

# ECE 590/COMPSI 590

## Special Topics: Edge Computing

Edge Helping Responsive IoT Applications

Monday September 3rd, 2018

## Last Class Recap

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

# 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

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# Quiz

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

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# Research Seminar Goals

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

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# Presenting a Research Paper: Logistics

- First presentation: Wednesday September 12<sup>th</sup>
- 20 minute presentation, 10 minute Q&A
  - Please practice your timing
- 20% of the grade
- Before the presentation:
  - One week before your presentation: Tell me which paper you selected
  - Two days before your presentation: Prepare two quiz questions, send them to me

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## Presenting a Research Paper: Components

- 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
- Comment on it
  - E.g., what are its strengths? Weaknesses?
  - How can the presented solution be extended?

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## Participating in the Seminar

- Skim the paper being presented
  - Two quiz questions will be from the paper
- Participate in the Q&A: ask at least one question

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# You and Your Research

- What did you think?

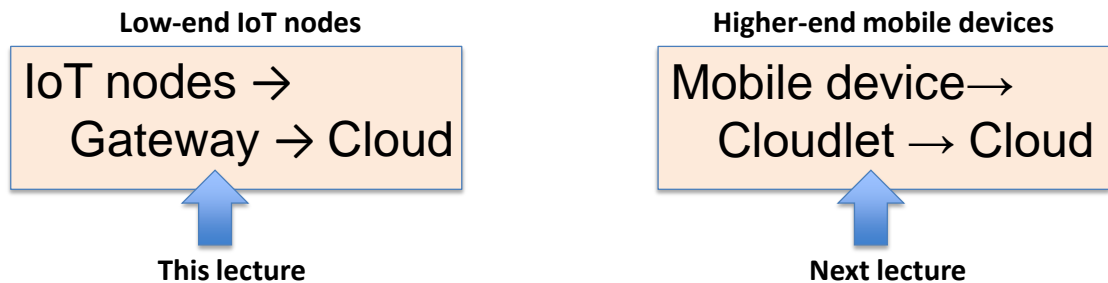
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## Edge for IoT Nodes vs. Edge For High-End Mobile Nodes



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## 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 in October

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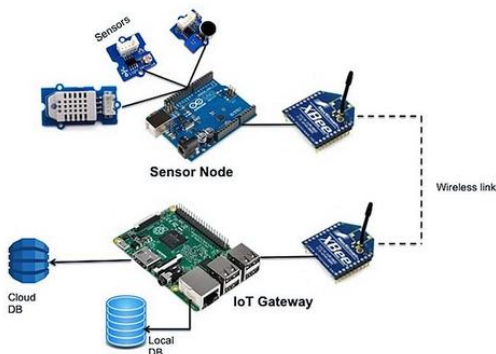
# Properties of IoT Nodes

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

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# 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

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## 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



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## 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

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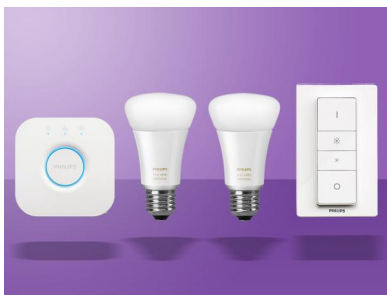
# Gateways: Dedicated Hubs

- A stationary plugged-in device
- Smart homes, smart factories, ...
- Many different ones: *“Best smart home hubs of 2018”*

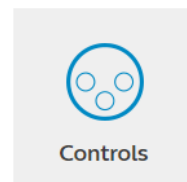
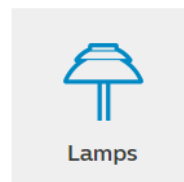
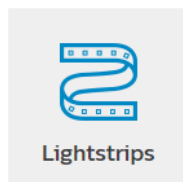
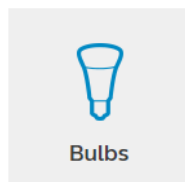
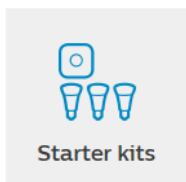


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## Phillips Hue Example (1/2)



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



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## Phillips Hue Example (2/2)



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

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## Samsung Smart Things Hub Example



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

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## 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

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## Gateway Roles

- IoT node centralization
- Unified cloud access

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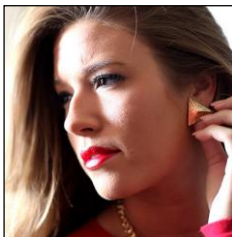
## Making Things Easier: AWS Greengrass, Azure IoT Edge

- 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

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## Gateways: Mobile Phones

- Wearables



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# Gateways: Mobile Phones or Tables

- Toys, accessories



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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

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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

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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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# Responsive Applications

- Currently:
  - Conveying simple commands
  - Performing simple actions
- It isn't doing anything *intelligent*, usually
  - Far from the smart shoe example of the first lecture



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## 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

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## Opportunities: Reactivity (2/2)

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



Stuart Thomas ✓  
@stuartthomas

Follow

Mmm. Can't turn some of my lights on at home cos @IFTTT is down. Welcome to the future!

- Privacy issues

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## 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

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# Towards Responsive Edge Intelligence (2/2)

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

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# Towards Responsive Edge Intelligence: Hardware Solutions

- Specialized custom ASICs, optimized for low-power operation
  - Movidius Neural Compute Stick
  - Google TPU – announced late July
  - ...
- FPGAs

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

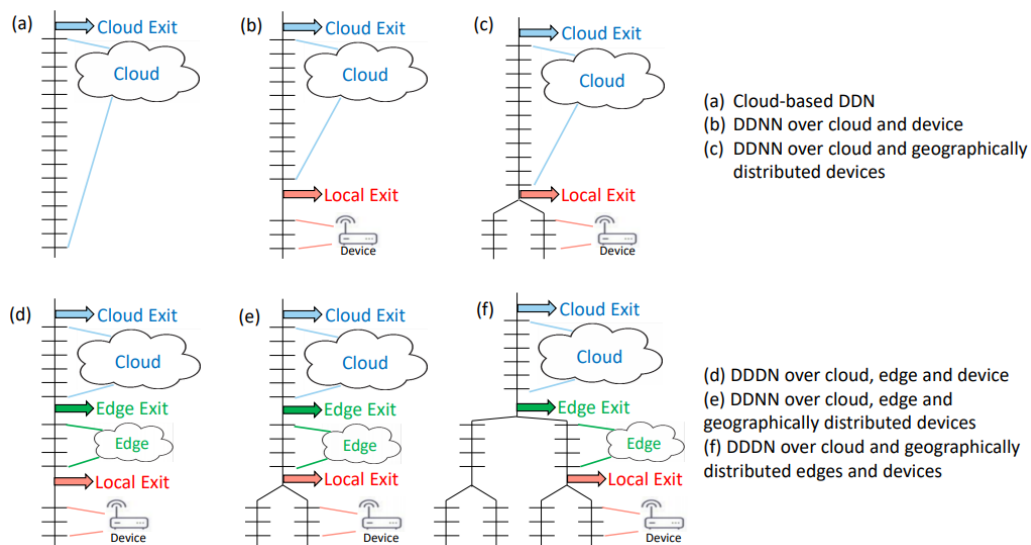
- E.g., for complex machine learning models:
  - Model optimization/compression techniques
    - Trade off resource use for accuracy
  - Model specialization

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

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

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

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## 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



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## 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

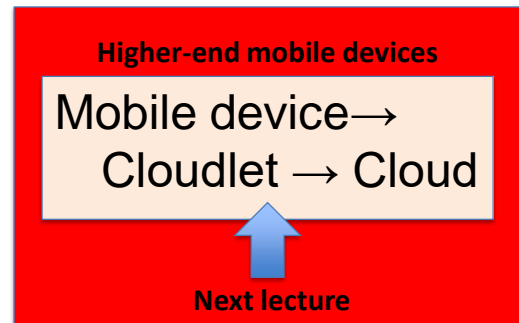
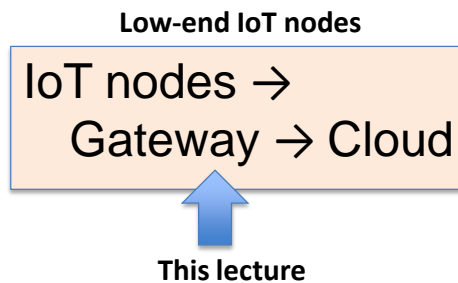
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# Next Class



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## Reading Material for the Next Class

- Reading for the next class:
  - *ePrivateEye: to the Edge and Beyond!*
- Optional reading: how to read research papers

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## Next Class: Additional Homework

- Sign up for the research paper presentation slot by the end of the week
- Think more about your research project

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