CSE570 Spring 2020

Wireless and Mobile Networks

IoT/Sensor Networks

Slides borrowed from https://www3.nd.edu/~cpoellab/teaching/cse34468/schedule.html

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What is IoT?

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How Does My Fridge Do That?

- You are leaving the home (sense user)
- There's no milk in fridge (sense object)
- Use this information to make a decision (process)
- Inform user of decision (communicate)

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How Does My Fridge Do That?

- **You are leaving the home (sense user)**
  - What type of sensor?
  - Distinguish between parent and child
  - Identify reason for leaving home
  - Identify other contexts (e.g., store hours)
- There's no milk in fridge (sense object)
- Use this information to make a decision (process)
- Inform user of decision (communicate)

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How Does My Fridge Do That?

- You are leaving the home (sense user)
- **There’s no milk in fridge (sense object)**
  - What type of sensor?
  - Is milk needed?
  - No milk or “little” milk? (prediction)
- Use this information to make a decision (process)
- Inform user of decision (communicate)

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How Does My Fridge Do That?

- You are leaving the home (sense user)
- There’s no milk in fridge (sense object)
- **Use this information to make a decision (process)**
  - Where is processor?
  - What are the rules?
  - Fixed rules versus dynamic rules (learning)
- Inform user of decision (communicate)

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How Does My Fridge Do That?

- You are leaving the home (sense user)
- There's no milk in fridge (sense object)
- Use this information to make a decision (process)
- **Inform user of decision (communicate)**
  - How?
  - When?
  - Privacy?
  - Subtleness?
  - Information overflow?

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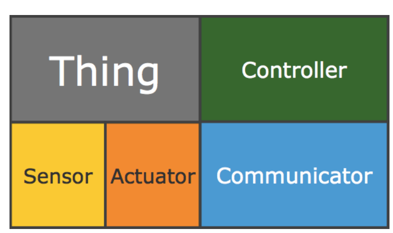
What is IoT?

Physical object ("thing")
+
Controller ("brain")
+
Sensors
+
Actuators
+
Networks (Internet)



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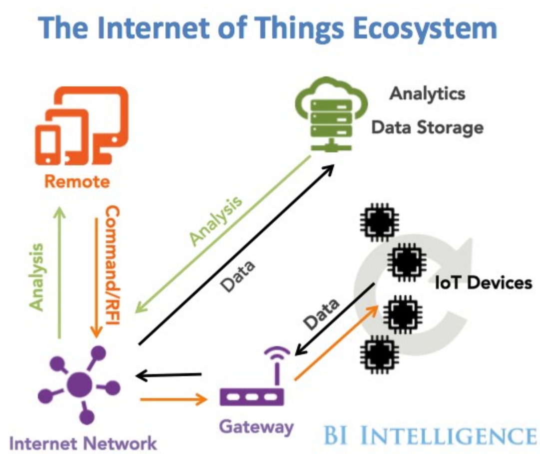
How does IoT System look like?



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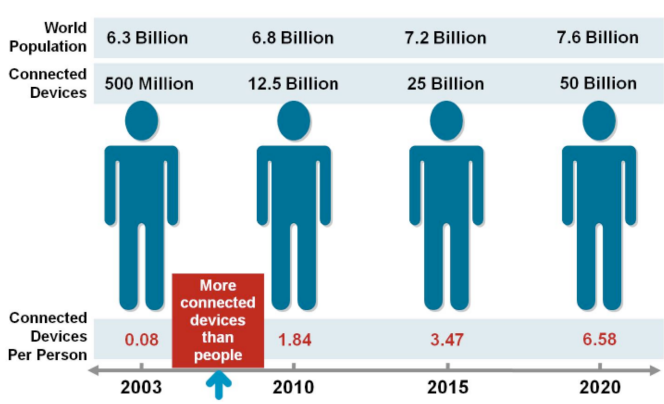
IoT Growth



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Some IoT Devices

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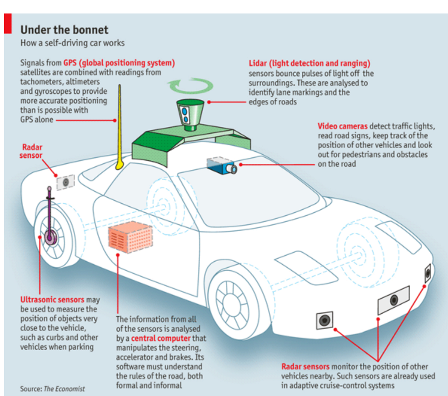
IoT in work



Connected Roadways

Connected buildings

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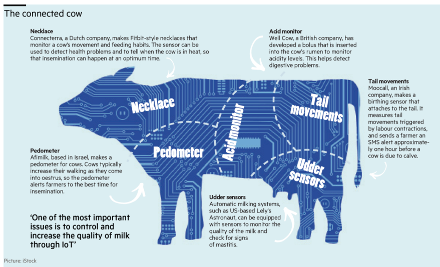
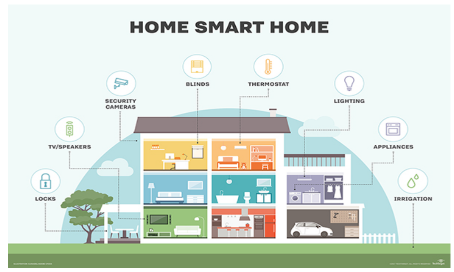
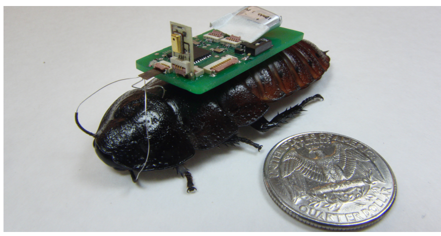
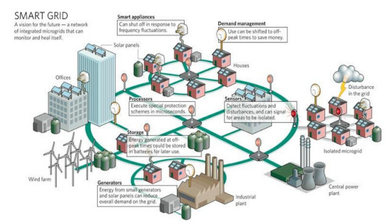
IoT in work









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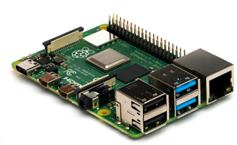
IoT Enablers

- Portability



- Miniaturization

50mm x 50mm | 35mm x 35mm | 15mm x 15mm

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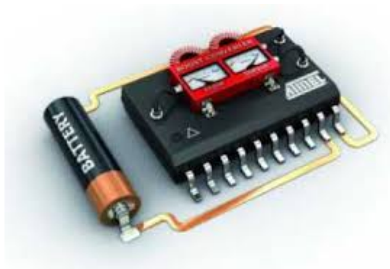
IoT Enablers

- Low power and Low heat



Low power architectures
Low power radios
Sleep modes
Energy harvesting

- Connectivity

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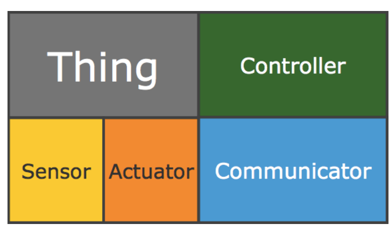
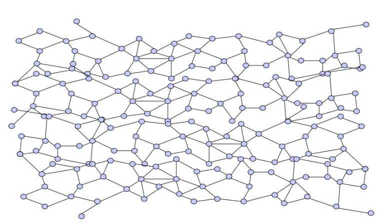
Key Component



Sensor

- A sensor is a device that receives a stimulus and responds with an electrical signal.
- Sensors talk to each other.
- Only a few sensors are connected to the internet through gateway/router.
- The data generated by sensors can grow huge.
  - GBs, TBs per minute, day etc



Wireless

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IoT/Wireless Sensor Networks

- What are the important features of WSNs?
- Fault tolerance/reliability
  - Network should be robust to individual node failures
  - Failures due to running out of energy, hardware failures, malicious intercept of sensor, etc.
- Scalability
  - Protocols must scale to thousands or millions of sensor nodes
  - Requires intelligent management of high density nodes
- Cost
  - Must have cheap sensors

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IoT/Wireless Sensor Networks

- Topology
  - Deployment: random or deliberate placement of nodes
  - Changes in topology during network operation
    - New nodes added to the system
    - Nodes failing
    - Environmental changes
- Energy consumption
  - Sensor functions: sensing, communication, data processing
  - All require energy

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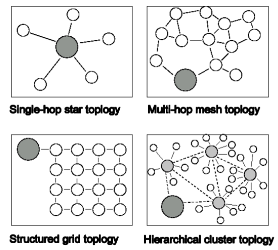
IoT/Wireless Sensor Networks

- Types of network topologies
  - Centralized
  - De-centralized (peer-to-peer)
  - Hybrid
- Mesh Networks
- Ad hoc Networks
- Mobile Ad hoc Networks (MANETs)
  - Definition
    - A collection of wireless mobile hosts forming a temporary network without the aid of any centralized administration or standard support services
  - Often ad-hoc network topology is dynamic—nodes enter and leave the network continuously
  - No centralized control or fixed infrastructure to support network configuration or reconfiguration



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Why Ad hoc Networks

- Setting up of fixed access points and backbone infrastructure is not always viable
  - Infrastructure may not be present in a disaster area or war zone
  - Infrastructure may not be practical for short-range radios; Bluetooth (range ~ 10m)
- Ad hoc networks:
  - Do not need backbone infrastructure support
  - Are easy to deploy
  - Useful when infrastructure is absent, destroyed or impractical

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MANET Characteristics

- Mobile nodes have limited communication range
  - Reduces battery drain
  - Enables spatial reuse of limited bandwidth → increased network capacity
- To connect all nodes in the network, each node is a
  - Packet source
  - Packet sink
  - Router
- Nodes must route packets for other nodes to keep the network fully connected
- In MANETs, a big problem is how to determine where a destination node is located relative to a sending node

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MANET Characteristics

- Route-finding is a current area of much research
  - Want to determine an “optimal” way to find “optimal” routes
- Dynamic links
  - Broken links must be updated when a node moves out of communication range with another node
  - New links must be formed when a node moves into communication range with another node
  - Based on this new information, routes must be modified
- Frequency of route changes a function of node mobility

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MANET Routing

- Proactive (Table-driven) protocols
  - Traditional distributed shortest-path protocols
  - Maintain routes between every host pair at all times
  - Based on periodic updates; High routing overhead
  - Example: DSDV (destination sequenced distance vector)
- Reactive (On-Demand) protocols
  - Determine route if and when needed
  - Source initiates route discovery
  - Example: DSR (dynamic source routing)
- Hybrid protocols
  - Adaptive; Combination of proactive and reactive
  - Example : ZRP (zone routing protocol)

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MANET Routing

- Proactive protocols
  - Always maintain routes
  - Little or no delay for route determination
  - Consume bandwidth to keep routes up-to-date
  - Maintain routes which may never be used
- Reactive protocols
  - Lower overhead since routes are determined on demand
  - Significant delay in route determination
  - Employ flooding (global search)
  - Control traffic may be bursty
- Which approach achieves a better trade-off depends on the traffic and mobility patterns

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Summary

- IoT Applications
- Sensors
- IoT/Senor Networks
- Ad hoc Networks

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Recent work in IoT Space

- Wireless Networking
- Emerging platforms for IoT
  - LivingIoT
  - Farmbeats

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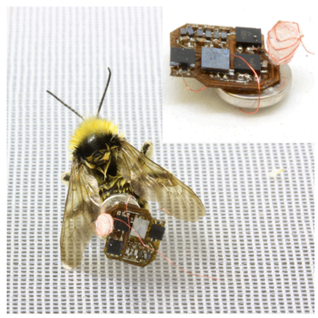
LivingIoT – Flying Sensors

- A Flying Wireless Platform on Live Insects



https://homes.cs.washington.edu/~gshyam/Papers/living-iot.pdf

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Drones as Flying Sensors

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Drones as Flying Sensors

Need recharging every 10-20 min

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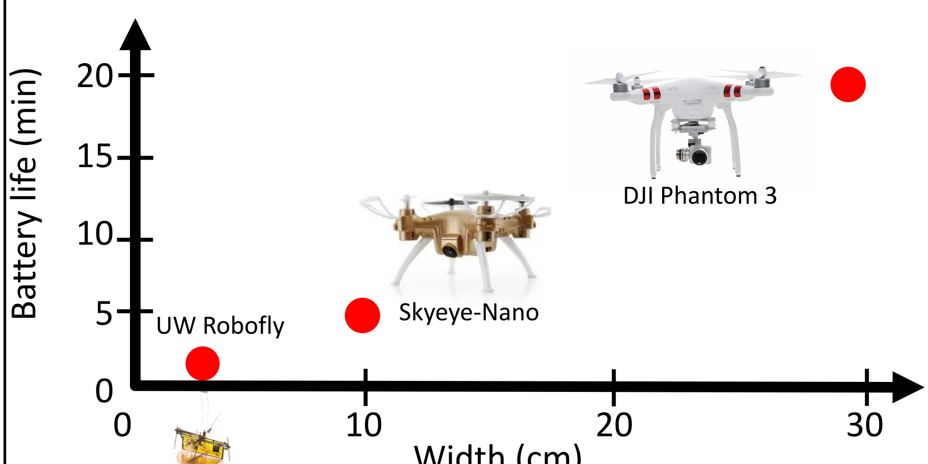
Drones consume lots of power



Fundamentally hard to get long battery life

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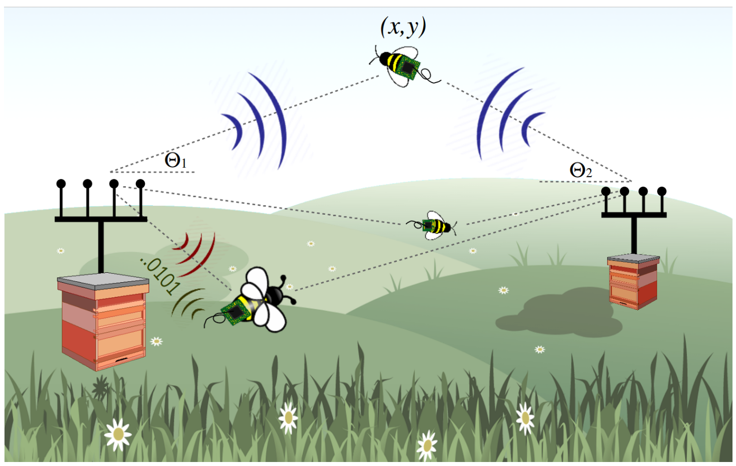
Idea: Use live insects to carry wireless sensors



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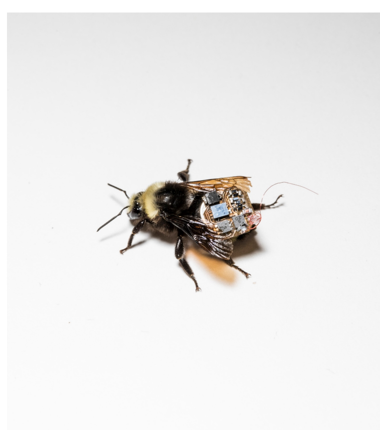
Benefits of LivingIoT

- Bio-based solution
- No need for mechanical propulsion
- Bees are introduced on farms for pollination
- Bees sense their environment



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Bee Carrying Sensors

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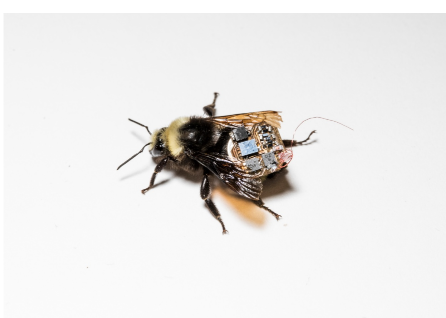
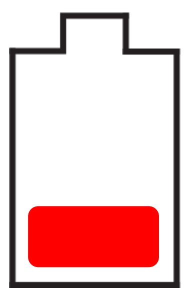
Key Challenges

Size/Weight



Power



~100 mg = 70 mg battery + 30 mg electronics

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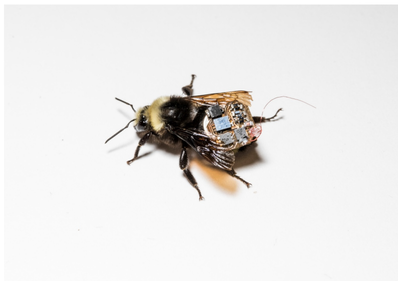
Key Challenges



Can't control bee motion

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LivingIoT Solutions

- Building lightweight hardware
- 2D location tracking of bees

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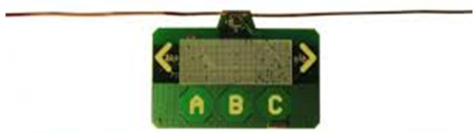
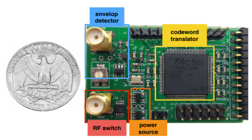
Designing small size and weight



Ambient backscatter



Freerider

Custom ASIC
+ Lowest power and size
- Needs external components
- Long expensive process
- Not programmable

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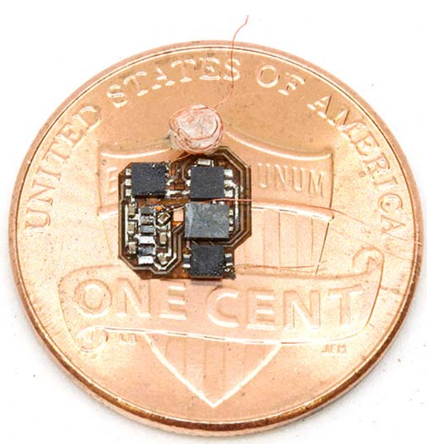
Programmable General-purpose Design

- Programmable microcontroller
- Interfaces with temperature and humidity sensors
- Low range backscatter communication
- Weighs < 30 mg



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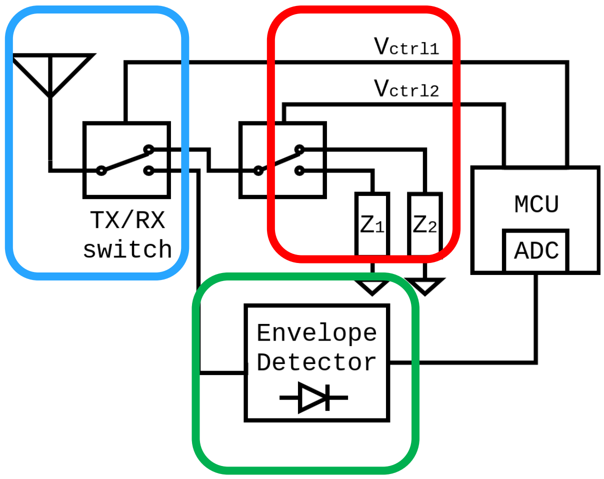
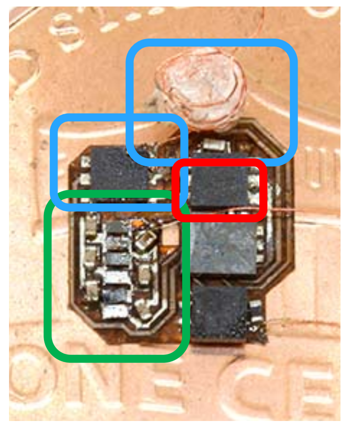
Programmable General-purpose Design





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LivingIoT Solutions

- Building lightweight hardware
- 2D location tracking of bees

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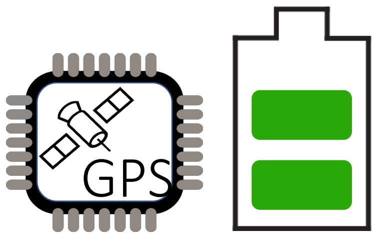
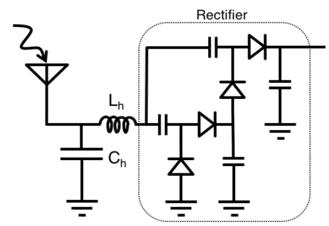
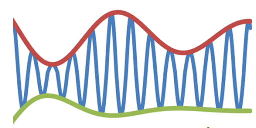
Bee Localization

Problem: GPS is power expensive



Solution: Passive receiver circuit





But, no phase info!

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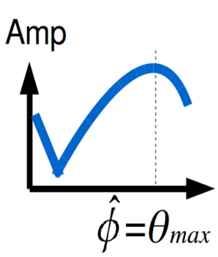
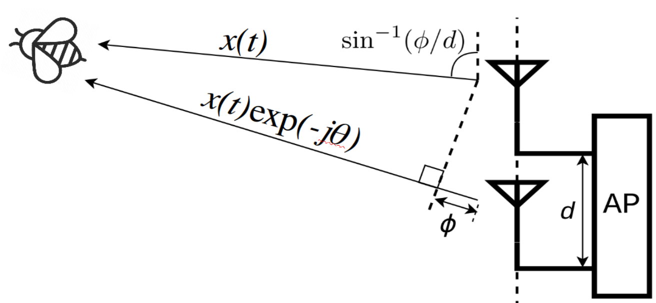
Extracting Phase from Amplitude





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What's Next with LivingIoT

- What other sensors can we use?
- Can we stream sensor data in real time?
- Can we use live insects to build bio-hybrid robots?
- Can we use these technologies to better study insects?

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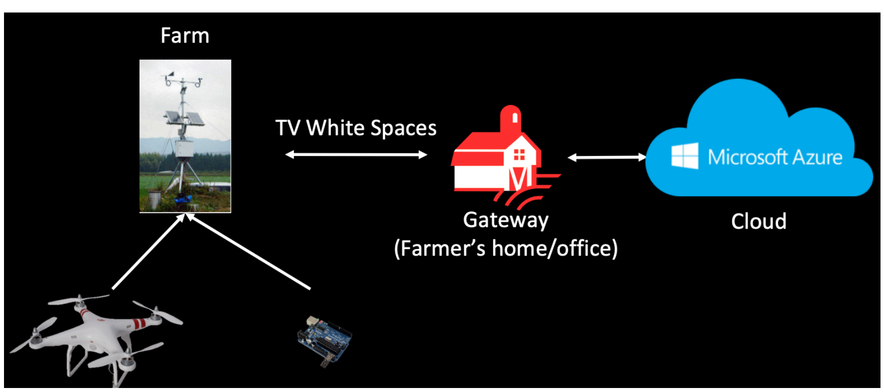
Farmbeats

An IoT System for Data-Driven Agriculture



NSDI'17

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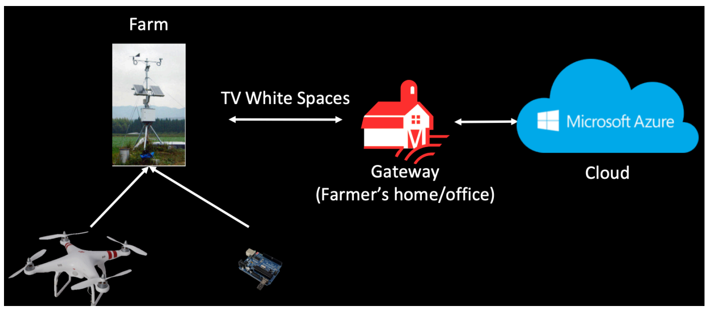
Key Challenges

- Internet Connectivity
- Power Availability
- Limited Sensor placement



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Deployment

- Six months deployment in two farms: Upstate NY (Essex), WA (Carnation)
- The farm sizes were 100 acres and 5 acres respectively
- Sensors:
  - DJI Drones
  - Particle Photons with Moisture, Temperature, pH Sensors
  - IP Cameras to capture IR imagery as well as monitoring
- Cloud Components: Azure Storage and IoT Suite

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Deployment

- Used 10 sensor types, 3 camera types and 3 drone versions
- Deployed >100 sensors and ~10 cameras
- Collected >10 million sensor measurements, >0.5 million images, 100 drone surveys
- Resilient to weeklong outage from a thunderstorm

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