CS 528 Mobile and Ubiquitous Computing
Lecture 1a: Introduction

Emmanuel Agu
About Me
A Little about me

- WPI Computer Science Professor
- Research interests:
  - mobile computing especially mobile health, computer graphics
- Started working in mobile computing, wireless in grad school
- CS + ECE background (Hardware + software)
- Current active research: Mobile health apps
  - E.g: AlcoGait app to detect how drunk Smartphone owner is
    - https://www.youtube.com/watch?v=pwZaoKmfq8c
Administrivia
Administrivia: Schedule

- **Week 1-8:** I will introduce class, concepts, Android (Students: Android programming, assigned projects)
  - **Goal:** Students acquire basic Android programming skills to do excellent project
  - Programming apps that use mobile & ubicomp components
- **Week 9:** Students will present final project proposal
- **Week 9-14:** Students work on final project
- **Week 11:** Students present on new mobile APIs, components
  - E.g. machine learning in Android, Augmented Reality
- **Week 14:** Students present + submit final projects
- Quizzes (5) throughout
Special Notes: This online offering

- Today’s class recorded, video posted to canvas after class
- From lecture 2 on:
  - Videos posted days BEFORE class
  - Class: quick summary of key points, more interactive (Question and Answer), Quiz
  - Default: I’ll assume all students can make it to class for quizzes
  - Please email me if you cannot. E.g. different time zone, illness, etc
Requirements to get a Grade

- **Grading policy:**
  - Presentation (tech topic) 15%, Assigned Projects 35%, Final project: 30%, Quizzes: 20%

- **Final project phases:** (See class website for deadlines)
  1. Pick partners, form project groups of 5 members
  2. Submit 1-slide of proposed idea (problem + envisioned solution)
  3. Present project proposal
     + plus submit proposal (intro + related work + methodology/design + proposed project plan)
  4. Build app, evaluate, experiment, analyze results
  5. Present results + submit final paper (in week 14)

- **Degree of difficulty of project taken into account in grading rubric**
Course Texts

- **Android Texts:**
  - *Head First Android Dev, (2nd ed)*, Dawn and David Griffiths, O'Reilly, 2017

- Will also use official Google Android documentation
- Learn from research papers: Why not text?

Gentle, visual intro

Bootcamp Tutorial

Visual kotlin intro
Grader

Will be hired
Class in 2 Halves

- 2 Halves: About 1 hour 15 mins each half
- Break of about 15 mins
- Talk to me at the end of class NOT during break
  - I need a break too
Poll Question

- How many students:
  1. **Own** recent Android phones (running Android 4.4, 5, 6, 7, 8 or 9?)
  2. **Can borrow** Android phones for projects (e.g. from friend/spouse)?
  3. **Do not own and cannot borrow** Android phones for projects?
  4. **Cannot come to class** (e.g. in very different timezone?) Other constraints?
Mobile Devices
Mobile Devices

- Smartphones (Blackberry, iPhone, Android, etc)
- Tablets (iPad, etc)
- Laptops
- Smartwatches
SmartPhone Hardware

- Smartphones have capabilities beyond calling and texting (or feature phones)

**Smart =** Communication $+$ Computing $+$ Sensors

- **Communication:** Talk, SMS, chat, Internet access
- **Computing:** Powerful processors, programmable operating system, Java apps, JVM, apps
- **Sensors:** Camera, video, location, temperature, heart rate sensor, etc

**Example:** Google Pixel XL 3 phone: 8 core 2.5 GHz/1.6GHz kryo CPU, Adreno 630 GPU, 128GB RAM
  - A PC in your pocket!!
  - Multi-core CPU, GPU, over 20 sensors (10 hardware sensors, over 10 soft sensors)
  - Linux OS, JVM, runs OpenGL ES, OpenCL and now Deep learning (Tensorflow)
Qualcomm SnapDragon System on a Chip (SoC)

- Core of most high end smartphones shipped in 2020
- **SoC**: Chip that integrates most computer components: CPU, GPU, memory, I/O, storage

Smartphone Sensors

- Typical smartphone sensors today
  - accelerometer, compass, GPS, microphone, camera, proximity
- Can sense physical world, inputs to intelligent sensing apps
  - E.g. Automatically turn off smartphone ringer when user walks into a class
Growth of Smartphone Sensors

- Smartphone generations have more and more sensors!!

Future sensors?
- Complex activity sensor,
- Pollution sensor,
- etc
Wireless Networks
Wireless Network Types

- **Wi-Fi (802.11)**: (e.g. Starbucks Wi-Fi)
- **Cellular networks**: (e.g. T-Mobile network)
- **Bluetooth**: (e.g. car headset)
- **Near Field Communications (NFC)**
  e.g. Mobile pay: swipe phone at dunkin donut
# Wireless Networks Comparison

<table>
<thead>
<tr>
<th>Network Type</th>
<th>Speed</th>
<th>Range</th>
<th>Power</th>
<th>Common Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>WLAN</td>
<td>600 Mbps</td>
<td>45 m – 90 m</td>
<td>100 mW</td>
<td>Internet.</td>
</tr>
<tr>
<td>LTE (4G)</td>
<td>5-12 Mbps</td>
<td>35km</td>
<td>120 – 300 mW</td>
<td>Mobile Internet</td>
</tr>
<tr>
<td>3G</td>
<td>2 Mbps</td>
<td>35km</td>
<td>3 mW</td>
<td>Mobile Internet</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>1 – 3 Mbps</td>
<td>100 m</td>
<td>1 W</td>
<td>Headsets, audio streaming.</td>
</tr>
<tr>
<td>Bluetooth LE</td>
<td>1 Mbps</td>
<td>100+ m</td>
<td>.01–.5 W</td>
<td>Wearables, fitness.</td>
</tr>
<tr>
<td>NFC</td>
<td>400 kbps</td>
<td>20 cm</td>
<td>200 mW</td>
<td>Mobile Payments</td>
</tr>
</tbody>
</table>

Table credit: Nirjoin, UNC

Different speeds, range, power, uses, etc
Mobile Computing
mobile

*adjective*

/ˈmōbəl, ˈmōˌbēl/

1. able to move or be moved freely or easily.
   "he has a major weight problem and is not very mobile"

*synonyms*: able to move (around), moving, walking; motile; ambulant
Mobile Computing

- Human computes while moving
  - Continuous network connectivity,
  - Points of connection (e.g. cell towers, WiFi access point) might change
- **Note**: Human initiates all activity, (e.g. launches apps)
- Wireless Network is passive
- **Example**: Using [foursquare.com](http://foursquare.com) on Smartphone
Mobile computing = computing while location changes

**Location-aware:** Location must be one of app/program’s inputs
- Different user location = different output (e.g. maps)

**E.g.** User in California gets different map from user in Boston
Location-Aware Example

- Location-aware app must have different behavior/output for different locations
- Example: Mobile yelp

  - **Example search**: Find Indian restaurant

- App checks user’s location

- Indian restaurants **close to user’s location** are returned
Example of Truly Mobile App: Word Lens

- Translates signs in foreign Language
- Location-dependent because location of sign, language? Varies
- Acquired by Google in 2015, now part of Google Translate
Some Mobile apps are not Location-Aware

- If output does not change as location changes, not location-aware
- Apps run on mobile phone **just for convenience**
- Examples:
  - Distinction can be fuzzy. E.g. Banking app may display nearest locations
Which of these apps are Location-Aware?

a. Yahoo mail mobile
b. Uber app
Notable: Sharing Economy Apps

- **Idea:** Share resource, maximize under-utilized capacity
- **E.g.** Uber: share care, Airbnb: Share house
- **Question:** How is mobile/ubicomp used in sharing apps?
Mobile Device Issue: Energy Efficiency

- Most resources increasing exponentially except battery energy (ref. Starner, IEEE Pervasive Computing, Dec 2003)

- Some energy saving strategies:
  - **Energy harvesting**: Energy from vibrations, charging mats, moving humans
  - **Scale content**: Reduce image, video resolutions to save energy
  - **Auto-dimming**: Dim screen whenever user not using it. E.g. talking on phone
  - **Better user interface**: Estimate and inform user how long each task will take
    - E.g: At current battery level, you can either type your paper for 45 mins, watch video for 20 mins, etc

![Image of mobile devices and charging mats](image1.png)

![Graph of improvements in laptop technology from 1990-2001](image2.png)
Ubiquitous Computing
ubiquitous
/yooˈbikwətəs/

adjective

present, appearing, or found everywhere.
"his ubiquitous influence was felt by all the family"
synonyms: omnipresent, ever-present, everywhere, all over the place, pervasive,
Ubiquitous Computing

- Collection of *active* specialized assistants to assist human in tasks (reminders, personal assistant, staying healthy, school, etc)
- App figures out user’s current state, intent, assists them
- **How?** array of *active* elements, sensors, software, Artificial intelligence
- Extends *mobile computing* and *distributed systems* (more later)
- **Note:** System/app initiates activities, has intelligence
- **Example:** Google Assistant, feed informs user of
  - Driving time to work, home
  - News articles user will like
  - Weather
  - Favorite sports team scores, etc
- Also supports 2-way conversations
User Context

- Imagine a genie/personal assistant who wants to give you all the “right information” at the right time
  - Without asking you any questions
- Examples:
  - Detect traffic ahead, suggest alternate route
  - Bored user, suggest exciting video, etc
- Genie/personal assistant needs to passively detect user’s:
  - Current situation (Context)
  - Intention/plan

Smart Assistant/speaker
- User asks questions
- Answer questions, user requests
- Stream music, order a pizza,
- Weather, news, control smart home
Ubicomp Senses User’s Context

- Context?
  - **Human**: motion, mood, identity, gesture
  - **Environment**: temperature, sound, humidity, location
  - **Computing Resources**: Hard disk space, memory, bandwidth
  - **Ubicomp example**:
    - **Assistant senses**: Temperature outside is 10F (environment sensing) + Human plans to go work (schedule)
    - **Ubicomp assistant advises**: Dress warm!

- Sensed **environment + Human + Computer resources = Context**
- **Context-Aware** applications adapt their behavior to context
Sensing the Human

- Environmental sensing is relatively straight-forward
  - Use specialized sensors for temperature, humidity, pressure, etc

- Human sensing is a little harder (ranked easy to hard)
  - **When**: time (Easiest)
  - **Where**: location
  - **Who**: Identification
  - **How**: (Mood) happy, sad, bored (gesture recognition)
  - **What**: eating, cooking (meta task)
  - **Why**: reason for actions (extremely hard!)

- Human sensing (gesture, mood, etc) easiest using cameras

- Research in ubiquitous computing integrates
  - location sensing, user identification, emotion sensing, gesture recognition, activity sensing, user intent
Sensor

- **Example:** E.g. door senses only human motion, opens
- **Sensor:** device that can sense physical world, programmable, multi-functional for various tasks (movement, temperature, humidity, pressure, etc)
- Device that can take inputs from physical word
  - Also includes camera, microphone, etc
- Ubicomp uses data from sensors in phone, wearables (e.g. clothes), appliances, etc.

(courtesy of MANTIS project, U. of Colorado)   RFID tags   Tiny Mote Sensor, UC Berkeley
Ubiquitous Computing: Wearables
Ubiquitous Computing:
Wearable Sensors for Health

remote patient monitoring
UbiComp: Wearables, BlueTooth Devices

Body Worn Activity Trackers

Bluetooth Wellness Devices

External sources of data for smartphone
Definitions: Portable, mobile & ubiquitous computing
Distributed Computing

- Computer system is physically distributed
- User can access system/network from various points.
- E.g. Unix cluster, WWW
- Huge 70’s revolution

**Distributed computing example:**
- WPI students have a CCC account
- Log into CCC machines,
- Web surfing from different terminals on campus (library, dorm room, zoolab, etc).

**Finer points:** network is fixed, Human moves
Portable (Nomadic) Computing

- **Basic idea:**
  - Network is fixed
  - device moves and changes point of attachment
  - No computing while moving

- *Portable (nomadic) computing example:*
  - Mary owns a laptop
  - Plugs into her home network,
  - **At home:** surfs web while watching TV.
  - Every morning, brings laptop to school, plug into WPI network, boot up!
  - **No computing while traveling to school**
Mobile Computing Example

- Continuous computing/network access while moving, automatic reconnection

**Mobile computing example:**
- John has SPRINT PCS phone with web access, voice, SMS messaging.
- He runs apps like facebook and foursquare, continuously connected while walking around Boston

**Finer points:**
- John and mobile users move
- Network deals with changing node location, disconnection/reconnection to different cell towers
Ubiquitous Computing Example

- **Ubiquitous computing:** John is leaving home to go and meet his friends. While passing the fridge, the fridge sends a message to his shoe that milk is almost finished. When John is passing grocery store, shoe sends message to glasses which displays “BUY milk” message. John buys milk, goes home.

- **Core idea:** ubiquitous computing assistants actively help John
SmartPhone Sensing
Smartphone Sensing

- Smartphone used to sense human, environment

  *Example:* Human activity sensing (e.g. walking, driving, climbing stairs, sitting, lying down)

  *Example 2:* Waze crowdsourced traffic
Sensor Processing

- **Machine learning** commonly used to process sensor data
  - Action to be inferred is hand-labelled to generate training data
  - Sensor data is mined for combinations of sensor readings corresponding to action
- Example: Smartphone detects user’s activity (e.g. walking, running, sitting,) by classifying accelerometer sensor data
What Can We Detect/Infer using Smartphone Sensors

Smartphone Sensing!!

Smartphone Sensor data → Machine Learning

- Eating/Drinking
- Social interactions
- Cardiac health
- Sleep Quality
- Stress, Mood
- Activity
- Mobility patterns
- Conversations

Image Credit: Deepak Ganesan, UMass
Internet of Things (IoT)
IoT: Definitions

- Internet extended to connect Devices
- New technology paradigm
- Internetworked smart machines and devices can
  - Interacting with each other
  - Exchanging information
  - Can be controlled over the Internet

IoT: Networked Smart Things (Devices)

- Smart things: Can be accessed, controlled over the network, learns users patterns

**Nest Smart thermostat**
- Learns owners manual settings
- Turns down heat when not around

**Smart Fridge**
- See groceries in fridge from anywhere
Other Ubicomp Systems

- **Smart Homes:** ambient intelligence, sensing, context-aware services, enable remote home control
  

  - Example: Falls kill many old people who live alone
  - Smartphone continuously monitors elders living in smart home, automatically dials 911 if elder falls or ill

- **Smart buildings:** intelligently improve comfort and energy efficiency
  

  - Senses presence of people, ambient temperature, people flow, dynamically adjusts heating/cooling
  - Up to 40% savings energy bill
Other Ubicomp Systems

- **Smart Cities:** intelligently improve citizens’ quality of life, transport, traffic management, environment, economy and interaction with government
  

- Example: About 30% of traffic jam caused by people hunting for parking
- Real time data from Sensors embedded in street used to direct drivers to empty parking spots

![TOP 10 SMARTEST CITIES IN 2019](image)
References

- Android App Development for Beginners videos by Bucky Roberts (thenewboston)
- Ask A Dev, Android Wear: What Developers Need to Know, https://www.youtube.com/watch?v=zTS2NZpLyQg
- Busy Coder’s guide to Android version 4.4
- CS 65/165 slides, Dartmouth College, Spring 2014
- CS 371M slides, U of Texas Austin, Spring 2014