Internet of Things

CSE 521S Wireless Sensor Networks

Chenyang Lu
Internet of Things

- Convergence of
  - Miniaturized devices: processor+sensors+radio, embedded OS.
  - Low-power wireless: connect millions of devices to the Internet.
  - Data analytics: make sense of sensor data.
  - Cloud and edge computing: scalable real-time data processing.

- Real-time monitoring and control of physical systems
  - Smart *: house, healthcare, manufacturing, transportation, grid…

- We are in the **Golden Age** of Internet of Things!
  - “A period in a field of endeavor when great tasks were accomplished.”
 Revolutionizing Industry

- [https://www.youtube.com/watch?v=LNMmmjz5nCo](https://www.youtube.com/watch?v=LNMmmjz5nCo) (Emerson)
- WirelessHART: wireless sensing/actuation in process industries
- Real-time and reliable wireless networks
- Dependable wireless control systems

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[Diagram showing a factory with various control points: tank level, temperature, vibration, motor, pressure, valve, controller.](https://www.automation.com)
Saving Energy

- [Video](https://www.youtube.com/watch?v=JwRTpWZReJk) (DoE)
- Communication between utility companies and household devices
- Home-Area Network (HAN) connects meters, appliances, HVAC
- Optimize energy efficiency while enhancing comfort
Improving Healthcare

- Clinical deterioration in hospitalized patients
  - 4-17% suffer adverse events (e.g., cardiac or respiratory arrest).
  - Up to 70% of such events could have been prevented.
  - Clinical deterioration is often preceded by changes in vitals.

- Goal: early warning of clinical deterioration → improved outcome

- Real-time patient monitoring in general hospital wards
  - Current practice: collect vital signs manually every 5-10 hours
  - Wireless monitoring system: collects data every minute!

- Large-scale, interdisciplinary research
  - Wireless sensor networks, data mining, medical informatics, clinical care
Wireless Clinical Monitoring


Rapid Response
Potential for Detecting Clinical Events

Large-Scale Clinical Monitoring

Scale up and integrate wireless monitoring with hospital IT infrastructure!

7 units, 4 floors, 14 months, 97 patients

Smartwatch as a Healthcare Tool

- Open, programmable platform
  - Wear OS, Research Kit, onboard analytics

- Continuous, passive measurements
  - activity, heart rate, sleep, location...

- Two-way communication
  - ecological momentary assessments
Predict Readmissions with Fitbit

- Hospital readmission rate is high for heart failure patients.
  - ~25% patients readmitted within 30 days
- Predict deterioration (readmission+death) after discharge
  - Fitbit provides continuous monitoring of outpatients
  - Just-in-time intervention → better outcome and lower cost

Joint work with Thomas Bailey (Infectious Diseases), Marin Kollef (Critical Care), Dingwen Li (CSE)
Bridges C+
- Almost four in 10 are 50 years or older.
- 56,007 (9.1%) bridges were structurally deficient.
- Backlog of bridge rehabilitation needs: $123 billion.

Dams D
Levees D
Roads D

America's Infrastructure GPA: D+

http://www.infrastructurereportcard.org
Inspecting Bridges Is Hard!

- Costly and time consuming
- US bridges: inspected manually once every two years.

**Highway 40 Closing for Boone Bridge Inspection**
Monday August 10, 2009

If you're heading to St. Charles this weekend, Highway 40 is not your best option. Westbound 40 from Long Road in St. Louis County to Route 94 in St. Charles County will be closed (weather permitting) while work crews inspect the Daniel Boone Bridge across the Missouri River. The road will close at 5:30 a.m. on August 15 and won't reopen until sometime after 9 p.m. on August 16.
Structural Health Monitoring

- Monitor a bridge using a wireless sensor network
  - Detect and localize damages to structures

- Smart
  - No human effort

- Real-time
  - Every week
  - Right after an earthquake

- Accurate
  - Technology instead of human eyes
Full-Scale Truss Experiments

Full-size highway sign truss @ Purdue

Making Cities Smart

- [https://youtu.be/CluvnRaVhqA](https://youtu.be/CluvnRaVhqA)

- IoT → large-scale sensing and control of physical world
  - Smart cities, manufacturing, grid, healthcare…

- Analytics turn sensor data into knowledge and decisions

- Cloud provides scalable resources and services for analytics
  - Real-time cloud and edge enables timely response and control

- Example: Intelligent Transportation
  - Collect data from cameras and roadside detectors.
  - Control the traffic signals and message signs in real-time.
  - SCATS @ Sydney: controlling 3,400 signals at 1s round-trip latency.
Smart Dust

- Processor + Sensors + Wireless
- Miniature hardware manufactured *economically* in large numbers
- Networked for monitoring and control → Internet of Things

Smart Dust (UCB)
Example: Epic Core

CC2420 radio
802.15.4
6LoWPAN/IPv6

RAM 10 KB

ROM 48 KB

TI MSP430

Clock 4/8 MHz

I/O (some shared)
8 ADC (12 bit)
2 DAC (12 bit)
1 I2C
1 JTAG
1 1-Wire
2 SPI
2 UART

8 general, 8 interrupt, and 5 special pin connectors

Typical sleep current 9μA at 3V, radio active ~20mA

Unique hardware ID

16 MB Flash memory

3 V

2.5 x 2.5 cm

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TelosB

- Six major I/O devices
- Possible Concurrency
  - I²C, SPI, ADC
- Energy Management
  - Turn peripherals on only when needed
  - Turn off otherwise
Jolley Testbed
What are you going to learn?

- Full IoT Stack
  - Miniaturized devices: processor+sensors+radio, embedded OS.
  - Low-power wireless: connect millions of devices to the Internet.
  - Data analytics: make sense of sensor data.
  - Cloud and edge computing: scalable and real-time data processing.

- Cutting-edge research papers

- Hands-on, integrated IoT system project
Grading

- Projects 60%
  - Proposal and presentation: 10%
  - Demo I: 5%
  - Demo II: 5%
  - Final report and demo: 40%

- Critiques 30%

- Participation 10%
Critiques

- 1/2 page critiques of research papers
- Due by 10am on the class day
- Email Ruixuan (Corey) Dai <dairuixuan@wustl.edu> in plain txt
- Back-of-envelop notes - NOT whole essays
- Critique requirement
Three students per team
- Need permission for a bigger or smaller team.

Perform a system project
- Develop/integrate software/hardware
- Perform experiments on real systems
- Write a paper
- Demos
Example: Follow-Me Music
Theme: IoT Cloud

- Hands-on, system projects involving IoT cloud.

- Develop IoT applications with Amazon cloud services
  - IoT, Alexa, streaming, messaging, analytics…

- Experiment, measure and analyze
Steps

1. Find your favorite topic
2. Form a team
3. Propose a design
4. Analyze and Implement your solution
5. Evaluate your solution
6. Demo 1, 2 and Final Demo
7. Write a technical report
Get Started Early

- Think about topics and ideas
- Talk to TA and me
- Put together a team

- A lot of work (and fun) throughout the semester!
Logistics

- Guidelines and slides are on the class homepage.
  - [http://www.cse.wustl.edu/~lu/cse521s/](http://www.cse.wustl.edu/~lu/cse521s/)

- Lectures will be delivered live on Zoom.
- Video recordings will be available for offline viewing after class.

- Discussions and communication will be on Piazza.
  - Post on Icebreaker (think about project ideas)
  - Search for teammate

- Plan to attend class for project proposals and demos.
Help

- Prof. Lu <lu@wustl.edu>
- TA: Ruixuan (Corey) Dai <dairuixuan@wustl.edu>
- Make appointment for Zoom meetings.
- Post on Piazza for Q&A.
Next Class

➤ Amazon Cloud Tutorial