ECE 590/COMPSI 590
Special Topics: Edge Computing

Edge Helping Responsive IoT Applications

Wednesday January 15th, 2020

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1

Last Class Recap

- Project proposals
- Origins of the edge
  - Cloud: CDNs, Peer to Peer systems
  - IoT: sensor networks
- Properties of edge systems
  - Hierarchy, heterogeneity

2

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2

Outline of This Class

- Quiz
- Projects, research paper presentations
- “You and Your Research”
- Edge and IoT devices
  - Common IoT architectures
  - Role of the gateway
- Opportunities: edge for responsive IoT applications
  - Hardware
  - Algorithms
  - Edge for system decisions

Quiz

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5

Does Anyone Have a Project Idea They Want to Run by the Group?

6

Research Seminar Goals

- Learn an area
- Get new ideas
  - Useful to attend talks **not** in your immediate area of interest

7

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Presenting a Research Paper: Logistics (1/2)

- First presentations: Wednesday January 29th
- 25% of the grade
  - More than many midterms
  - High bar: a well-developed, polished presentation
  - Expected to invest significant amounts of time and energy into preparation
  - Feel free to ask TA/instructor whether what you plan to present is sufficiently polished

8

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Presenting a Research Paper: Logistics (2/2)

- 20 minute presentation, 10 minute Q&A
  - **Please practice your timing**
- Before the presentation:
  - One week before your presentation: enter paper title into the spreadsheet
  - 3 days before your presentation: prepare two quiz questions, send them to me

9

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Presenting a Research Paper: Components (1/2)

- Put the paper in context
  - Help others understand where it fits in
- Present the material in the paper
  - Focus on helping others understand the work and on conveying the most important insights
  - May not be able to cover all the details – can select sub-sections if necessary

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Presenting a Research Paper: Components (2/2)

- Comment on it
  - What are its strengths?
  - What are its weaknesses?
  - Is the work important, and why?
  - How can the presented solution be extended?

Presenting a Research Paper: 3 Components to Grading

- Presentation skills
- Knowledge base
- Critical thinking

- Side note: format similar to Duke ECE PhD program qualifying exams

Participating in the Seminar

- Skim the paper being presented
  - Quiz questions will be based on the papers
- Participate in the Q&A: ask at least one question

13

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You and Your Research

- What did you think?

14

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14

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15

Edge for IoT Nodes vs. Edge For High-End Mobile Nodes

Low-end IoT nodes

IoT nodes → Gateway → Cloud

This lecture

Higher-end mobile devices

Mobile device→ Cloudlet → Cloud

Next lecture

16

Edge for Responsive vs. Data-collection Applications

- Responsive applications: reacting to conditions
- Data collection applications:
  - E.g., environmental monitoring
  - E.g., model training
  - Will cover later on

17

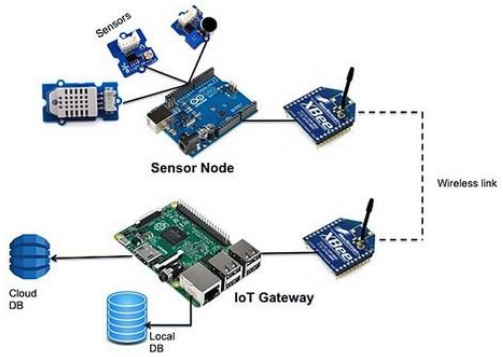
Properties of IoT Nodes

- Tightly constrained design space
- Reduced energy consumption
- (Extremely) low computing capability

18

Standard IoT Architectures

- IoT nodes → Gateway → Cloud



Note-to-gateway communication

6LoWPAN	DASH7	Wireless M-Bus
ANT	ISA100	Z-Wave
Bluetooth	Wireless HART	Zigbee and Zigbee IP

19

Other Architectures: Direct WiFi Connectivity

- Usually for plugged-in devices
  - Have the power budget for it

- Low-end mobile devices: uncommon
- Amazon Dash Button
  - Setup via ultrasound
  - On-demand communication via WiFi

20

Other Architectures: Low-Power Wide Area Communications

- Long-range connectivity specifically for the IoT
  - Narrowband IoT – cellular standards
  - Low-power wide-area networking solutions: SigFox, LoRa

21

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Gateways: Dedicated Hubs

- A stationary plugged-in device
- Smart homes, smart factories, …
- Many different ones: "*Best smart home hubs for 2019*"

22

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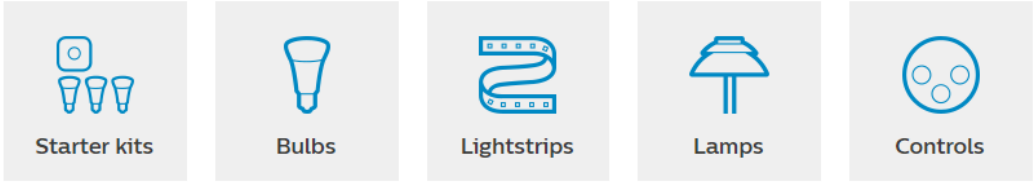
Phillips Hue Example (1/2)

- Control your lights
  - White, color
- Switches and lights



23

Phillips Hue Example (2/2)

- Zigbee Light Link communications
  - Low-power
  - Low data rate
  - Short distance
- Hue Bridge: “the heart of the system”

24

Samsung Smart Things Hub Example

- Lights, speakers, locks, thermostats, sensors
- Z-Wave, Zigbee
- “The brain of the smart home”

25

Gateways are Not Particularly Computationally Capable

- For instance:
  - MacBook Air: 1.8GHz dual-core Intel Core i5, Turbo Boost up to 2.9GHz
  - Samsung SmartHub: 528 MHz ARM Cortex-A7
- All different
  - Raspberry Pis are a reasonable approximation for many cases

26

Gateway Roles

- IoT node centralization
- Unified cloud access

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Making Things Easier: AWS Greengrass, Azure IoT Edge

- Can create your own gateway
  - Connect devices with the cloud and with one another
- Physical protocol translation is separate
  - E.g., for low-power BLE devices, needs a BLE/WiFi gateway

28

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Gateways: Mobile Phones

- Wearables

29

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Gateways: Mobile Phones or Tables

- Toys, accessories

30

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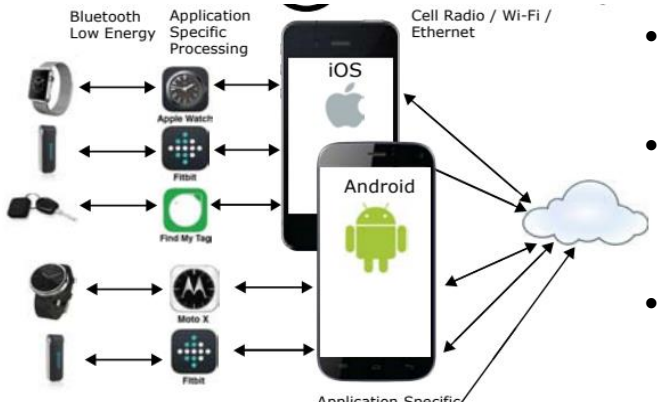
Often Per-Application



From: The IoT Has a Gateway Problem, by Zachariah et al, *ACM HotMobile'15*.

- Not really about centralization
- Usually substantial gateway-based data processing
- Phones/tables more capable than hubs, but restricted in capability compared to other devices

31

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Some Things Fall Through the Cracks

- 3-tier architecture is natural for some cases
  - Wearables: everyone has a cell phone
  - In-home installations: every device can access a single control unit
    - Set-top box paradigm
- Things that fall through the cracks:
  - Non-wearable non-home IoT nodes, e.g., smart city scenarios

32

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Role of the Gateway: Protocol Translator

- BLE, ZigBee, Z-Wave, Infrared, …
  - ➢Short-range connectivity
  - ➢IoT devices can save energy

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Role of the Gateway: Usability

- IoT devices offer limited interfaces
  - ➢See the two cases below, for example

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35

Responsive Applications

- Currently:
  - Conveying simple commands
  - Performing simple actions
- It isn't doing anything *intelligent*, usually

36

Opportunities: Reactivity (1/2)

- Does not react
  - This sensing-only mode has its uses, e.g., environmental monitoring applications
- React in limited ways
  - E.g., my smart watch beeping when my heart rate is in the wrong zone
  - Sprinklers turn on at 9 AM unless it has rained and the soil is wet

37

Opportunities: Reactivity (2/2)

- Reacts by accessing the cloud
  - Reliability issues → AWS outage example

  - Privacy issues

38

Towards Responsive Edge Intelligence (1/2)

- Running Deep Neural Networks (DNNs) and other complex algorithms on the edge
  - Large
  - Computationally expensive
- Recall that gateways are not particularly powerful

Towards Responsive Edge Intelligence (2/2)

- Hardware solutions
- Algorithmic solutions:
  - Edge-only
  - Edge+cloud (“fog”)

Towards Responsive Edge Intelligence: Hardware Solutions

- Specialized custom ASICs, optimized for low-power operation
  - Intel Neural Compute Stick2
  - Google TPU
  - …
- FPGAs

41

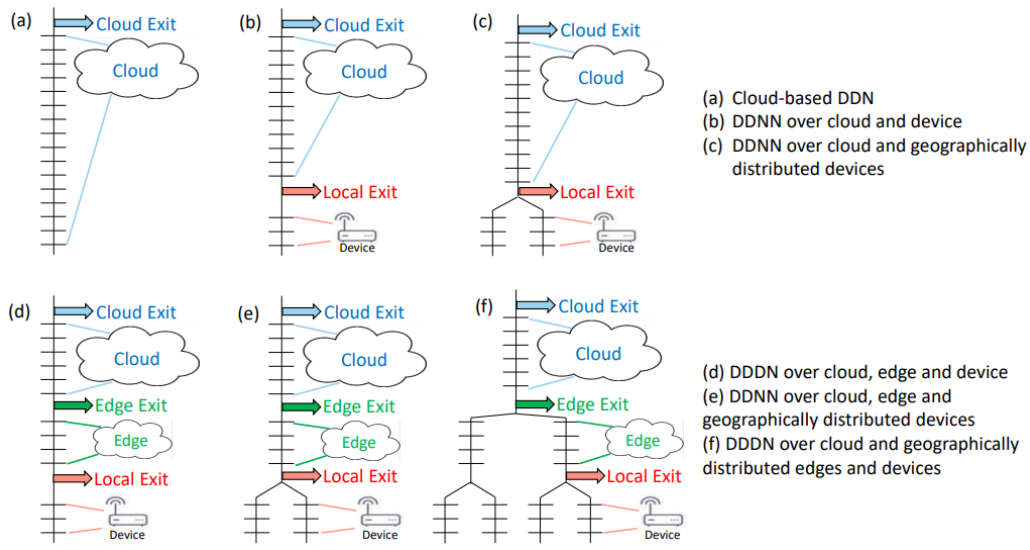
Solution: Simplify Algorithms Developed for Desktop-Grade and Cloud-Grade Nodes

- E.g., for complex machine learning models:
  - Model optimization/compression techniques
    - Trade off resource use for accuracy
  - Model specialization

42

Solutions: Algorithms that Take Advantage of the Hierarchical Structure of the System

- Algorithms that are split between IoT devices, gateways, and the cloud



From: Distributed DNNs over the cloud, the edge, and end devices, by Teerapittayanon et al, *IEEE ICDSC'17*.

Opportunities: Self-Adaptive IoT: Intelligent System Operation (1/2)

- Currently:
  - Simple fixed rules
  - Manual setup
- Opportunities: Intelligence for System Design
  - Gateways can easily collect a lot of local and remote information on system behavior and properties

45

Opportunities: Self-Adaptive IoT: Intelligent System Operation (2/2)

- Using gateways to:
  - Monitor and probe local and remote conditions
  - Make intelligent choices
  - One possibility: **reinforcement learning**
- E.g., automatic protocol selection, automatic parameter settings
- Starting to appear for the cloud → interesting to extend it to the edge

46

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47

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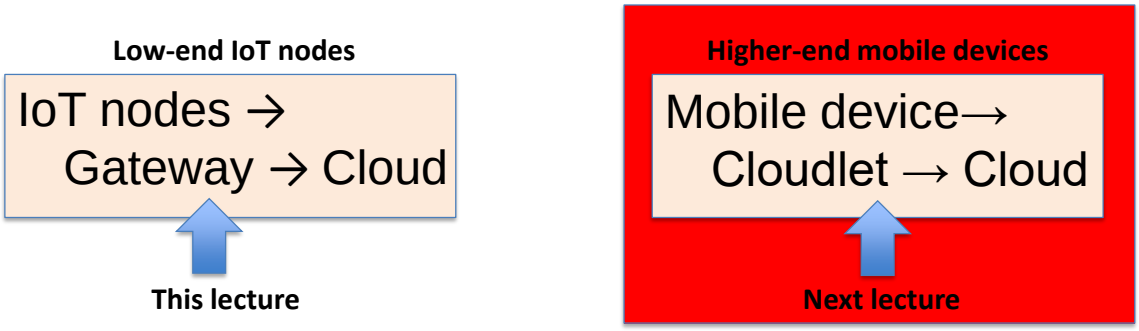

48

Reading Material for the Next Class

- Reading for the next class:
  - *ePrivateEye: to the Edge and Beyond!*
  - *Technology and Courage*, by Ivan Sutherland

Next Class: Additional Homework

- Sign up for the research paper presentation slot by **Wednesday January 22nd**
- Think more about your research project