CSE 291: Topics in Embedded Computing and Communication

Lecture 1: Introduction
Aaron Schulman
UC San Diego

http://cseweb.ucsd.edu/~schulman/class/cse291_f19/
“Roughly every decade a new, lower priced computer class forms based on a new programming platform, network, and interface resulting in new usage and the establishment of a new industry.”

Adapted from D. Culler and P. Dutta
Mobile devices are today’s primary computing platform

Market size (# of devices shipped in 2015):

- Mobile:
  - 1.4 billion **smartphones** [stabilizing] (source IDC)
  - 78 million **wearables** [growing] (source IDC)

- Desktop/Notebook
  - ~ 300 million **PCs** [shrinking] (source IDC)
Mobile is stabilizing & IoT is growing

• The saturation point for mobile is when every human has at least one mobile device.

• There can be hundreds of Internet of Things (IoT) devices per human.

Healthcare

Agriculture

Home

Source: Phillips

Source: Phytech

Source: stuff.tv
Smart home IoT devices are finally gaining traction

<table>
<thead>
<tr>
<th>Category</th>
<th>2019 Shipments*</th>
<th>2019 Market Share*</th>
<th>2023 Shipments*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video Entertainment</td>
<td>346.5</td>
<td>41.2%</td>
<td>424.4</td>
</tr>
<tr>
<td>Home Monitoring/Security</td>
<td>163.9</td>
<td>19.5%</td>
<td>349.3</td>
</tr>
<tr>
<td>Smart Speaker</td>
<td>138.5</td>
<td>16.5%</td>
<td>206.2</td>
</tr>
<tr>
<td>Others</td>
<td>191.7</td>
<td>22.8%</td>
<td>483.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>840.7</td>
<td>100.0%</td>
<td>1,463.5</td>
</tr>
</tbody>
</table>

Source: IDC Worldwide Quarterly Smart Home Device Tracker, June 25, 2019
What’s inside a mobile computing device?

- High pixel density capacitive **touchscreen**
- Powerful **multi-core CPUs**
- Powerful **GPUs**
- Variety of communication radios: **Cellular** (wide) / **WiFi** (local) / **Bluetooth** (personal)
- Generic **sensors** (gyro, accel, heart-rate, GPS)
- High capacity batteries (at least 3,000 mAh)

Mobile is the primary interface between computers and humans.
What’s inside an IoT device?

- Application-specific **sensor**
  (humidity, blood Alcohol Content, indoor positioning, microphone)

- Low-power **microcontroller**

- Application-specific radio:
  **Bluetooth LE** (personal), **WiFi** (local), **LPWAN** (wide)

- Application-specific **actuator**: (pill dispenser, speaker)

- Application-specific **power**: (energy harvesting, long lasting battery, grid)
### Difference between mobile and IoT

**Mobile**
- High pixel density capacitive **touchscreen**
- Powerful **multi-core CPUs**
- Powerful **GPUs**
- Variety of communication **radios**: **Cellular** (wide) / **WiFi** (local) / **Bluetooth** (personal)
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**IoT**
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Main themes of Embedded & Mobile research

- How do these devices enable new *interdisciplinary* work?
- What new *applications* can these devices enable?
- How can we make them *secure*?
- How do we improve their *energy efficiency*?
Battery capacity is not improving quickly

In past 30 years: only 4x improvement in energy density

Source: Panasonic
We can no longer rely on efficient transistors

End of Dennard Scaling

2005

Source: Horowitz et al.
We now rely on heterogeneous design and power management logic. However, this makes it difficult for developers to reason about energy.
What are wireless systems?

**Systems that primarily use radio frequency signals for:**

- **Communication** (LTE, WiFi, Zigbee, DVB, FM/AM)
- **Localization** (GPS, RADAR, VOR)
- **Tracking and authentication** (RFID, Apple Beacon)
- **Imaging** (Body scanners)

*There are new applications every few years…*
The evolution of devices in wireless systems

<table>
<thead>
<tr>
<th>System</th>
<th>Device size</th>
<th>Device power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telegraph</td>
<td>Large</td>
<td>Mains</td>
</tr>
<tr>
<td>TV/Radio</td>
<td>Medium</td>
<td>Mains</td>
</tr>
<tr>
<td>Handhelds</td>
<td>Small</td>
<td>Battery</td>
</tr>
<tr>
<td>Cellular/WiFi</td>
<td>Small</td>
<td>Battery</td>
</tr>
<tr>
<td>Sensors/RFID</td>
<td>Tiny</td>
<td>Battery or Harvesting</td>
</tr>
</tbody>
</table>

Most of the cutting edge research challenges widely held beliefs about the capability of these constrained devices.
The problems appearing in the wireless session

Communicating efficiently with tiny devices…
   …with sufficient range and throughput.
    (BackFi)

   …in the presence of many other devices.
    (Caroke & Laissez-Faire)

Localizing devices indoors using radio signals…
   …with 10 meter accuracy using existing infrastructure.
    (SpotFi)
Communicating efficiently with tiny devices…
  …with sufficient range and throughput.
  (BackFi) *interfere, reflect*

  …in the presence of many other devices.
  (Caroke & Laissez-Faire) *imperfect, interfere*

Localizing devices indoors using radio signals…
  …with existing infrastructure and sufficient accuracy.
  (SpotFi) *vector*
What are we going to read in this class?

Research papers from top venues in several areas:

- **Mobile**: MobiCom and MobiSys
- **Systems**: SOSP and OSDI
- **Networking**: SIGCOMM and NSDI
- **Security**: S&P, USENIX Sec., and CCS
Will we talk about the cloud?

• Yes and no.
• We will talk about it as an enabling tech for mobile/IoT.
• Cloud/datacenter computing is its own research area.
Instructor

• Aaron Schulman <schulman@cs.ucsd.edu>

• Office hours: Tue & Thur 11am-12pm - CSE 3120
My humble opinion:

Research changes the way we think.
• Best ideas have the most impact on how the community thinks.
• Practicality is rewarded only when it pushes the boundary.

Industry changes the way we live.
• Best ideas tap into new markets and make lots of $$$$.
• Practicality is necessary.

The two are connected, but often in unexpected ways.
Research project

• Proposal - 2 page writeup on the goals of your project
• Presentation - 20 minute talk on your project
• Writeup - 6 page (workshop-style) paper
  • [Abstract, Intro, Motivation, Related Work, Contributions, Evaluation, Conclusion]
Grading

- Project (50%)
  - Proposal, Implementation, Writeup
- Paper notes and discussion lead (25%)
- Class participation (25%)
Next class

Mark Weiser’s (PARC) visionary work defining ubiquitous computing (pads, tabs, boards).

1st class, so I’ll lead the discussion