A Case for Smartphone Reuse to Augment Elementary School Education

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What we see everyday is what we use everyday
Trend of Smartphones

Smartphone Shipments

Source: The Information Network
Some Numbers

• Nokia alone sells over 1 million handsets a day
• Over 300,000 iPads were sold in the first day
• iPhone 4 made another astonishing record by selling 1.7 million units in just 3 days
Some Numbers

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Is this good?
Resource Use in Silicon Fabrication

- 1.6 kilowatt-hrs / cm²
- 20 liters water / cm²
- 3.3 billion active cell phone subscriptions
- ~20 cm² / phone
- 106 billion kilowatt-hrs (recall that datacenters use 80 billion kWh annually)
Throughput

- 280 Million phones sold / quarter
- Average lifetime of a phone: 1.5-2 yrs
- Old phones sitting in drawers, but throughput of over 1 billion phones / yr
- 32 billion kilowatt-hrs / yr just for uproc
Other Impacts

- 400 billion liters of water
  - 160,000 olympic swimming pools
  - More than double annual global bottled water consumption
- 400 million kg of soil to remediate just the copper
  (more copper on surface than inside the earth!)
What can we do?

- Recycling is an option but should happen when the phone is completely unusable
- Reusing Smartphones
  - Old phones are still in the market
  - Building sensor networks
  - Reuse is nothing new. What is new is the need to reuse.
Smartphone Reuse for Education
-- A Preliminary Study

• A Match: Reused Smartphones & Education
  ▪ Why education?
  ▪ What benefit Smartphones can bring?

• Feasibility of Reusing
  ▪ Does the functionality of reused Smartphones satisfy educational applications?

• Challenges of Reusing
Smartphone Reuse for Education -- A Preliminary Study

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Why Elementary School Education?

• Elementary school students do not have access to Smartphones
• They are in the stage of learning that needs most fun stuff
Future of Education

- Text- vs. Visualization-based Learning
- Passive vs. Active Learning
- Individual vs. Cooperative Learning

Smart devices/PDAs are key elements of future education

Reused Smartphones have equivalent function with PDAs
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Methodology

- Experiments on Smartphones running educational applications
- Static Resource Requirement
  - Function Requirement
  - Storage Requirement
- Dynamic Resource Requirement
  - Memory Usage
  - Power Consumption
  - Network Communication
Methodology - Platform

- HTC Nexus One

<table>
<thead>
<tr>
<th>Processor</th>
<th>Qualcomm® QSD8250\textsuperscript{TM} 1 GHz Snapdragon ARM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating System</td>
<td>Android\textsuperscript{TM} 2.1 (Éclair)</td>
</tr>
<tr>
<td>Memory</td>
<td>ROM (Flash memory): 512MB, RAM: 512MB</td>
</tr>
<tr>
<td>Display</td>
<td>3.7-inch AMOLED with 480x800 WVGA resolution</td>
</tr>
<tr>
<td>GPS</td>
<td>Internal GPS antenna</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Wi-Fi® IEEE 802.11 b/g</td>
</tr>
<tr>
<td>Camera</td>
<td>5.0 megapixel color camera with auto focus, 2X digital zoom, LED flash, and geo tagging</td>
</tr>
<tr>
<td>Battery</td>
<td>Rechargeable Lithium-ion polymer battery Capacity: 1400 mAh</td>
</tr>
<tr>
<td>External Storage</td>
<td>4GB microSD Card</td>
</tr>
</tbody>
</table>
## Methodology - Applications

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plink Art</td>
<td>An application for identifying, discovering and sharing art.</td>
</tr>
<tr>
<td>Word Puzzle</td>
<td>Designed to provide a fun way to learn basic English words for preschool children.</td>
</tr>
<tr>
<td>Celeste</td>
<td>Help learning the Solar System by showing 3D planets in the direction that the camera aims at.</td>
</tr>
<tr>
<td>Trippo</td>
<td>Translate any given phase from both audio and text among over 30 different languages.</td>
</tr>
<tr>
<td>Voicetrans</td>
<td>Similar to Trippo plus being able to speech received SMS.</td>
</tr>
<tr>
<td>mobiProfessor</td>
<td>A learning platform that gives one access to community created courses.</td>
</tr>
<tr>
<td>Robotic Guitarist</td>
<td>A guitar emulator and chord guide.</td>
</tr>
<tr>
<td>FUN2Learn</td>
<td>A game for learning and practicing foreign languages.</td>
</tr>
<tr>
<td>Botanica</td>
<td>Helps researching the best plants for certain climate and locations by simulating food growing.</td>
</tr>
<tr>
<td>Learn!</td>
<td>A flashcard learning application which enables learning, creating learning material and sharing.</td>
</tr>
<tr>
<td>Flu Tracker</td>
<td>A highly effective flu prevention and educational app for everyone during flu season.</td>
</tr>
</tbody>
</table>
### Static - Function Requirement

Most applications only need around 3 in all 10 device features

<table>
<thead>
<tr>
<th>Application</th>
<th>Internet Access</th>
<th>SD Card Access</th>
<th>Camera</th>
<th>Network Location</th>
<th>GPS Location</th>
<th>Audio Record</th>
<th>Total Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plink Art</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Word Puzzle</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>3</td>
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<tr>
<td>Celeste</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Trippo</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td>2</td>
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<tr>
<td>VoiceTrans</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>mobiProfessor</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Robotic Guitarist</td>
<td></td>
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<td></td>
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<tr>
<td>Botanica</td>
<td>✓</td>
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<tr>
<td>Learn!</td>
<td>✓</td>
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<td></td>
<td>2</td>
</tr>
<tr>
<td>Flu Tracker</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
Static - Storage Requirement

![Graph showing static storage requirement for various applications.](image-url)
Flash storage wear-out

- Less frequent for Smartphone
- A 512MB flash memory will have a useful lifespan of 6.5 years.
Dynamic – Memory Usage

![Bar graph showing memory usage for various applications.](image)

- **Plink Art**
- **Word Puzzle**
- **Celeste**
- **Trippo**
- **Voicetrans**
- **mobiProfessor**
- **Robotic Guitarist**
- **FUN2Learn**
- **Botanica**
- **Learn!**
- **Flu Tracker**
- **All**

- **Minimum**
- **Average**
- **Peak**
Dynamic – Power Consumption
Dynamic – Power Consumption

- A fully charged battery (1400mAh) could run educational applications for 6.5 hours
Battery Degrading

- After 18 months use, 1250-mAh capacity is still left for the battery
Battery Degrading

![Graph showing battery degradation over time]

- **Regular Use**: battery capacity decreases over time, taking about 1.8 months to reach a certain level.
- **Reuse**: another battery is used, showing a different degradation pattern.
- **Battery still usable**: indicating a threshold where the battery is still functional.

The graph illustrates the decline in battery capacity over years, with distinct lines for regular use and reuse scenarios.
Dynamic – Network Comm.

![Bar chart showing network transmission for different applications with average and peak values.]
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Challenges

• Heterogeneity
  ▪ Different manufactures
    • Apple, HTC, Nokia, Blackberry…
    • Different Device features / interface
    • Different OS: Linux / Windows / Palm / iOS…
  ▪ Different generations
    • iPhone Original, 3G, 3GS, 4G…
    • HTC T-Mobile G1, Nexus One…
  ▪ Device wear-out
Challenges

• Degraded reliability
• Partially configured devices
• Different processing power and timing guarantees
Conclusion

- Fast evolution of Smartphones is alarming
- Good match between Smartphone reuse and education
- Reused Smartphones can satisfy different resource requirement of educational applications
- Handling heterogeneity will be future work

Questions?