An Analysis of the Goals and Requirements of IoT Systems

2019 CSCI Senior Seminar

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Schedule

What is IoT?

What do we think of when we hear Internet of Things?

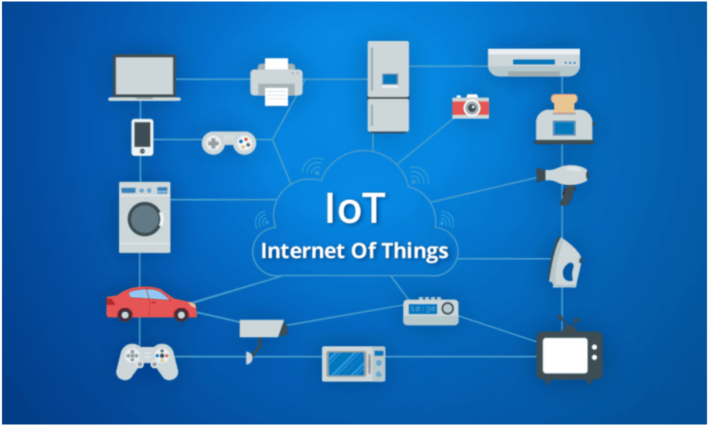


Figure: Interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data

Layers - What makes up an IoT system

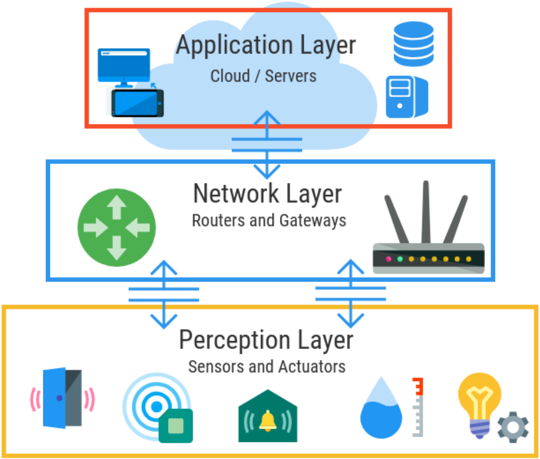


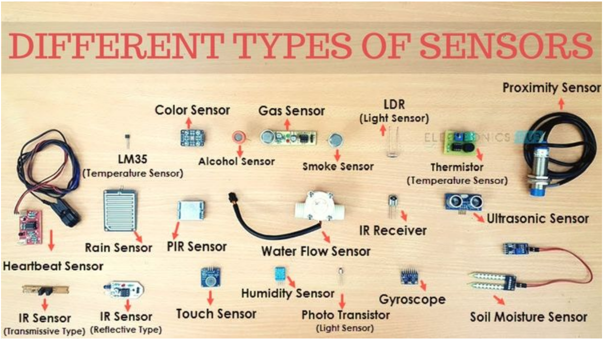
Figure: IoT is made up of 3 layers

Layers

Perception

Detects the physical properties of things around us and generates data

That data will be processed by the application layer



Application

Data is processed in the application layer

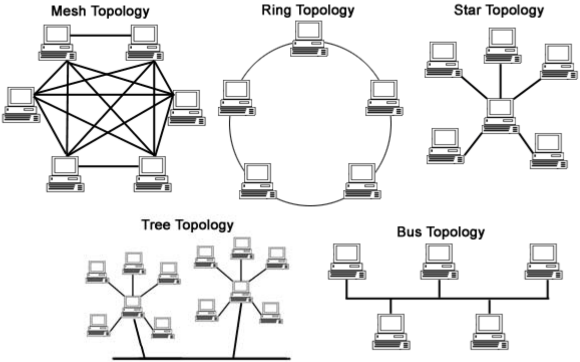
The devices used in my examples include:

- Single board computers
  - Raspberry Pi 3
  - Intel Edison
- Cloud computing
  - Samsung SmartThings
  - Amazon AWS
  - IBM Watson
  - Microsoft Azure

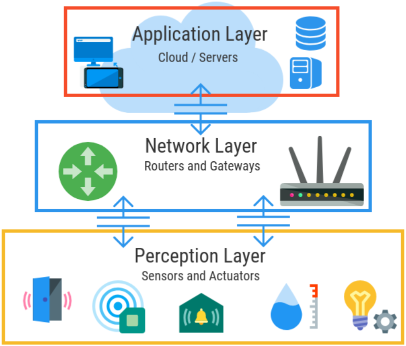
Network

IoT network technologies include WiFi, cellular, and Ethernet

These technologies facilitate the transfer of data between the other two layers



Layers - What makes up an IoT system



Computing

Data transfer

Data collection and reaction

Figure: interconnection via the Internet of computing devices enabling them to send and receive data

Options

Goals and requirements of a system must be considered when designing these layers

- What must be detected?
- Where should the data be processed?
- How is the data going to get there?

Mosquito detection system

Why

Vector-borne diseases such as malaria account for 17% of all infectious diseases
More than a million deaths annually

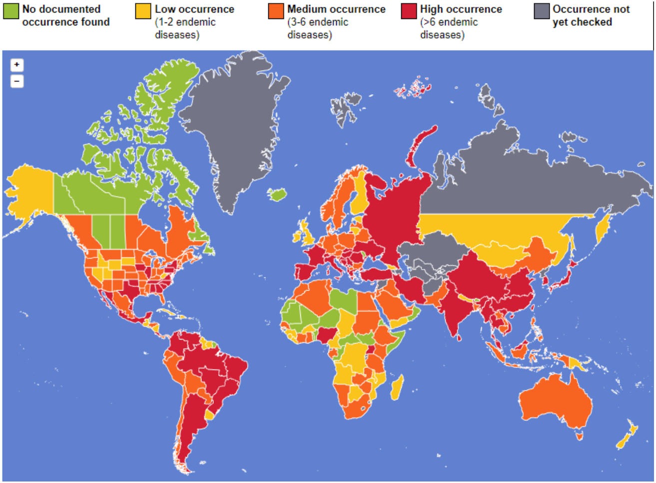


Figure: Nearly half of the world's population is at risk of malaria

System design

Designed a system that analyzes fundamental frequency of an audio sample in order to classify whether or not the sample contained mosquito like frequencies

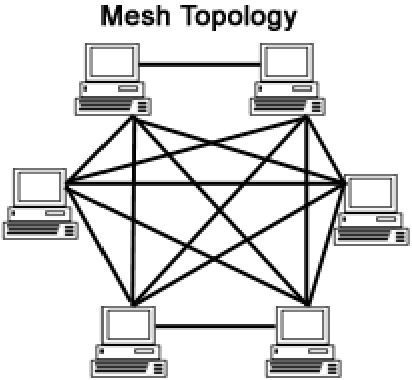
- Perception: Microphones, single board computer
- Application: Single board computers, central server node
  - Raspberry Pi 3
  - Intel Edison
- Network: Various methods were considered but ended up with WiFi with mesh topology

Perception layer sensors are installed on the single board computer.

Goals

- Low cost per device
- Ability to be deployed in remote locations for extended period
- High computational and energy efficiency using optimizations

- Perception: Microphones, single board computers
- Application: Single board computers, central server node
- Network: WiFi with mesh topology



Research findings

Sending raw audio over radio communication using WiFi was costly to energy usage

The devices were powered by a 2000 mAh AA battery and resulted in only 20 hours of battery life under continuous use.

Research findings

Instead, they found performing lightweight computation on the embedded board reduced the communication bandwidth needs and lowered overall energy use

Using an "optimized implementation of the algorithm" on an Intel Edison platform requires 5 ms of compute time and under 5 mJ of energy.
Approximately 80x reduction in best-case energy use stretching the battery life to around 2 months.

Optimized algorithm

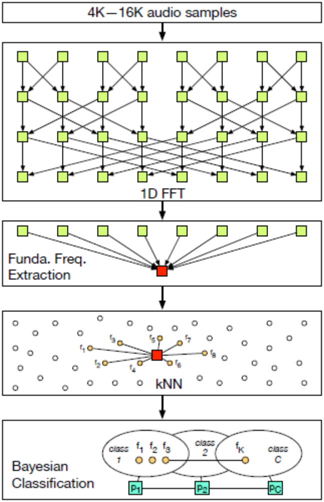


Figure: FFT and frequency extraction components takes up almost 80–90% of the overall runtime

Optimized algorithm

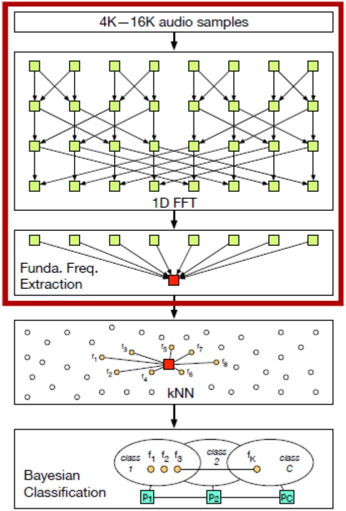
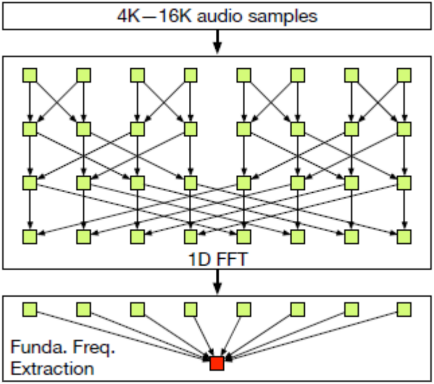
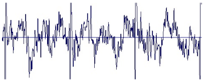


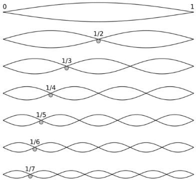
Figure: FFT and frequency extraction components takes up almost 80–90% of the overall runtime

Fast Fourier Transform

What does the Fourier Transform do? Given a smoothie, it finds the recipe.
How? Run the smoothie through filters to extract each ingredient.







How it is optimized

Raspberry Pi 3 and Intel Edison: compared to other tested single board computers, both are far more powerful.

Their processors also provide in-built hardware acceleration for computations such as FFTs.
Some boards can be put into a low-power sleep mode when not in use to save energy

How it is optimized

Output data type

- Floating-point 32 byte data types
- Reduced precision to 16 byte fixed-point

C compiler optimization

- Use of flags in C allow for auto vectorization of the code
- Type of parallel computing made available by using multiple cores of CPU

Found overall classification accuracy to be unaffected - around 80%

Resilient smart home

Why

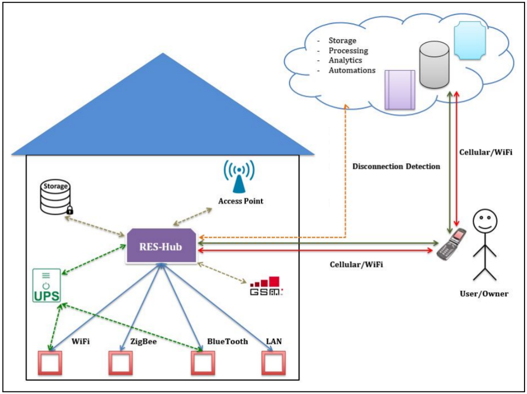
More and more devices in our homes are connected to the internet.

What happens when the services that drive these devices goes down?

System design

Designed RES-Hub to acts as a gateway between the home IoT devices and the cloud services by connecting to the Internet.

Work in conjunction with cloud computing in case of service failure.



Service failure

Each layer is vulnerable

- Sensors can go break or become disconnected
- The network can go down
- The cloud service may be unavailable or in home computing is disrupted

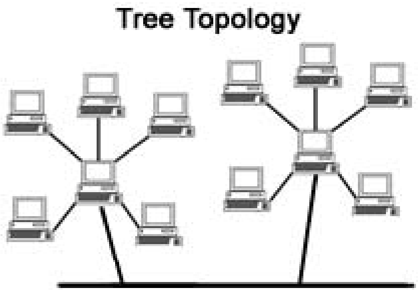
Causes for loss of service

- Technical problems
- Natural causes
- Scheduled maintenance
- Targeted attacks

Goals

- Able to detect cloud failure
  - Notify the user or system to react accordingly
  - Alternative channel to send/receive data
  - Provide reactive security
- Cloud neutral - able to transfer computation to itself

- Perception: Various sensors and actuators
- Application: RES-Hub and cloud computing service
- Network: Ethernet, WiFi, cellular



System design

If network connection is lost or the cloud service is down devices will remain on but will not be able to be interacted with in their full capacity

- Lights will stay on but they can't be toggled remotely
- Sensors could collect data but not send it to be processed or receive it to react

System design

When service is lost RES-Hub has the ability to transfer computational service from cloud to the local unit, itself

Performing the computation and data storage locally provides some of the same benefits provided using encrypted cloud computing

Once service returns the information would be sent to the cloud to supplement the data missing from the cloud during the outage

Research findings

Type of Service	Function	Operation	Example
Connectivity (Internet)	Notification	Sends notification to user's mobile device on home status	Fire alarm is on or Cloud connection lost
	Remote Access	Allow a user to directly control home devices remotely	Open the door or view the live camera
Health Care	Patient Monitoring	Tracking patient vital signs and health status indicators using data collected from smart wearables	Smart device attached to user for pain treatment. Keeping track of heart rate, breathing, temperature, steps, detect body position in case if a person falls
	Remote Doctors	Able to read the victim's health information in real time and give instructions	In case the emergency medical services need instruction related to patient's health
Security	Smart Lock	Auto open or close	On smoke alarm, auto open door
	Smart Monitoring	Motion detection and Live camera	View live camera feed
	Smart Alarm	Sound alert, notify user, security patrol or police	Send notifications to user
Safety	Smoke Detector	Sound alert, run emergency automation, auto calling	Auto calling Fire, EMS and police
	Leak Detector	Sound alert, run emergency automation, auto calling	Alerting user or residents, calling security and fire
Reliability	Local Automations	Able to execute emergency routines	Auto calling authorities during emergency (e.g. fire)
Storage	Local Storage	Keep track of important data	Saving front door camera feed

Figure: Identified essential services

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Research findings

Smart home systems can vary greatly

The system administrator would need to define which services will remain and in what capacity according to the computational capabilities of their RES-Hub

Only a proof of concept but we can imagine different levels of RES-Hub that would be able to scale according to system needs

Discussion

Comparison

Each system has different requirements and goals.

- Mosquito case: Optimization and highly energy efficient
- Resilient smart home case: Secure and resilient

Both needed to be cloud independent for different reasons.

Each layer (Perception, network, and application) can be modified to better serve the function of a IoT system.
Each layer is important to consider when designing around system requirements and goals.

While these are only two examples, goal and requirement based layer analysis can be applied whenever analyzing or designing an IoT system.

Closing

Aknowledgements and Questions

Thank you Professors Machkasova and Lamberty for your help and feedback; also thank you friends and family.

Questions?

Citations

Prashant Ravi, Uma Syam, and Nachiket Kapre. 2016. Preventive Detection of Mosquito Populations using Embedded Machine Learning on Low Power IoT Platforms. In Proceedings of the 7th Annual Symposium on Computing for Development (ACM DEV '16). ACM, New York, NY, USA, Article 3, 10 pages. DOI: https://doi-org.ezproxy.morris.umn.edu/10.1

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