
5    }
```

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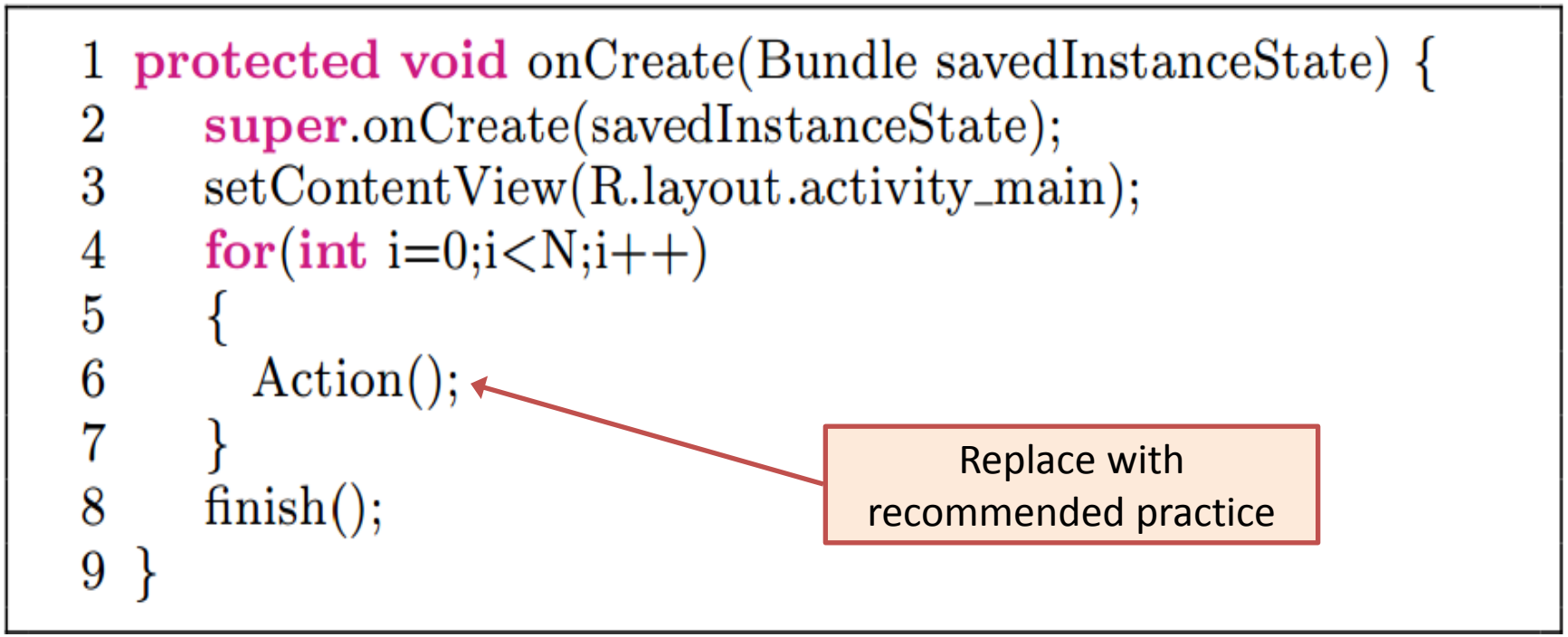
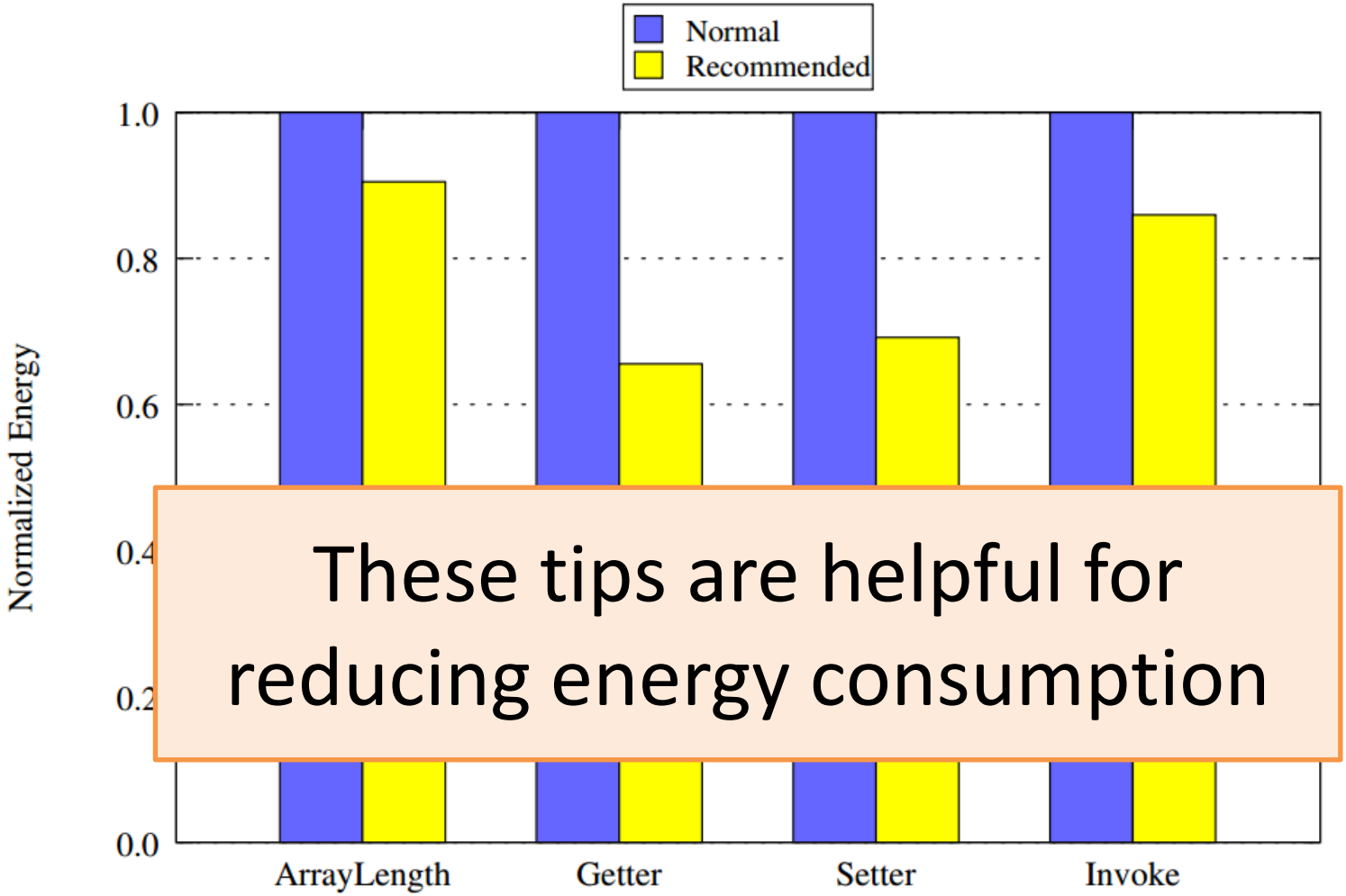
Performance Tips: Experiment



Performance Tips: Result



These tips are helpful for reducing energy consumption

Performance Tips: More Results

- Iterate with variable initialized to array length
  - Reduce baseline loop energy by 10%
  - But that was an almost empty loop
- Direct field access avoids overhead of virtual invocations of getters and setters. Can be as high as 35%!
- Virtual table lookup costs make static invocations more energy efficient as well

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Summary

We performed a small scale empirical evaluation of developer-oriented energy tips

- Bundle small HTTP requests
- Use memory to improve the performance and reduce energy consumption of other components
- Performance tips: don't use length() in loops, access fields directly, use static invocations.

Future Work

- Expand the scope
  - More platforms
  - More operating systems
  - More suggestions from the community
- Increase the depth
  - More data points
  - More comprehensive statistical analysis