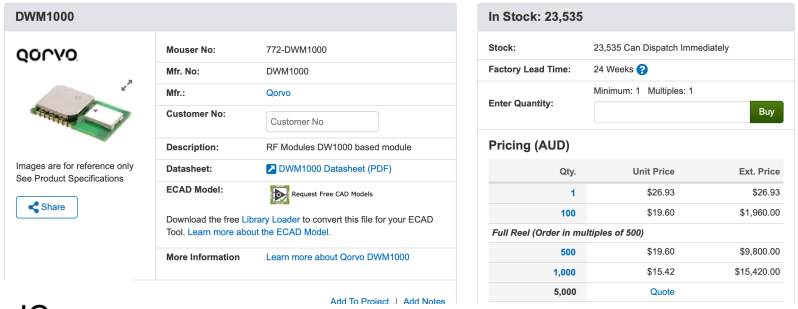
COMP6733
IoT Design Studio

Week 1: Introduction

This lecture

- *Course Organisation*
- Internet of Things (IoT)
  - Introduction and foundation topics
- Video on IoT: https://www.youtube.com/watch?v=LVIT4sX6uVs
- Safezone:

  https://www.youtube.com/watch?v=yqAwgtKESE8



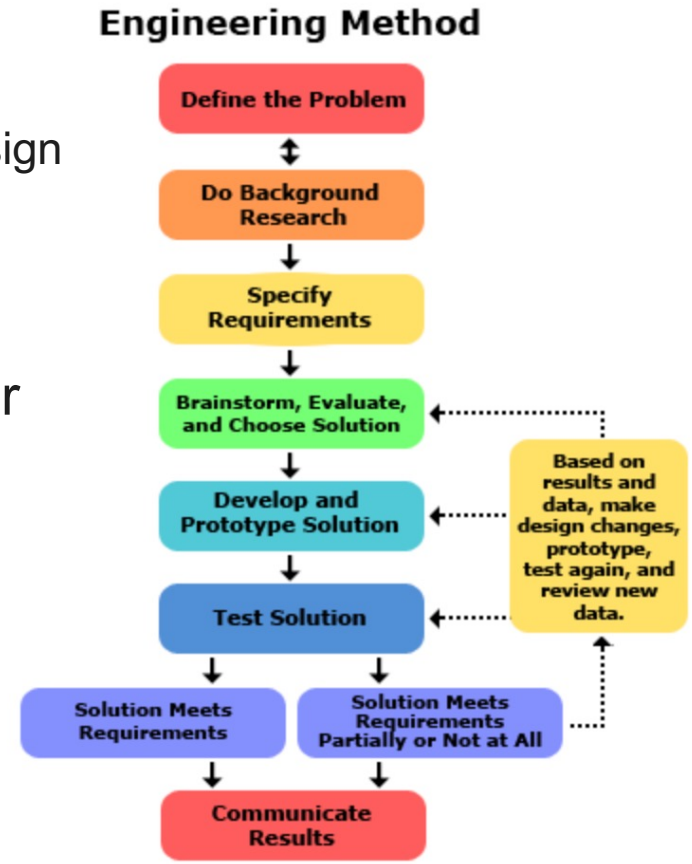
Qorvo's DWM1000 module is based on the DW1000 ultra-wideband (UWB) transceiver IC, which is an IEEE 802.15.4a UWB implementation. It integrates antenna, all RF circuitry, power management and clock circuitry in one module. It can be used in two-way ranging or TDOA location systems to locate assets to a precision of 10 cm and supports data rates of up to 6.8 Mbps.

Course staff

- Lecturer: Wen Hu
  - Guest lecturer (Dr Brano Kusy, CSIRO)
  - Guest lecturer (Mr. Daniel Barber, and Mr. Paul Thompson, DNA Energy)
- Tutors:
  - Cheng (Jacob) Jang, T14A Tuesday Lab
  - Jiawei (Gary) Hu, W09A Wednesday Lab
  - Mark Cardamis, W14A Wednesday Lab

The emphasis of this course: The **design** of IoT

- Simplified design recipe:
  - Step 1: Ask questions like
    - What are the design requirements?
    - What are the constraints? Etc.
  - Step 2: Find a solution and examine
    - How well does the proposed solution meet the design requirements?
    - Does the proposed solution meet the all the constraints? etc
- When presenting a topic, we will very often ask or do:
  - What is the problem to be solved?
  - Why is it a problem?
  - What are the constraints?
  - Why is it designed this way?
  - Examine different solutions and critique them.
- The aim is expose you to the fundamental principles behind designing IoT systems



Course organisation

- Course web site: www.cse.unsw.edu.au/~cs6733
- Three course components
  - Lecture, laboratory, project
- Week 6 (Session break)

Lectures

- Lectures
  - Weeks 1-4, 7: Fundamental Concepts of IoT
  - Weekly revision questions
    - Will discuss the week after in the lecture if time is available
  - Assessment: 1 Problem Set (i.e., take-home test)
    - Issued in Week 4, Due: Week 9
  - Guest lectures from industries
    - DNA Energy (Smart grid IoT)
    - CSIRO (Environmental IoT)
  - Project presentation (Weeks 5, 8, 11)
    - Peer marking (compulsory attendance)
  - **Note: No final exam**

Laboratory

- Aims:
  - Programming IoT devices
  - Develop communication protocols, applications, and cloud service with these devices
  - Hardware: Arduino Nano 33 BLE sense, NVIDIA Jetson Nano Developer Kit, amd TI SensorTag wireless devices.
  - Each student will be loaned 1 Arduino Nano 33 BLE sense, which are to be returned after project demo completed
- Laboratory: Weeks 2 – 5, 7
  - 4 guided lab exercises
    - Week 7: Marking of Lab 4 and optional machine learning/edge computing lab
    - Week 6 is a break
  - Specific demonstration tasks to be shown to your tutor in the next lab
  - Individual tasks

Project

- Teams of 3-4 students
  - Get to know your classmates now!
- Solve a problem in IoT
  - https://unsw-my.sharepoint.com/:v:/g/personal/z2260468_ad_unsw_edu_au/Ee4JPJjEGk9Glivf4MmoOosBKmR9BgsNZg7ri_Iv23HyVA?e=lGgL2b
  - Research, propose a solution, demonstrate
  - List of projects available in Week 1
  - Form teams and bid for projects or propose your own project
- *Modus operandi*
  - Week 3: Project team finalised
  - Week 5: Preliminary Project Presentation
  - Week 8: Intermediate Project Presentation
  - Week 11: 6 Aug: Report + code due, 7 Aug: Demo

Project replaces the final exam

Assessment

- Three (3) assessment components
  - Problem set (10%)
  - Laboratory exercises (30%)
  - Project (60%)
    - Project plan report and preliminary presentation (10%)
    - Intermediate project presentation in Week 8 (10%)
    - Final Report (15%) and demo (25%)
- Two important rules
  - Must attempt all components
  - Final mark calculation:
    - Raw mark = weighted average of your marks
    - If you score 40% or more in **all** components, your final mark = raw mark;
    - otherwise, final mark = min (raw mark, 64)

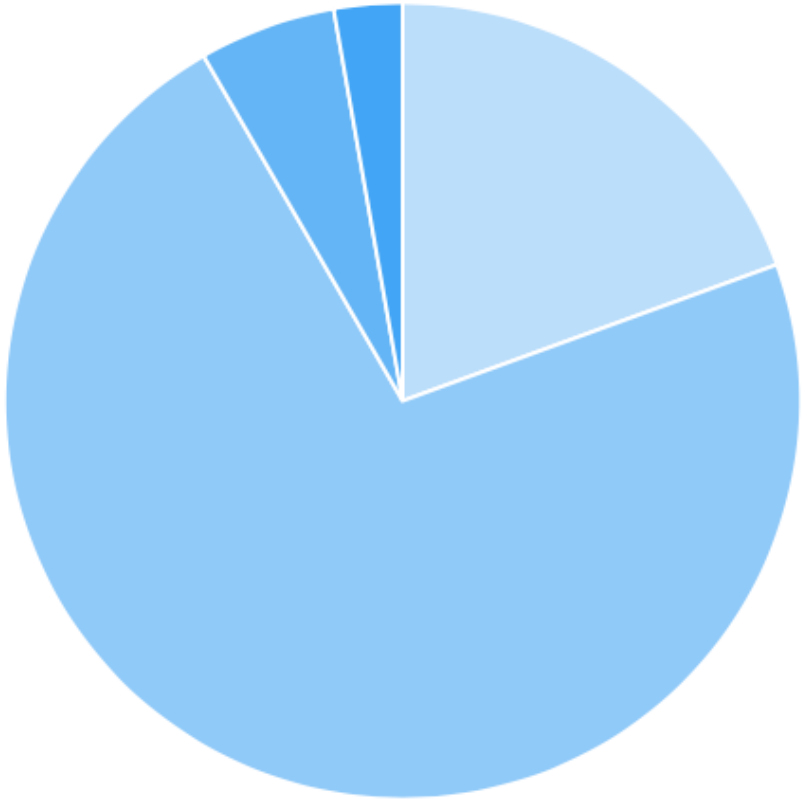
Course pre-requisite and resources

- Pre-requisite
  - Familiarity with Kurose and Ross (COMP331/9331 text)
  - Knowledge of probability, graph theory, algorithms from earlier courses
  - Experience with Linux, and Python
  - Microcontroller programming (will help)
- Resources
  - Practical Guide
    - Bahga and Madisetti, *Internet of Things: A Hands-On Approach*
    - Kellmereit and Obodovski, *Designing the Internet of Things*
  - Research papers from journals, conferences and magazines
    - Will be available on the course web site
    - **You are expected to read them**
- Please read course outline on the website carefully
  - Information on plagiarism which has severe penalty!
  - Use of Generative Tools such as ChatGPT and Copilot is NOT permitted.

Course Evaluation and Development

- Which programming languages you are comfortable with?

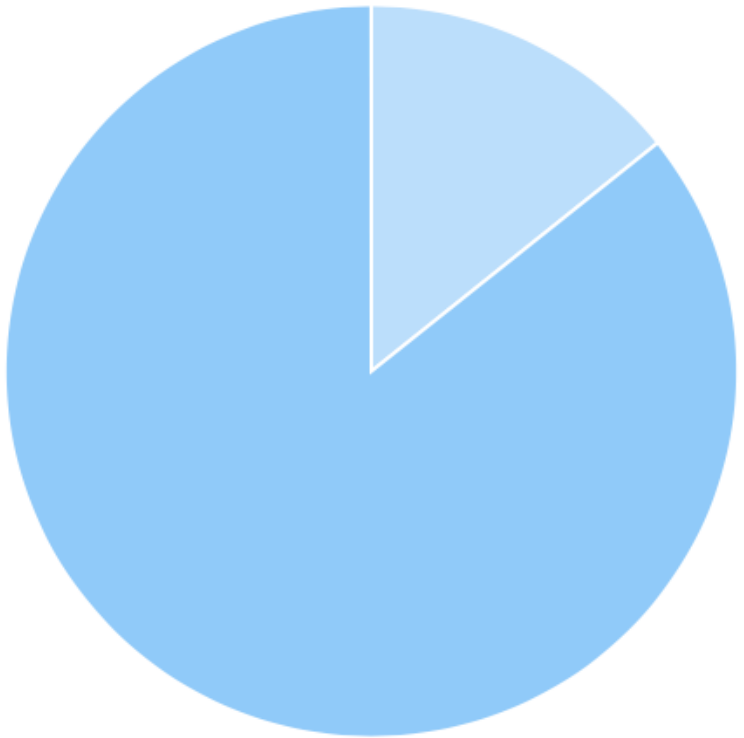
(a) C	7
(b) Python	26
(c) Java	2
(d) Other	1



Which programming languages you are comfortable with?

- 72% => 86%

(a) C	2
(b) Python	12
(c) Java	0
(d) Other	0

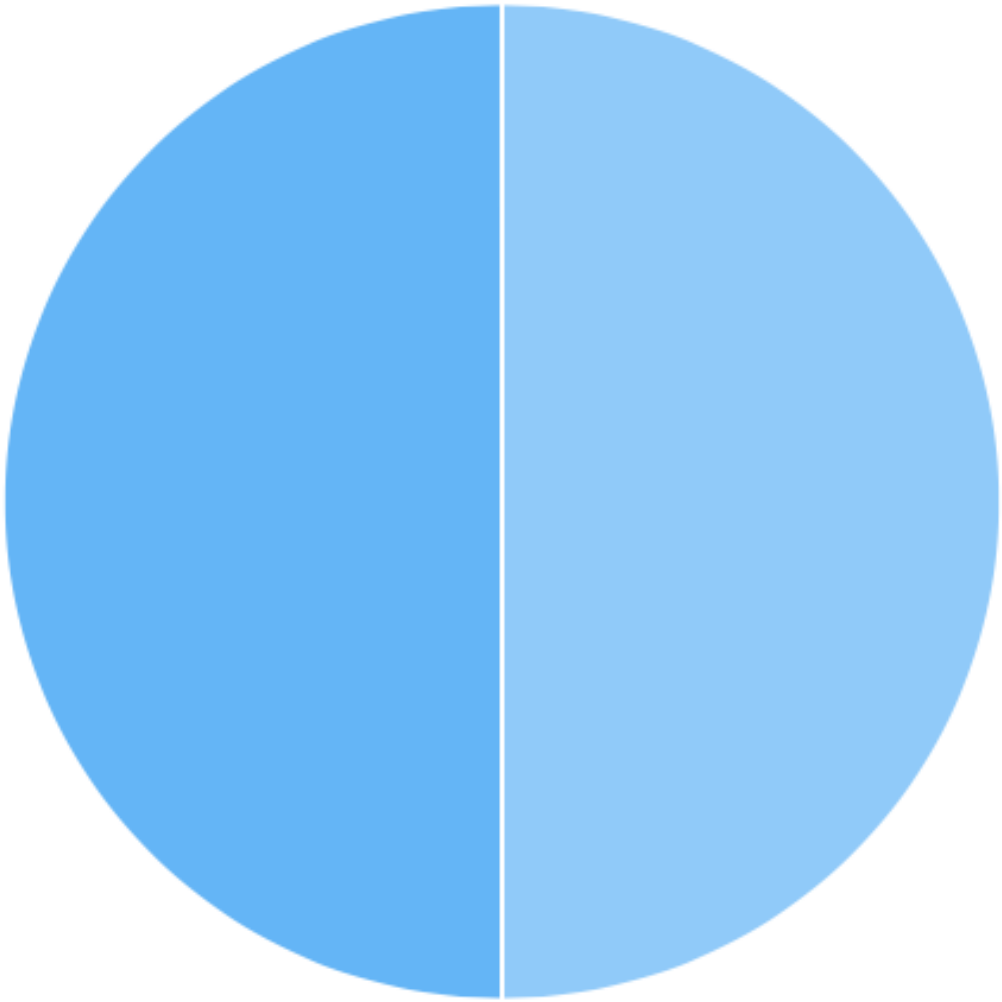


What was the main reason you chose to do COMP6733? What do you want to learn after taking the course?

- Interested in IoT (sensors)/curious and want to try to use IoT
- IoT will be a trend in the future
- Jarvis:) ,application of IOT
- Industrial IoT and its applications
- Facility framework e.g., smart home
- Programming physical objects
- Embedded dev, hardware/software
- Doing a project, learn more networks
- Improving practical skills.

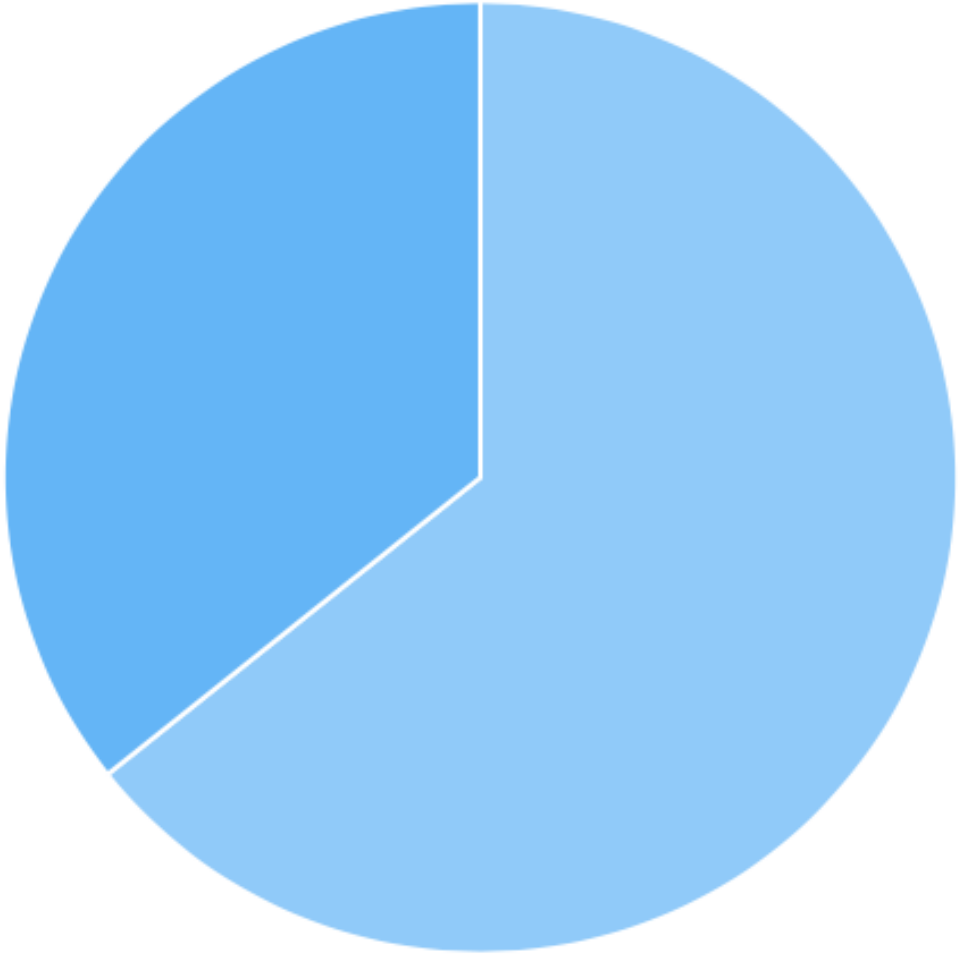
How well you know socket programming?

(a) Very well	0
(b) Not much	7
(c) A little	7



How well you know embedded device programming?

(a) Very well	0
(b) Not much	9
(c) A little	5



Read the syllabus in the course outline. Which topics you think you are more familiar with and which ones you have never heard of?

- never heard of all of it/Unfamiliar with most topics/All topic but ML
- No knowledge about RPL, LPWAN, CoAP
- familiar with Bluetooth
- Good at network and security.
- IEEE 802.15.4, Bluetooth Low Energy
- only familiar with machine learning
- machine learning, signal processing
- Web Services for Internet of Things
- AWS services (AWS CCP certified)

Read the syllabus in course outline. Is there any topic(s) beyond those listed that you would like your lecturer to teach in this course?

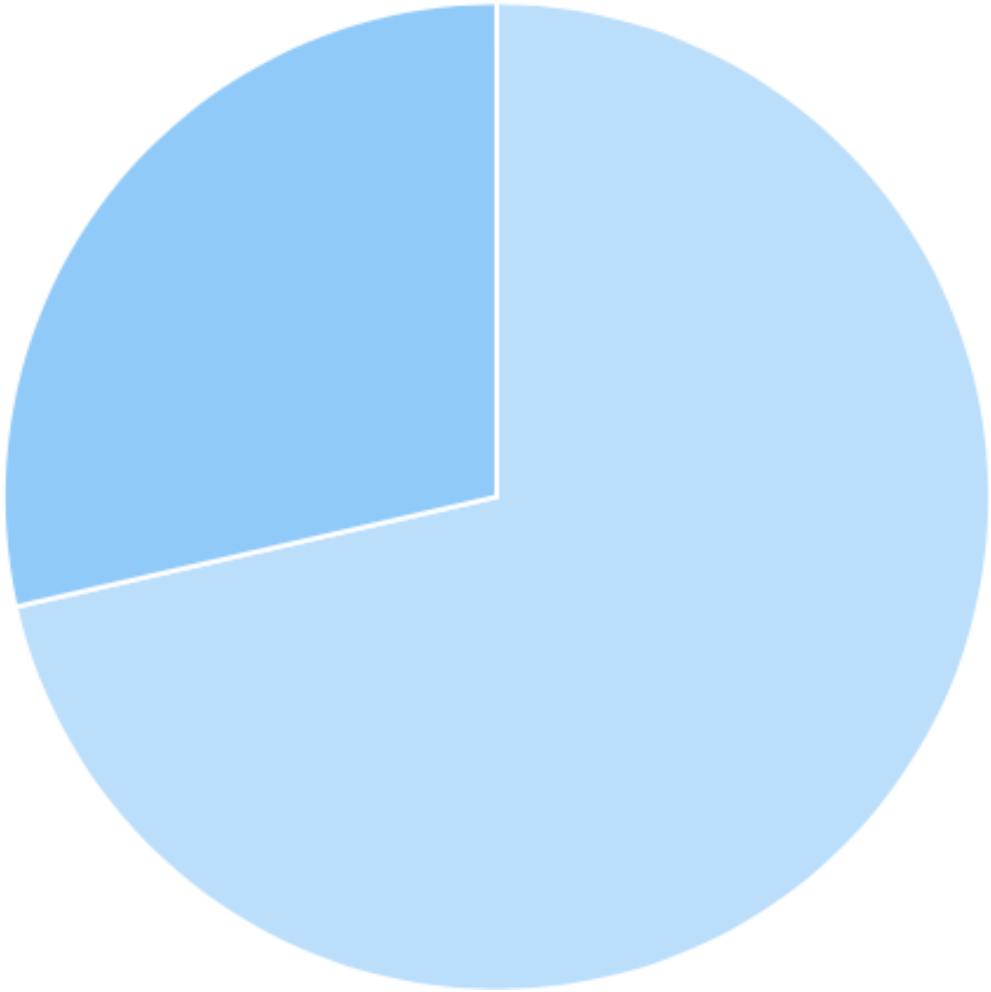
- N/A, nope, Not sure, Not yet, no idea, no, since I'm a beginner
- IIOT protocols like MQTT
- Protocols used in IoT industry
- Distributed systems in IoT
- More on smart IoT
- yes

Go through the course outline and identify the tasks and activities that you'll be involved in. Is there any other activities you think would be useful for you

- N/A, No, since I'm a beginner, Not sure, no idea, no
- Lab work/lab/ The practical side of using Arduino/ Lab exercises
- ML on edge is the most interesting.
- Mostly just the project
- All are useful.
- 35 character(s) limited my response

Do you have experience with a course assessment without final exam?

	(a) Yes	10
	(b) No	4



This lecture

- Course organisation

- *Internet of Things (IoT)*
  - What is IoT?
  - …

What is the “Internet of Things”

Internet of things

Syllabification (Inter•net of things)

noun

A proposed development of the Internet in which everyday objects have network connectivity, allowing them to send and receive data:

- Source: Oxford Dictionary, yep, it’s really in the Oxford Dictionary. It got added at the end of August, 2013

- *"Today computers—and, therefore, the Internet—are almost wholly dependent on human beings for information. Nearly all of the roughly 50 petabytes (a petabyte is 1,024 terabytes) of data available on the Internet were first captured and created by human beings—by typing, pressing a record button, taking a digital picture or scanning a bar code…"*

Source: Kevin Ashton, "That 'Internet of Things' Thing: In the real world, things matter more than ideas", RFID Journal, June 2009

- *"If we had computers that knew everything there was to know about things—using data they gathered without any help from us—we would be able to track and count everything, and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best."*

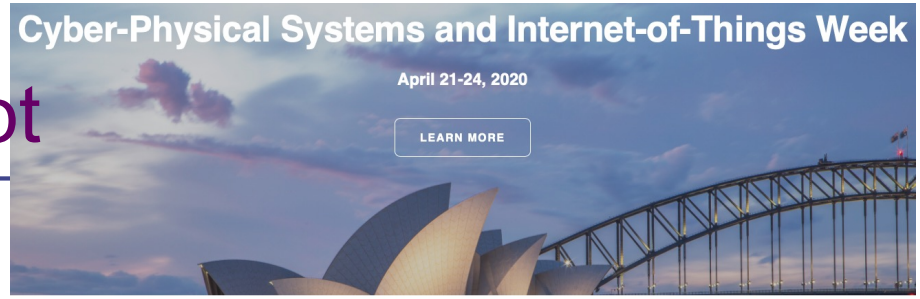
- Source: Kevin Ashton, "That 'Internet of Things' Thing: In the real world, things matter more than ideas", RFID Journal, June 2009

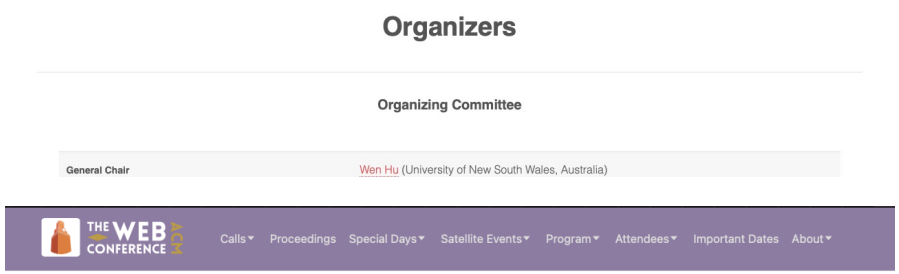
- *"We need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory. RFID and sensor technology enable computers to observe, identify and understand the world—without the limitations of human-entered data."*

- Source: Kevin Ashton, "That 'Internet of Things' Thing: In the real world, things matter more than ideas", RFID Journal, June 2009

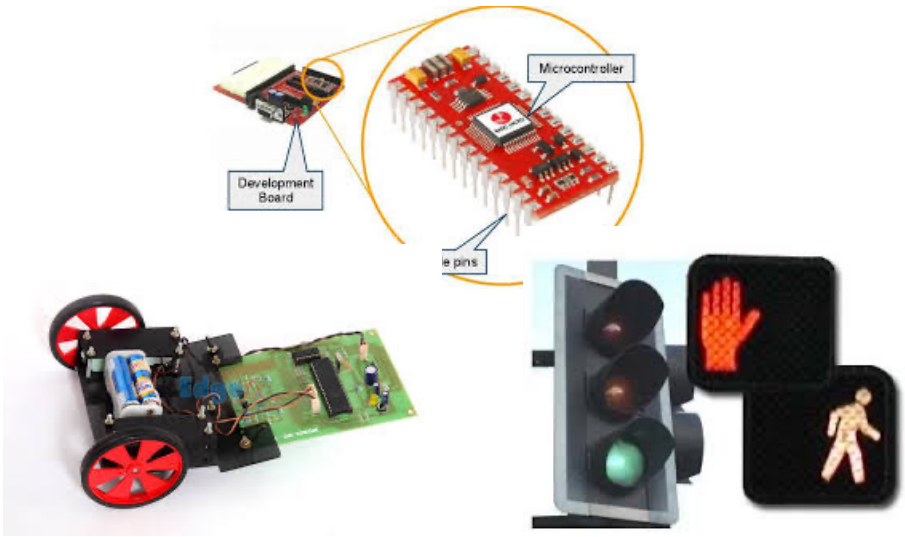
Various Names, One Concept

- M2M (Machine to Machine) or D2D (Device to Device)
- Cyber Physical Systems
- Internet of Everything (Cisco)
- World Size Web (Bruce Schneier)/Web of Things
- Skynet (Terminator)





Embedded Systems



The Internet

- Physical world
- Limited Resources
- Limited Context

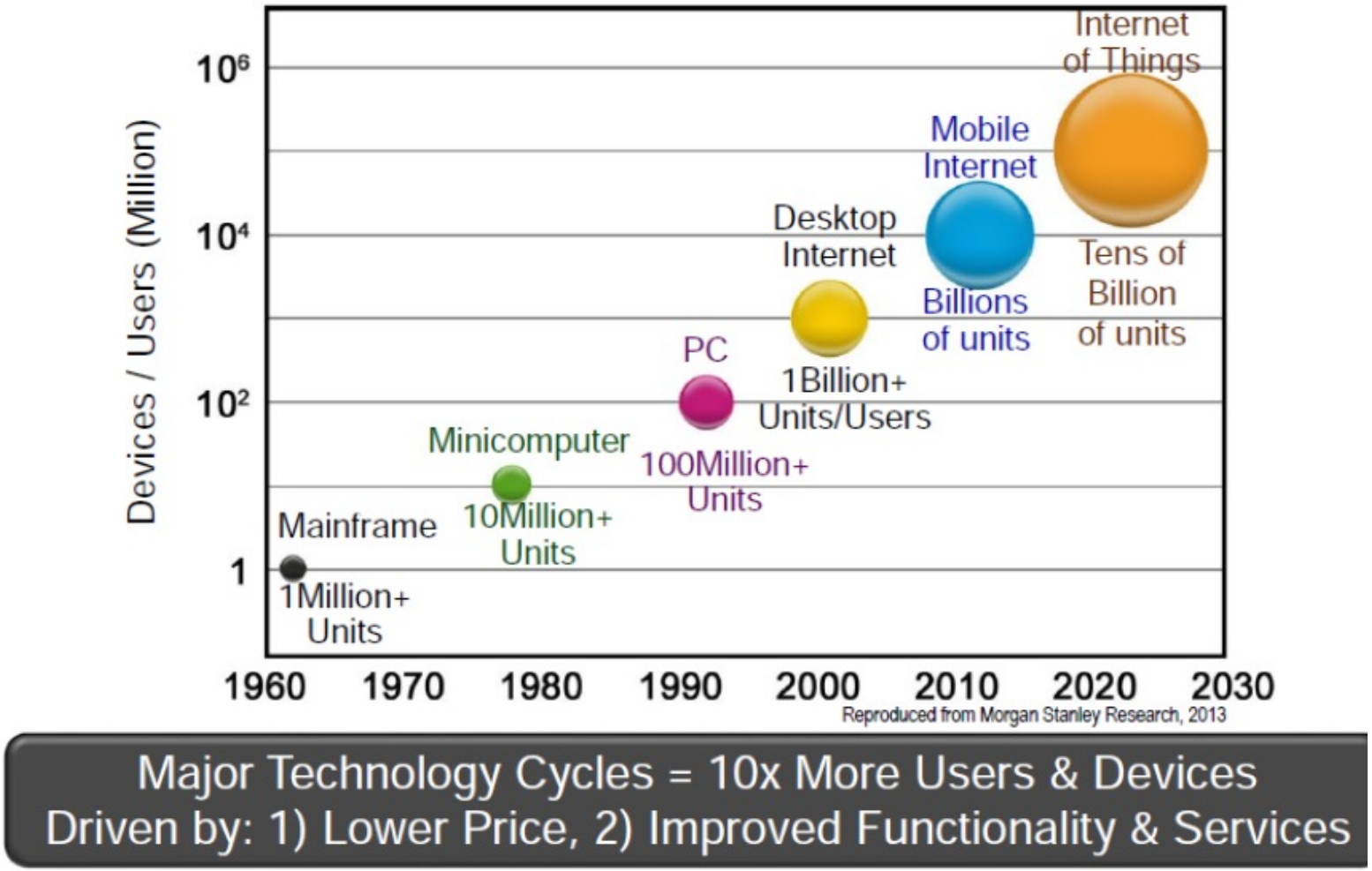
- Cyber world
- Unlimited Resources
- Rich Context

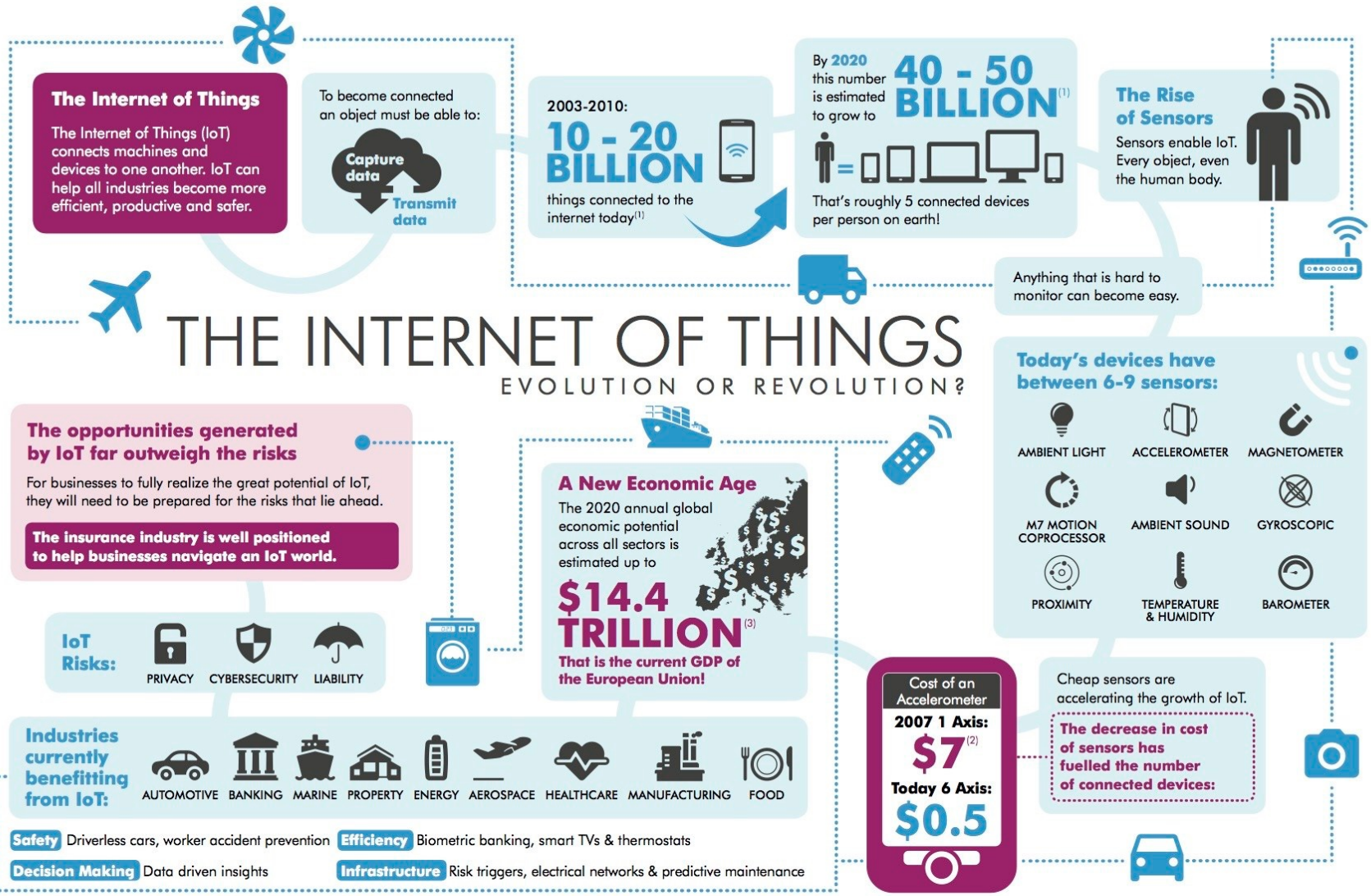
?

IoT is everywhere

- Why is it important?
  - IoT will touch everything
  - Every *thing* will have IoT
  - Fourth Industrial Revolution
- Ideal IoT
  - Ubiquitous
  - Smart
  - Agile
  - On demand
  - Blend into the background
  - Secure
  - Low maintenance
  - Fast
  - Upgradable
  - Growing
  - Adaptable

IoT is becoming a “big thing”





AIG

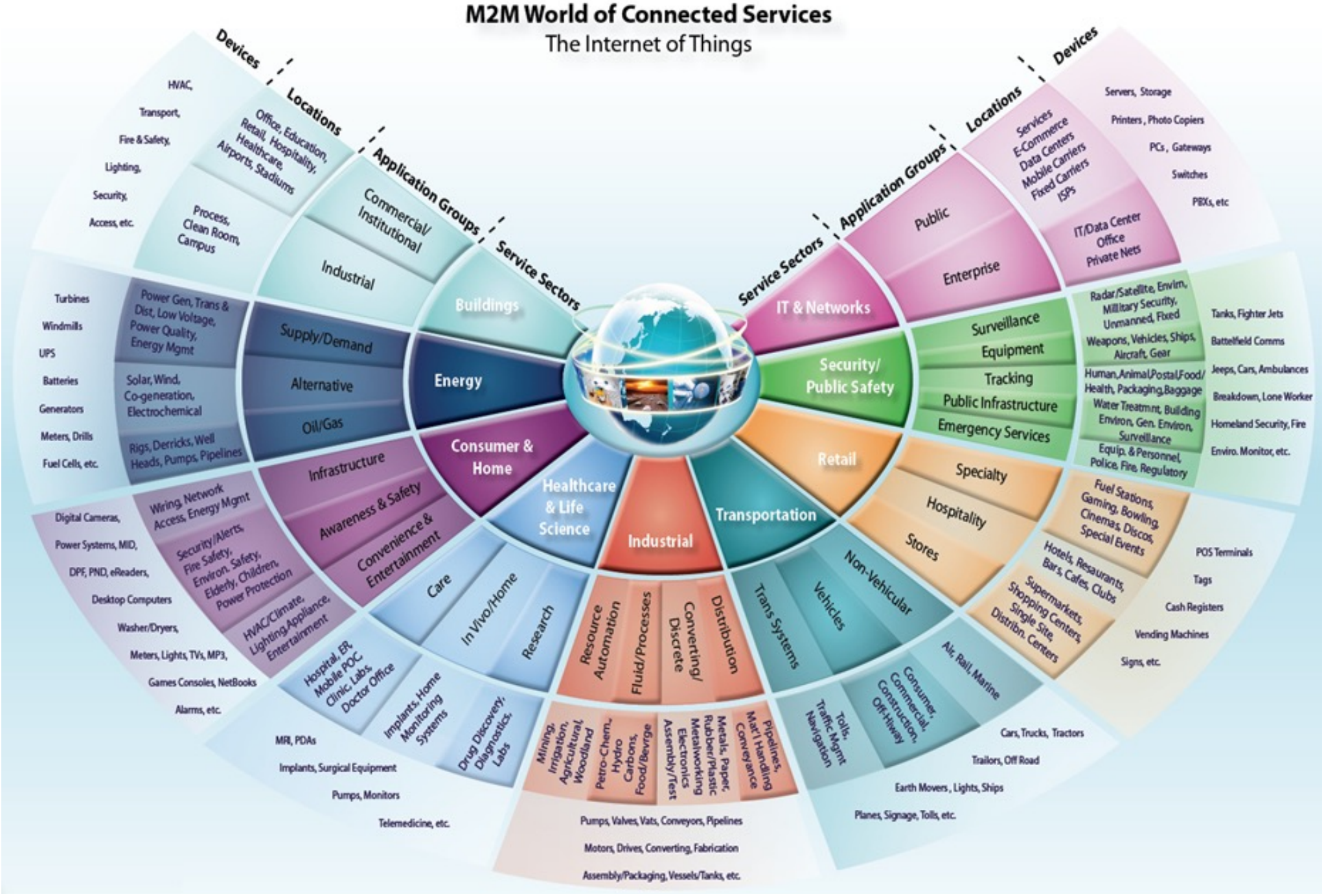
Visit **www.aig.com/iot**

Source: (1) Dubravac, Shawn. "Digital Destiny." (2) CISCO: The Internet of Things How the Next Evolution of the Internet Is Changing Everything, 2011 (3) RAND: Europe's policy options for a dynamic and trustworthy development of the Internet of Things,


www.jklossner.com
©14 c'world klossner
"WE HAVE TO GO OUT FOR DINNER. THE REFRIGERATOR ISN'T SPEAKING TO THE STOVE."

- Course organisation
- Internet of Things (IoT)
  - **How IoT will improve the world**
  - How IoT will break the Internet
    - (…and what we are doing to fix it)
- What to expect in this class

http://www.beechamresearch.com/article.aspx?id=4

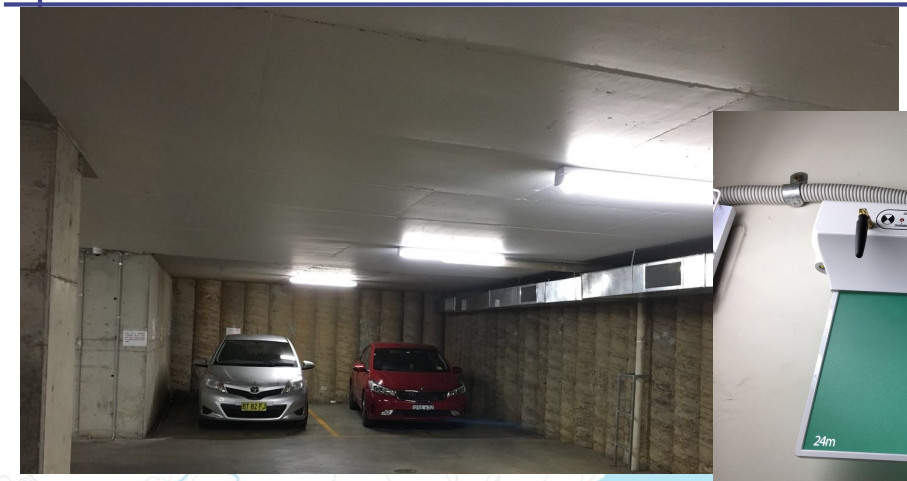


Cool Applications: Smart Cities

Smart Building

Smart Building (Cont)

Deployment



350+
Projects Completed

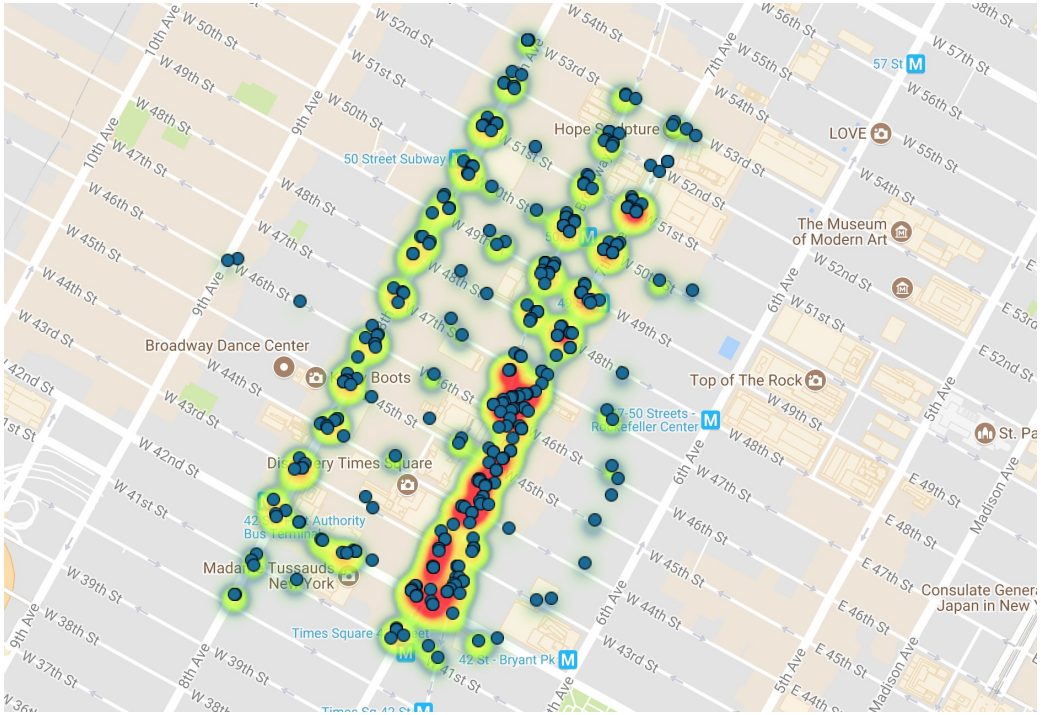
$18m+
Annual Energy Savings

100,000+
Devices Connected

JLL Bupa CBRE TAFE NSW Stockland

Smart Waste Management

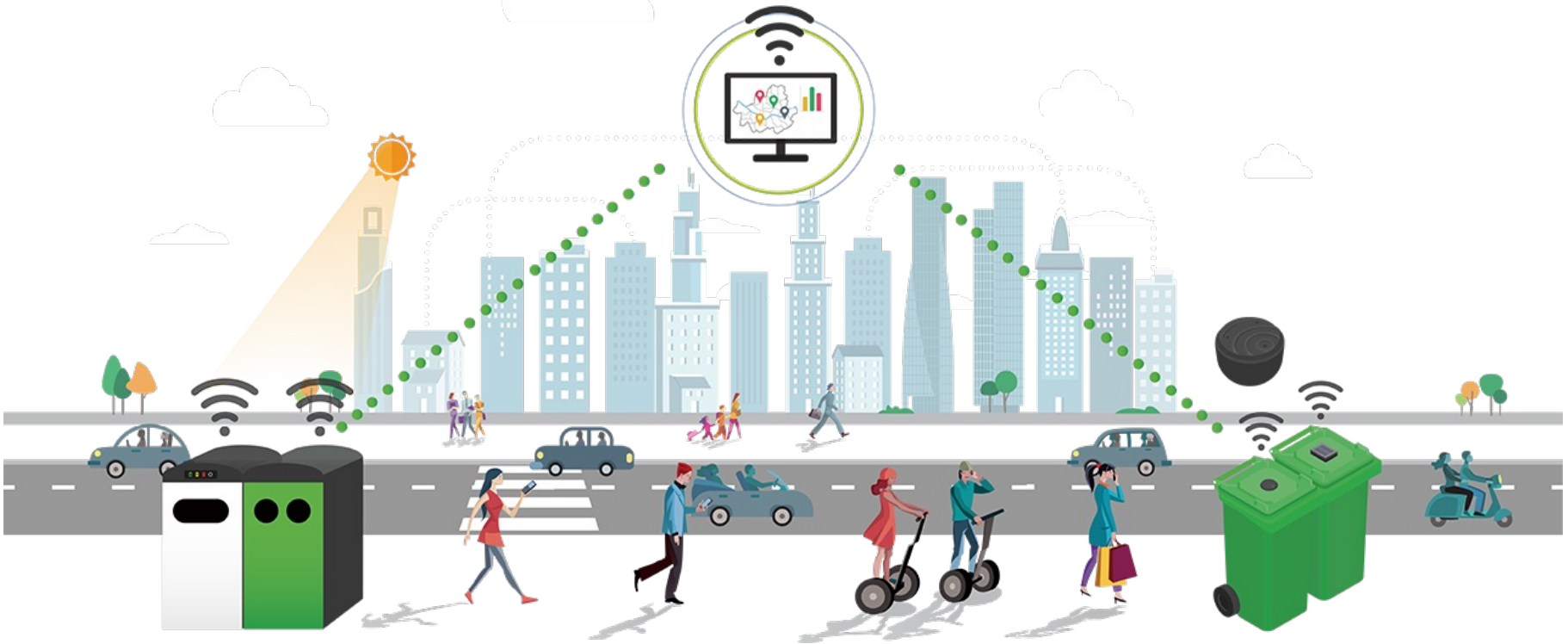
https://www.ecubelabs.com/references/dublin-airport/



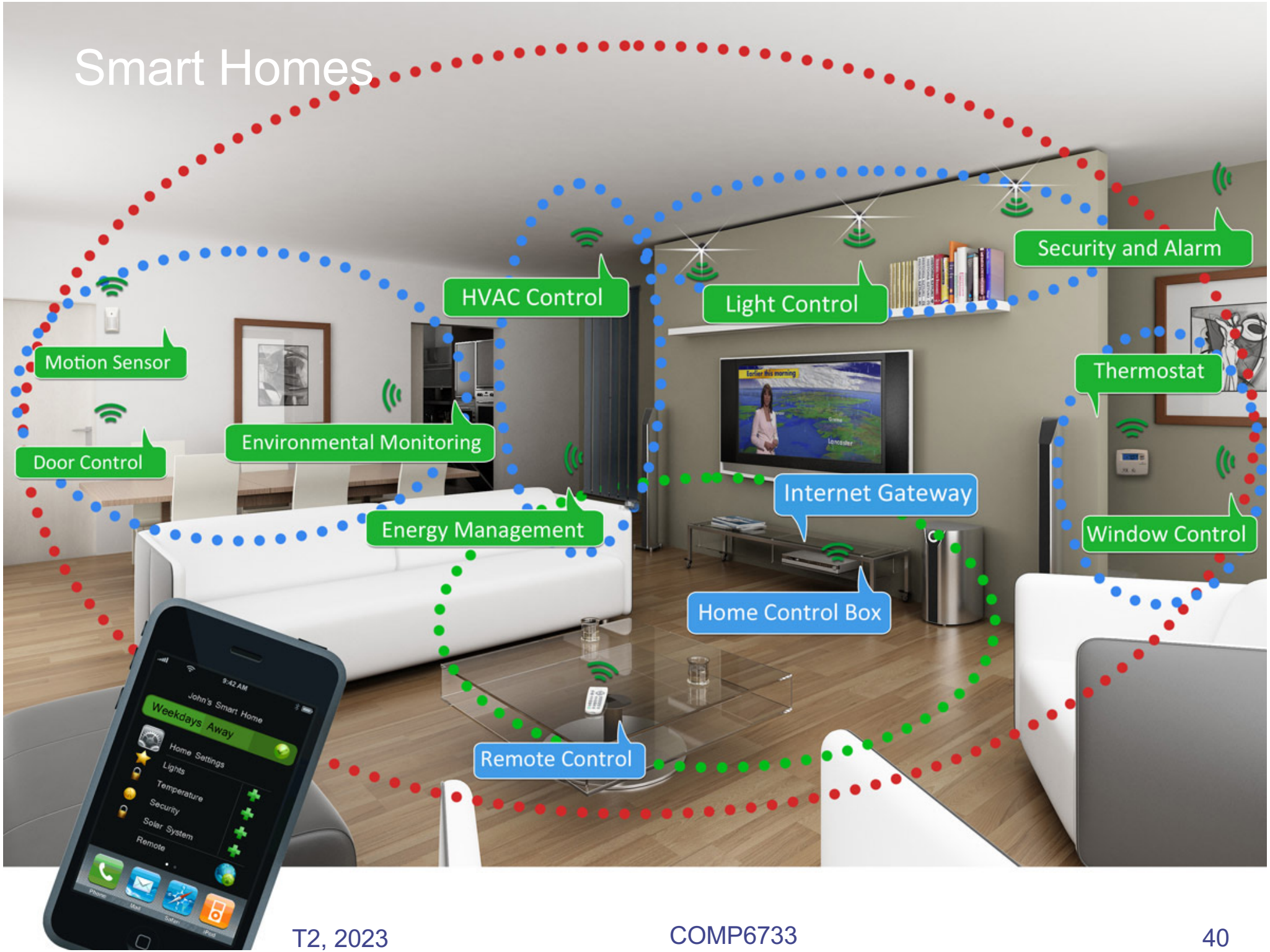
Heatmap of waste bin occupancy in Times Square
www.bigbelly.com

Smart Waste Management

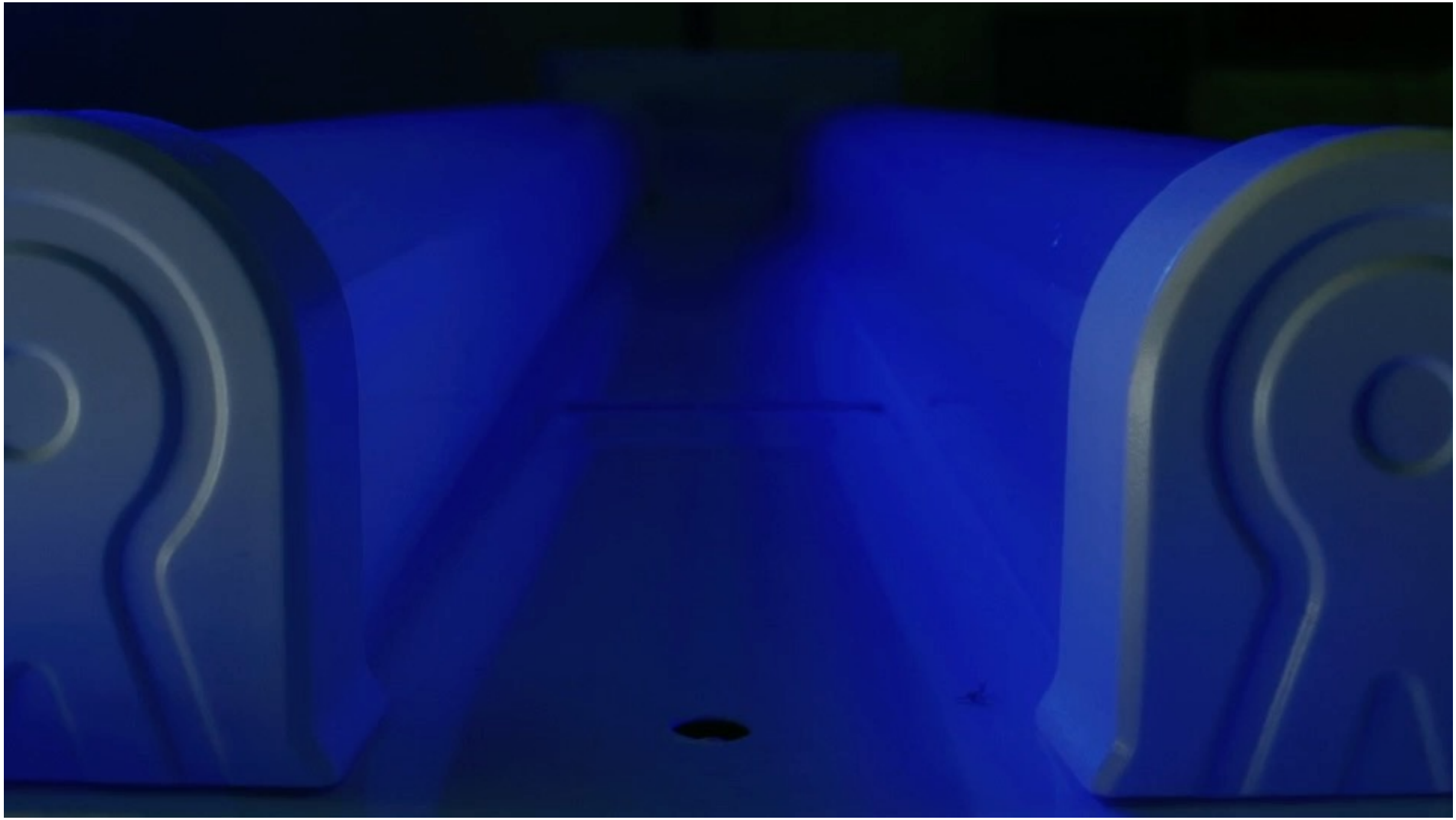
- Ultrasonic fill level sensor
- Cellular IoT
- Solar powered
- Predictive pattern recognition



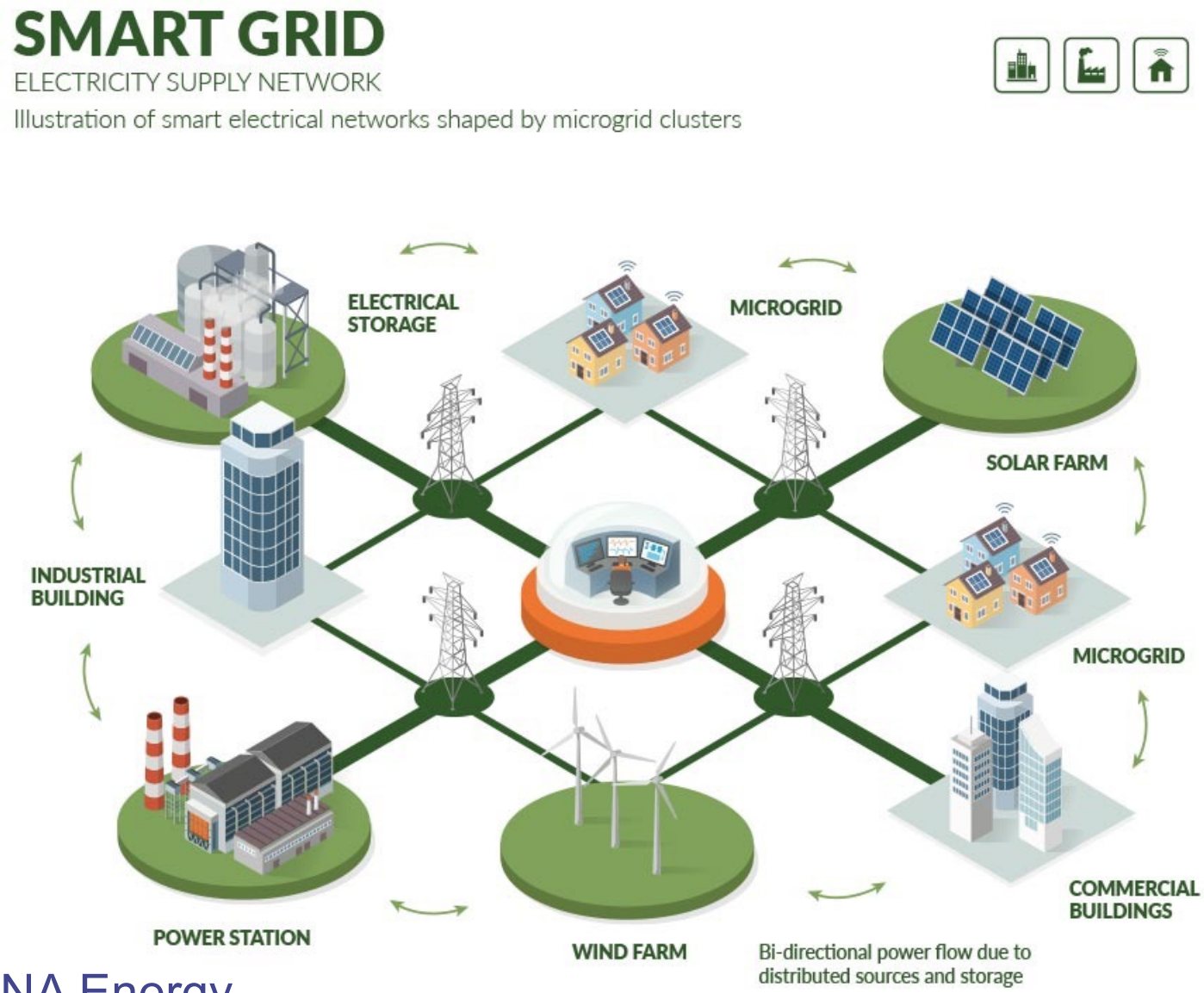
Smart Homes


HVAC Control
Light Control
Security and Alarm
Motion Sensor
Thermostat
Environmental Monitoring
Door Control
Internet Gateway
Energy Management
Window Control
Home Control Box
Remote Control
9:42 AM
John's Smart Home
Weekdays Away
Home Settings
Lights
Temperature
Security
Solar System
Remote

Smart Grid

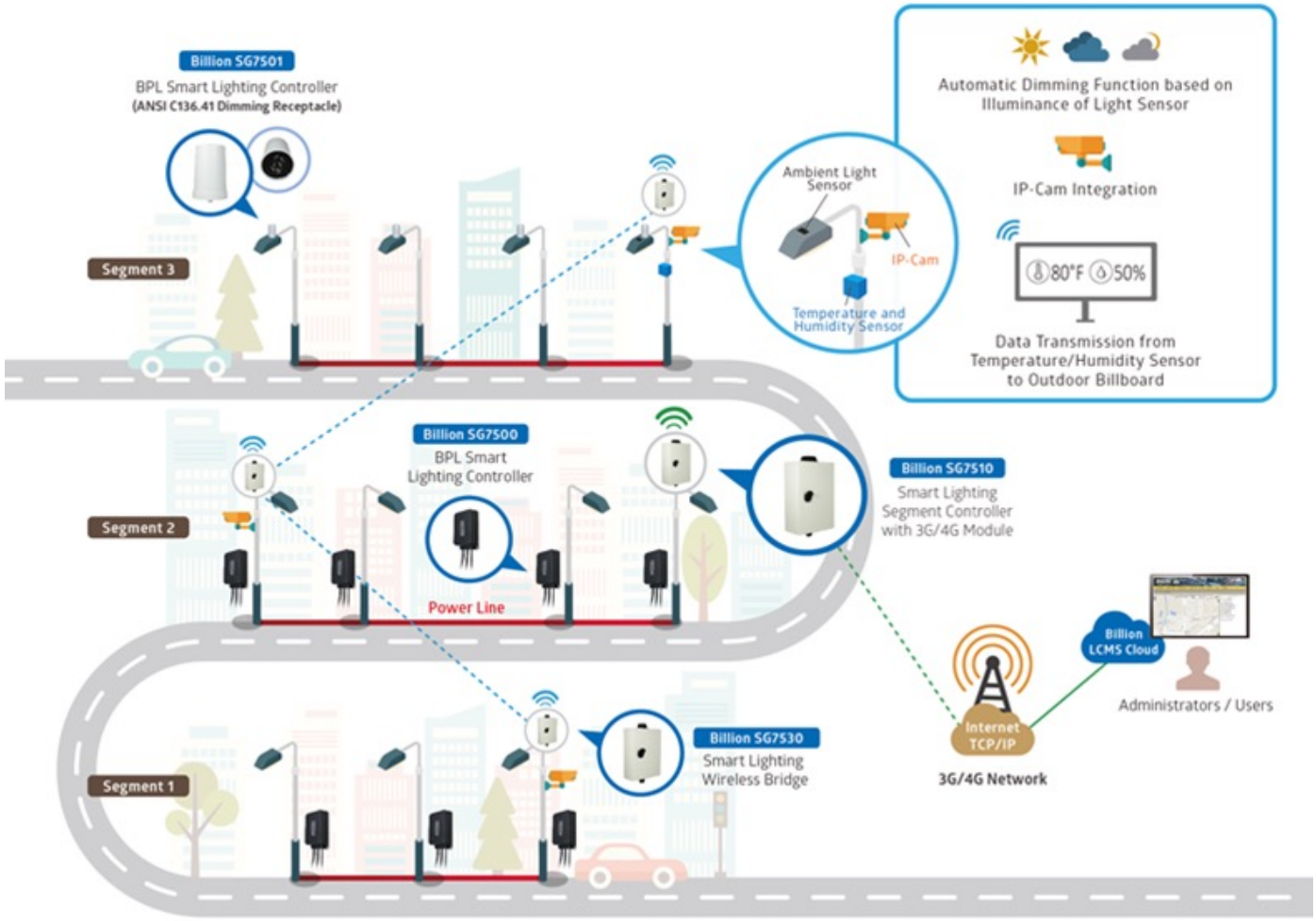


Smart Grid



- DNA Energy

Smart Street Lights

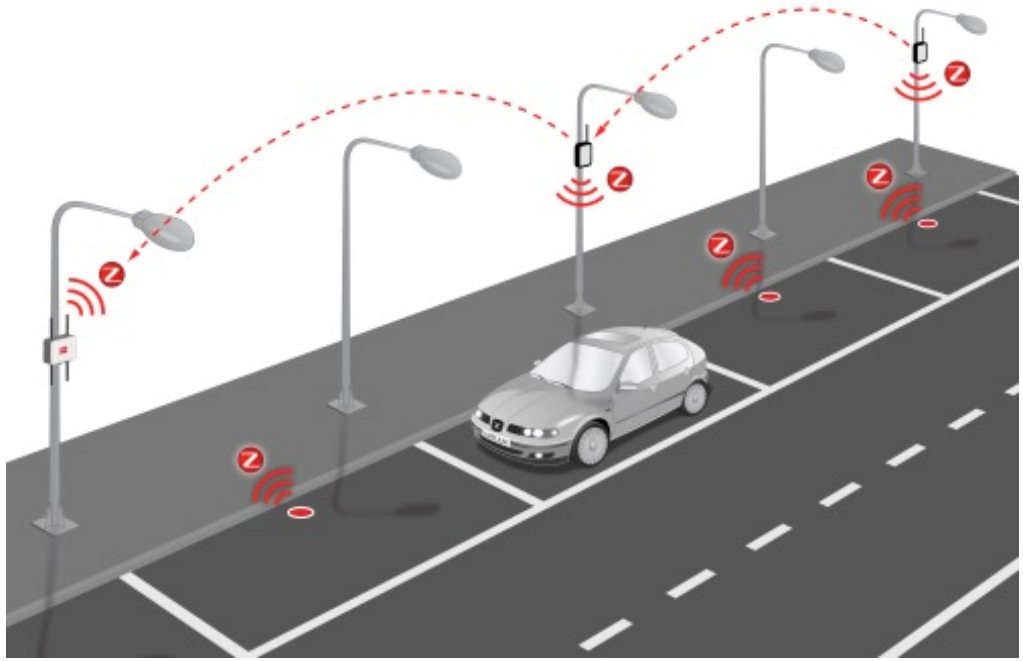


▲ Smart Lighting BPLC (Broadband Power Line Communication) System Architecture

www.envirofina.com

Smart Street Parking

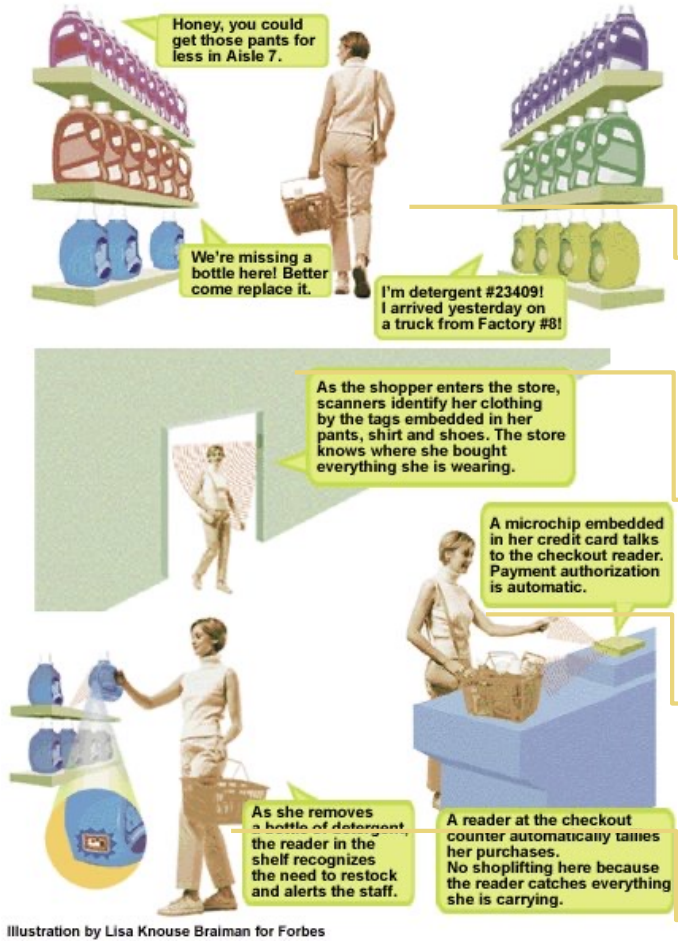
- Infrared-and magnetic based vehicle detection sensor mounted on the road surface
- Wireless mesh connectivity
- Apps to direct drivers to empty spaces
- Dynamic parking prices
- City council can be informed of infractions



Connected Vehicles

http://government-2020.dupress.com/trend/connected-vehicles/

Smart Retail



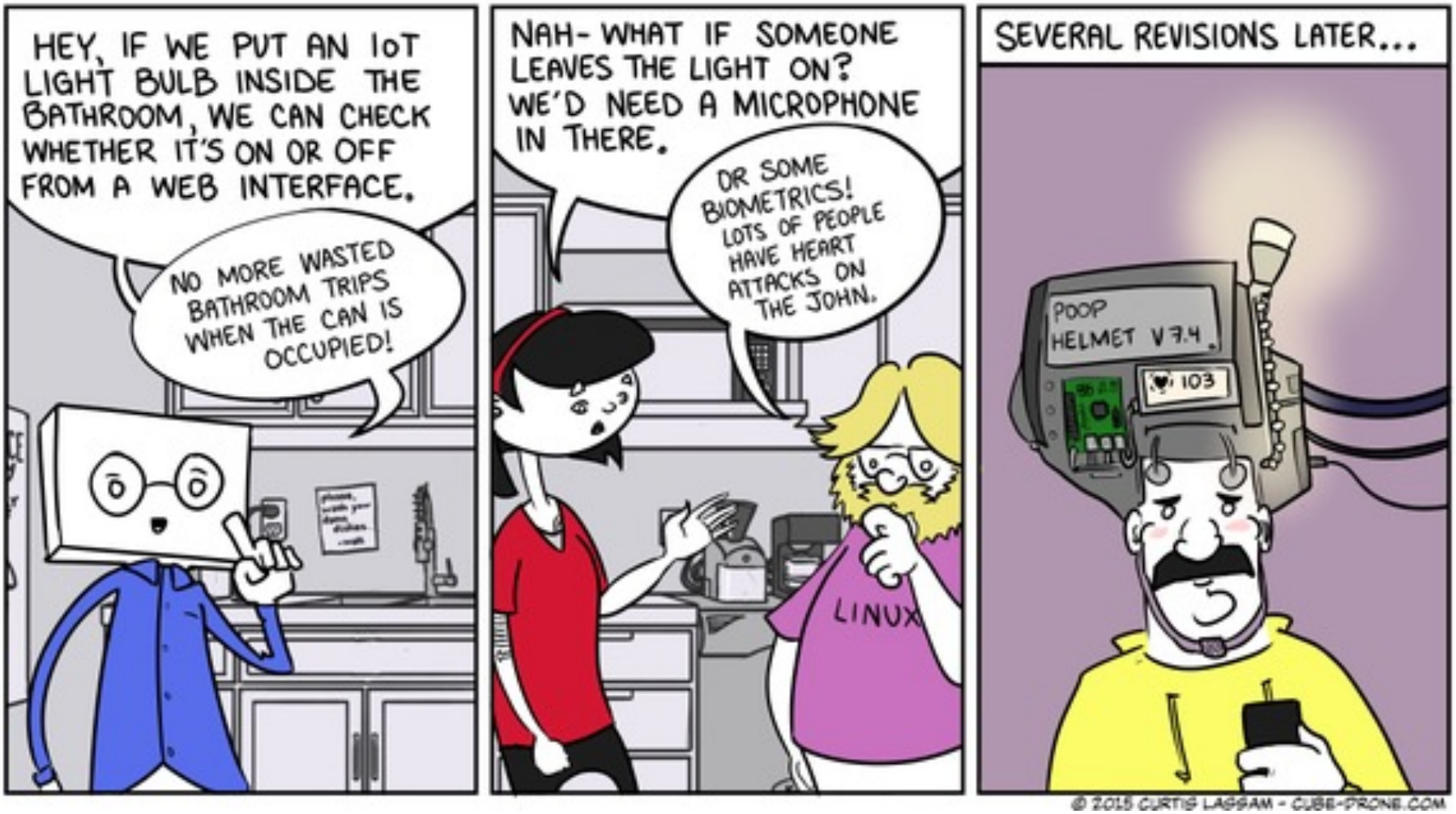
(2) When shopping in the market, the goods will introduce themselves.

(1) When entering the doors, scanners will identify the tags on her clothing.

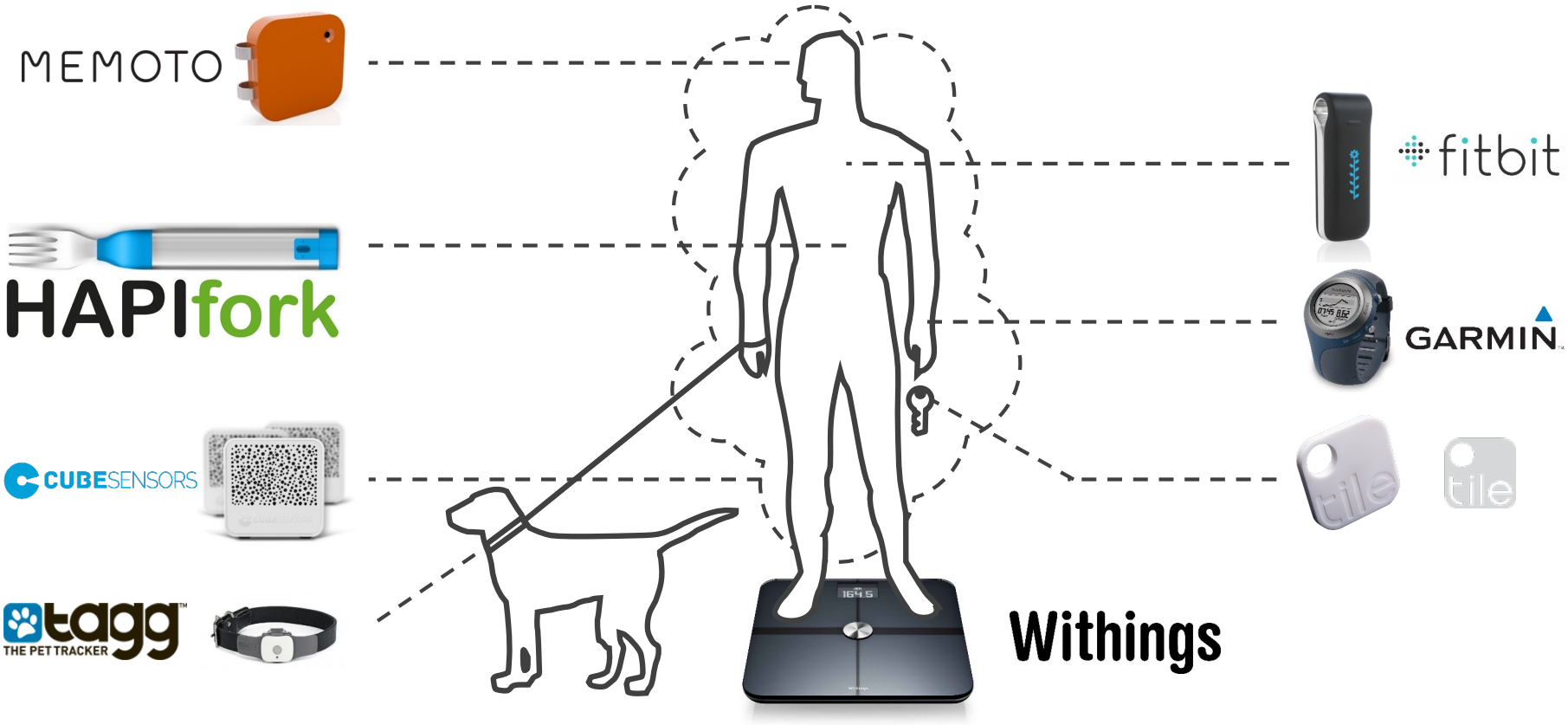
(4) When paying for the goods, the microchip of the credit card will communicate with checkout reader.

(3) When moving the goods, the reader will tell the staff to put a new one.

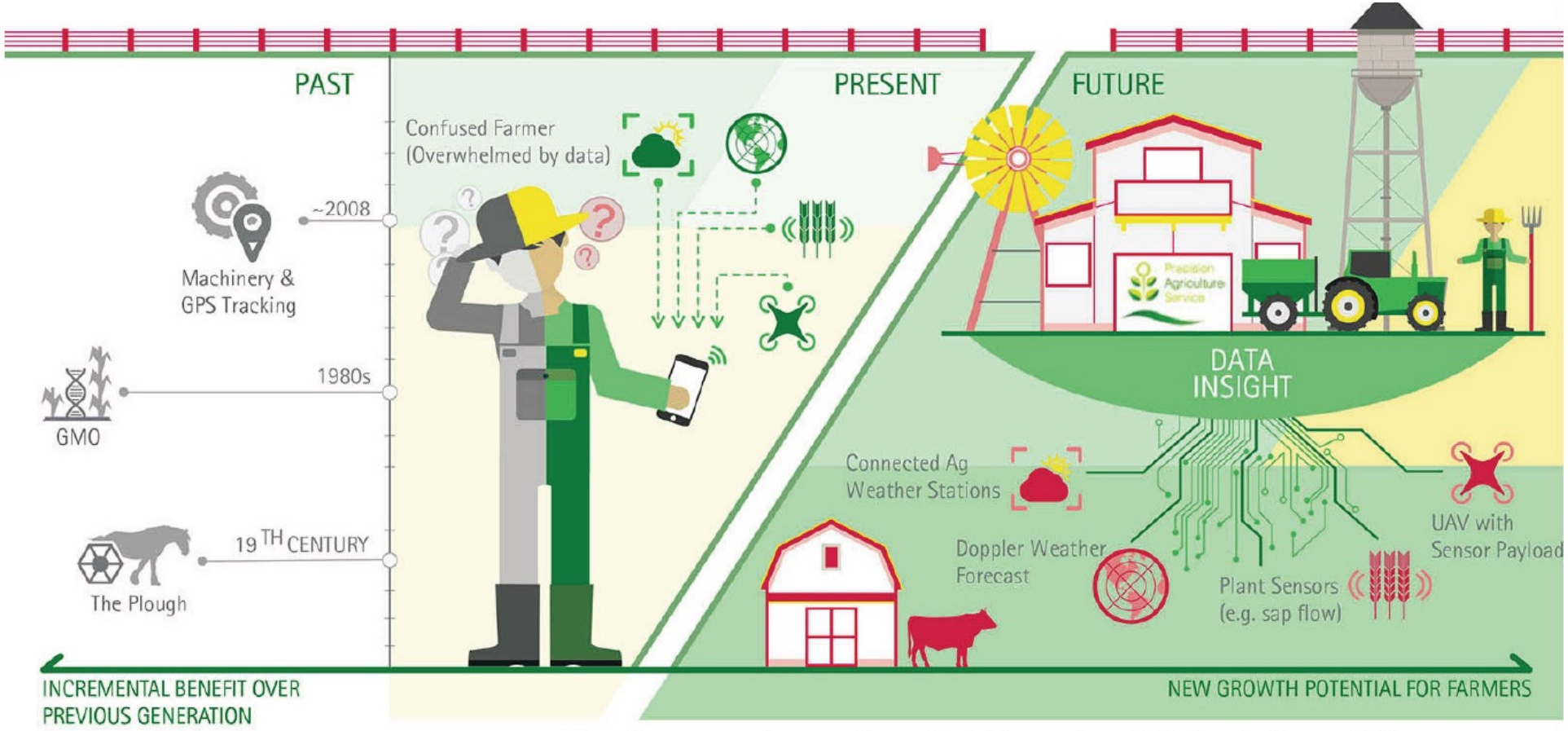
- Amazon Go: https://youtu.be/NrmMk1Myrxc


HEY, IF WE PUT AN IoT LIGHT BULB INSIDE THE BATHROOM, WE CAN CHECK WHETHER IT'S ON OR OFF FROM A WEB INTERFACE.
NO MORE WASTED BATHROOM TRIPS WHEN THE CAN IS OCCUPIED!
NAH- WHAT IF SOMEONE LEAVES THE LIGHT ON? WE'D NEED A MICROPHONE IN THERE.
OR SOME BIOMETRICS! LOTS OF PEOPLE HAVE HEART ATTACKS ON THE JOHN.
LINUX
SEVERAL REVISIONS LATER...
POOP HELMET V7.4
103
© 2015 CURTIS LASSAM - CUBE-DRONE.COM

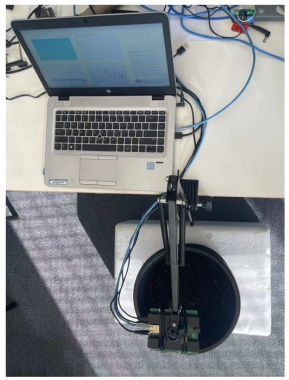
The Quantified Self (health & fitness)

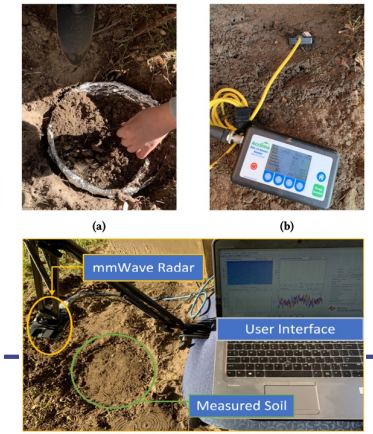


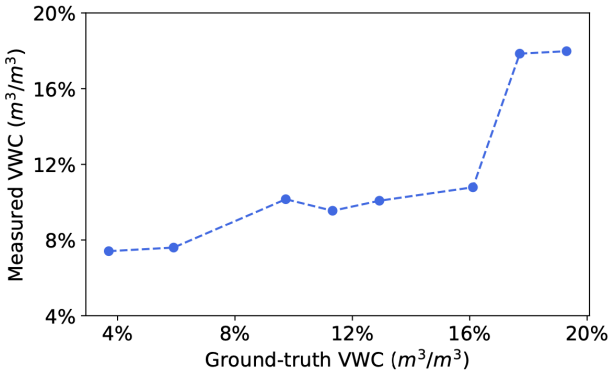
Precision Agriculture



https://www.accenture.com/cn-en/insight-accenture-digital-agriculture-solutions



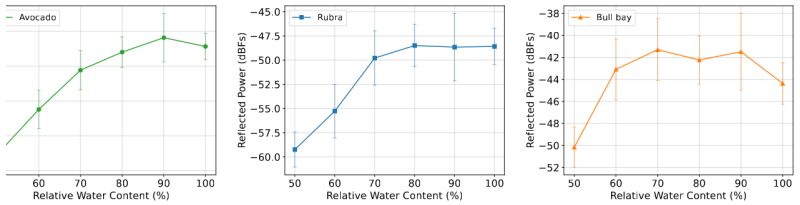




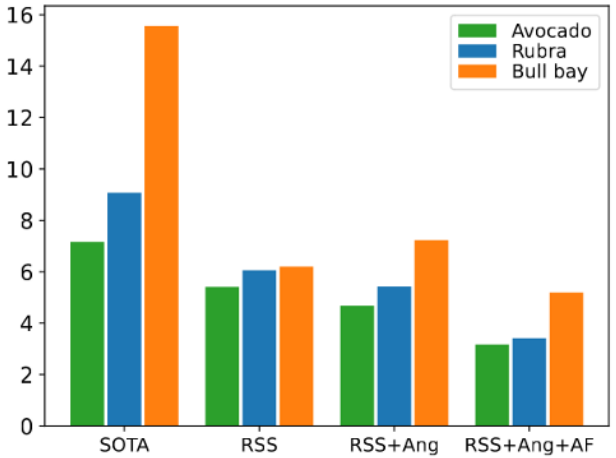
Indoor Farming

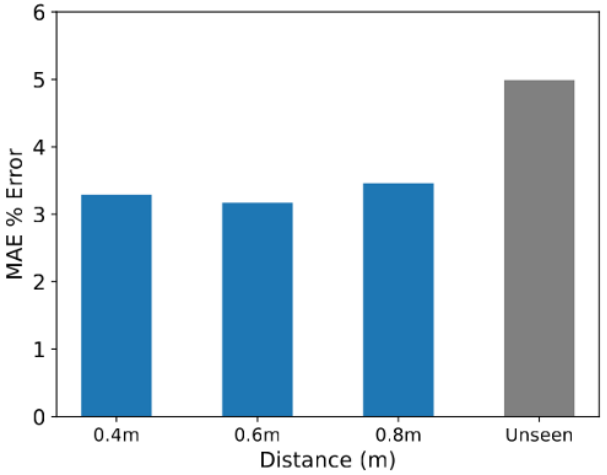
IoT for leaf moisture sensing

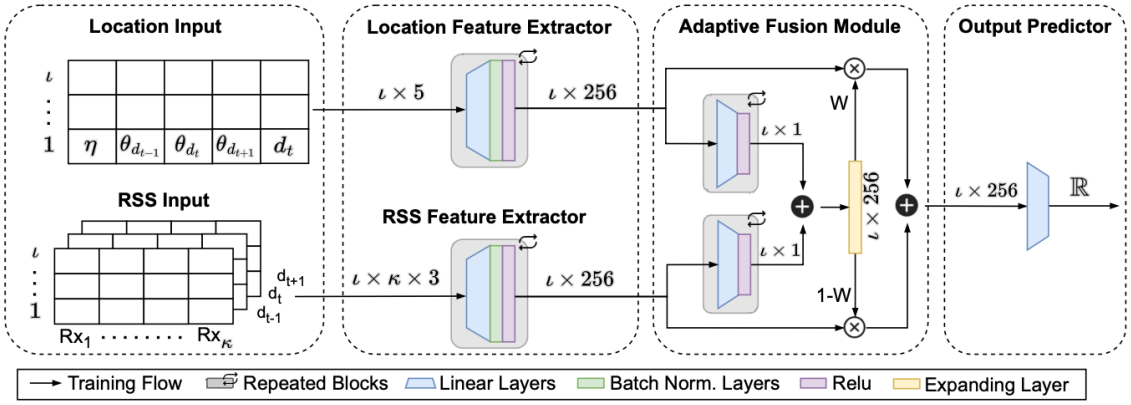
(a) Persea americana (Avocado) (b) Hibiscus tiliaceus rubra (Rubra) (c) Magnolia grandiflora (Bull bay)



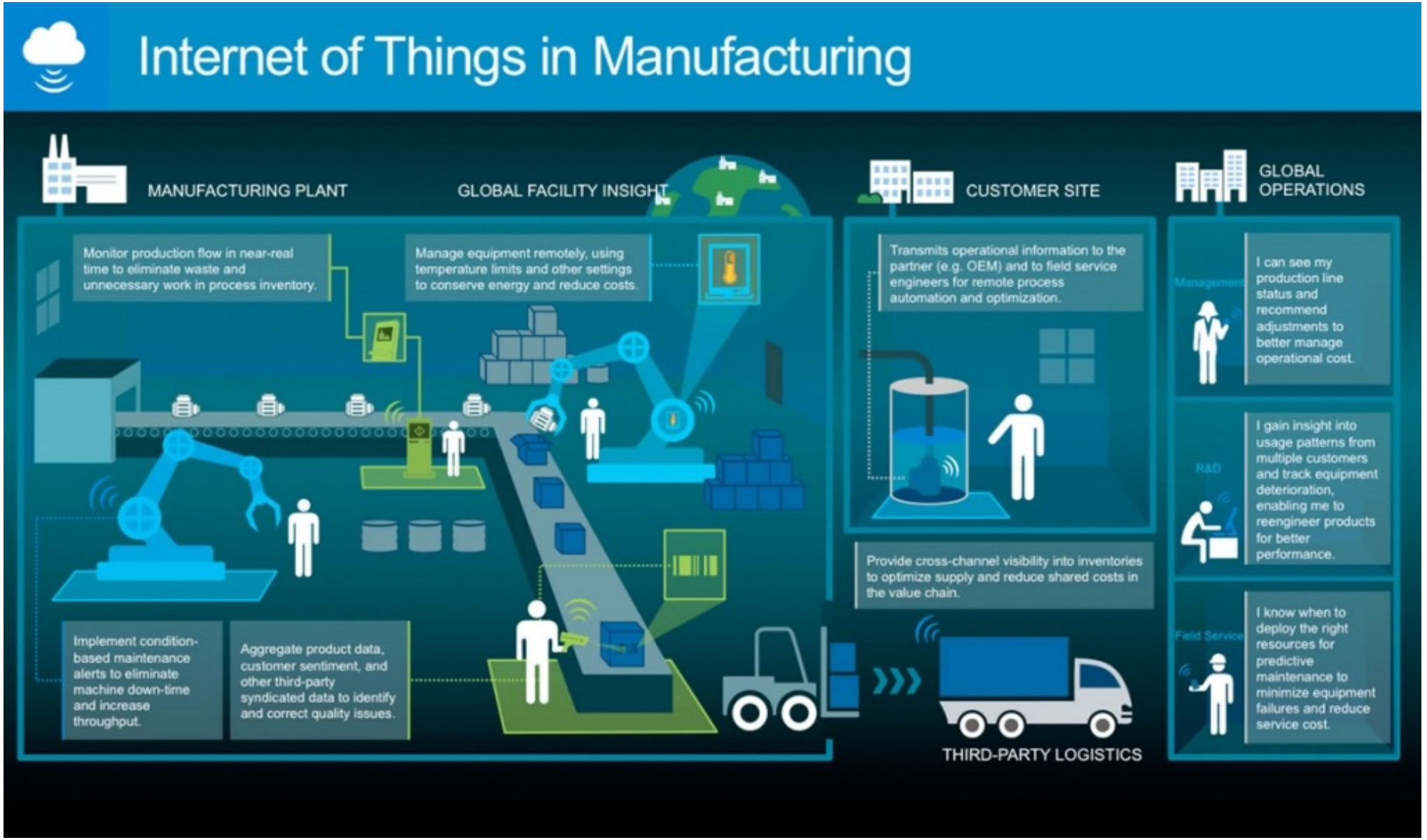
(a) Avocado (b) Rubra (c) Bull bay







Smart Manufacturing

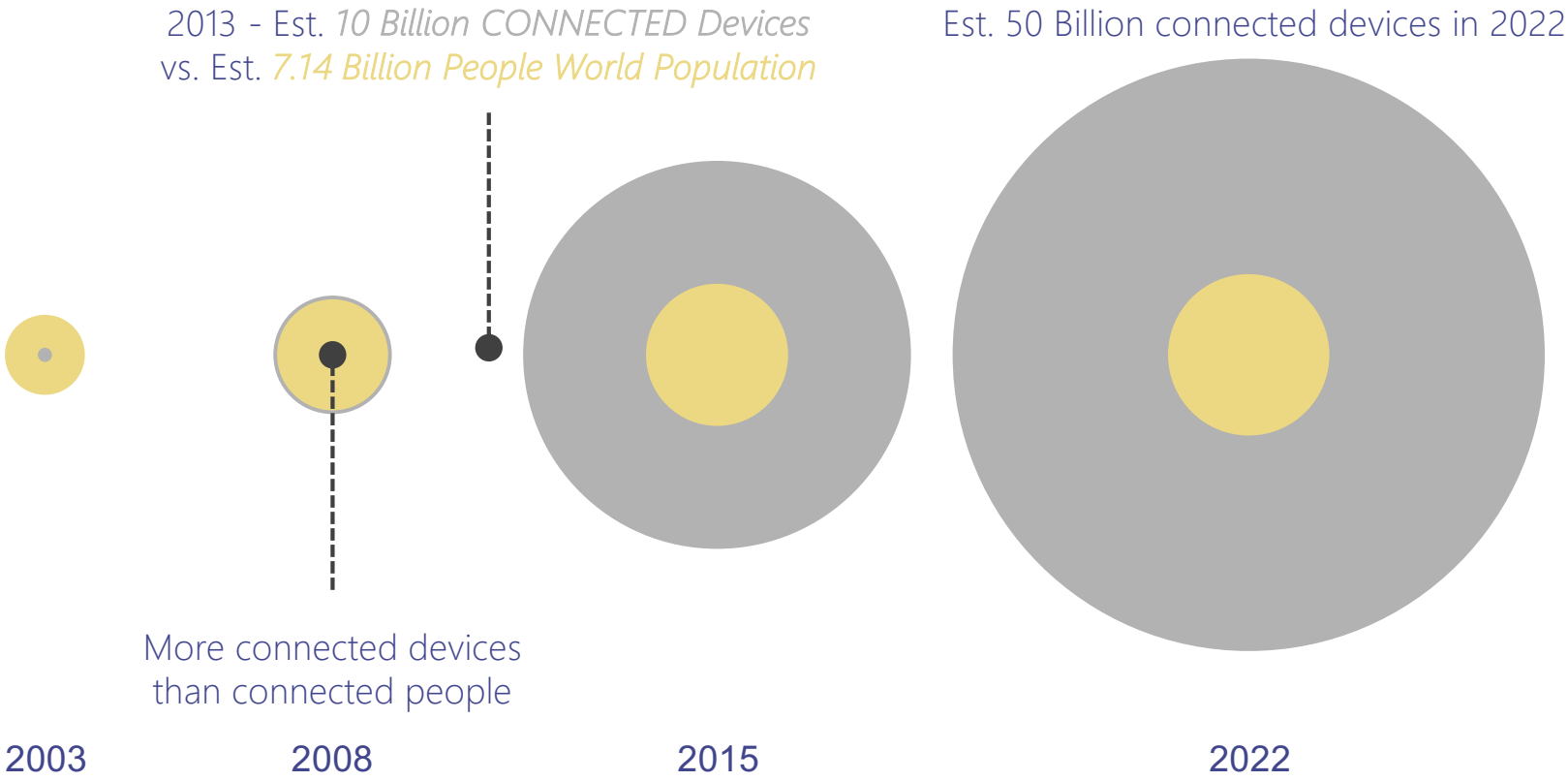



I THINK MY NEST SMOKE ALARM IS GOING OFF. GOOGLE ADWORDS JUST PITCHED ME A FIRE EXTINGUISHER AND AN OFFER FOR TEMPORARY HOUSING.
TOM FISH BURNE
© marketoonist.com

Outline

- How IoT will improve the world
- **How IoT will break the Internet**
  - **(…and what we are doing to fix it)**
- What to expect in this class

More Devices



Source: Cisco & Internet World Stats

IPv4 (32bit) address space

4,294,967,295
or
4.3 Billion Addresses

IPv6 (128bit) address space

340,282,366,920,938,463,463,374,607,431,768,211,456

or

340.3 Undecillion Addresses

More Traffic

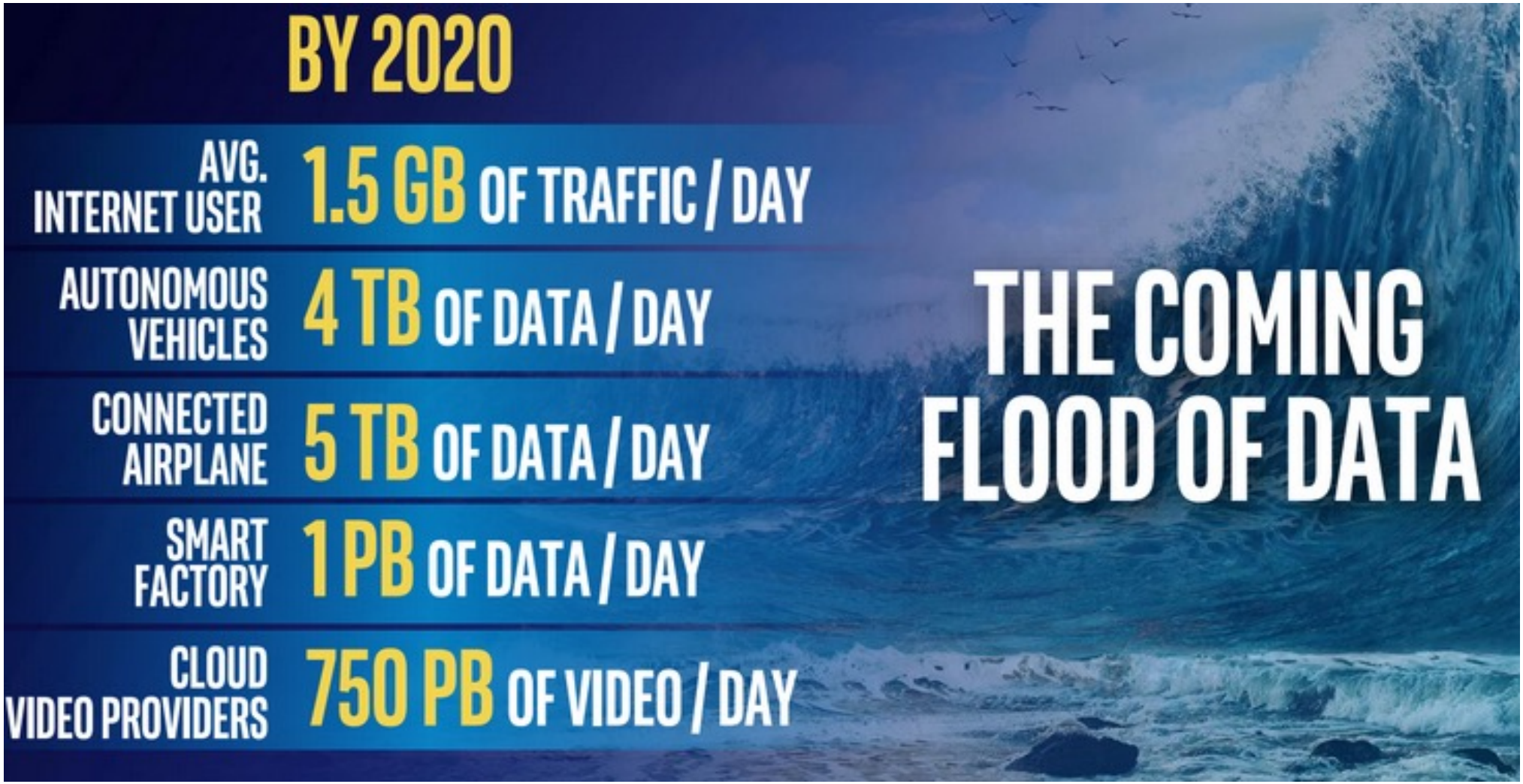
- Total IP Traffic on the global Internet:
  - 2003 – 1.8 Petabytes
  - 2007 - 161 Exabytes
  - 2009 - 487 Exabytes
  - 2010 - ½ Zettabyte
  - 2011—1 ZettaByte (540,000X increase from 2003)
- Expected to double over the next 18 months
- 2012 - 91% expected to be video traffic

A Zettabyte is a billion terabytes (250 billion DVDs)

"By 2011, 20 typical households will generate more traffic than the entire Internet did in 2008."

Jim Cicconi, VP, AT&T

Source: Cisco IBSG, 2006-2011, VentureBeat, IDC, C|Net, The Guardian, U.K.


BY 2020
AVG. INTERNET USER
1.5 GB OF TRAFFIC / DAY
AUTONOMOUS VEHICLES
4 TB OF DATA / DAY
CONNECTED AIRPLANE
5 TB OF DATA / DAY
SMART FACTORY
1 PB OF DATA / DAY
CLOUD VIDEO PROVIDERS
750 PB OF VIDEO / DAY
THE COMING FLOOD OF DATA

Giga, 16 Hours

Tera, 1.8 Years

Exa, 1913 Years

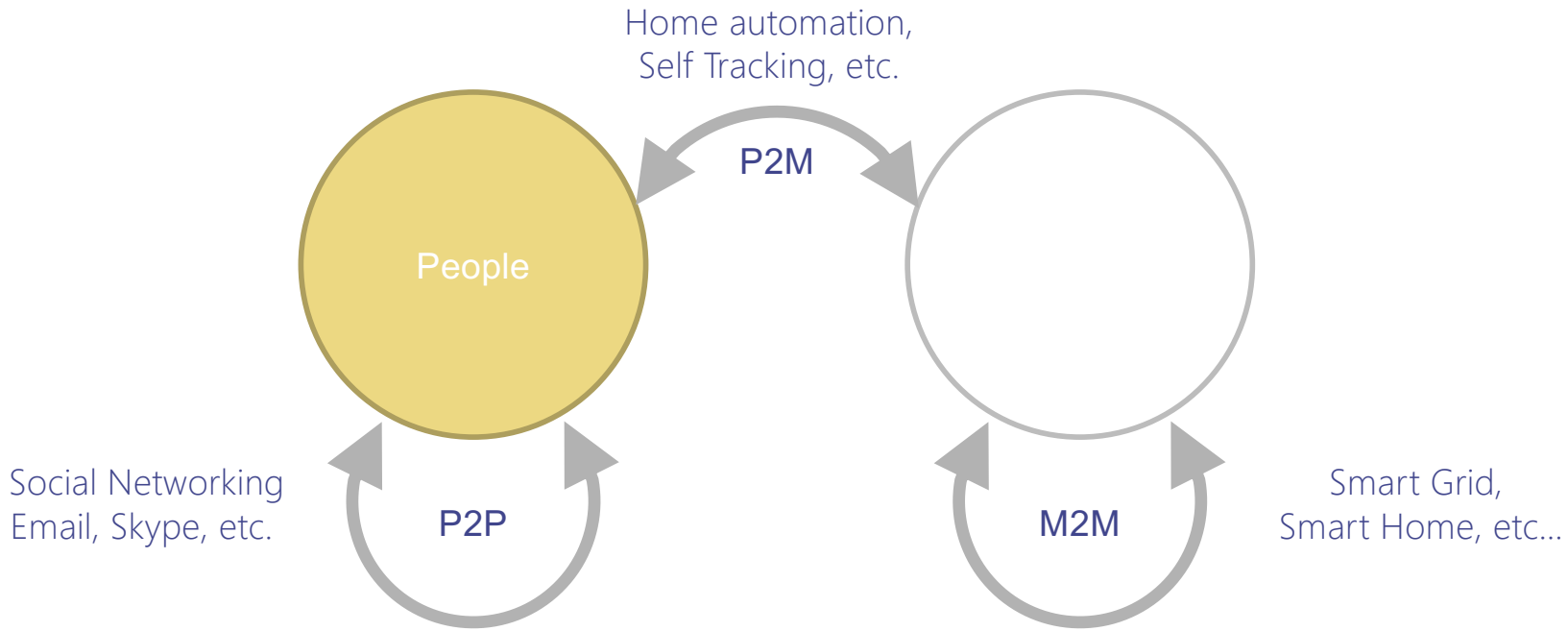
Peta, 1.9 Million Years

Zetta , 2 Billion Years

Yotta That's a "yotta" music!

If a one minute mp3 music file is about 1.1MB then…

New Connection Paths



Different Traffic Patterns






sensors

1/hour 1/minute 1/second 10/second

actuators


New Connectivity Models

dispersed	Smart grid, meter, city Remote monitoring	Car automation eHealth Logistics Portable consumer electronics
concentrated	smart home factory automation eHealth	on-site logistics
	fixed	mobile

Source: OECD (2012), "Machine-to-Machine Communications: Connecting Billions of Devices", *OECD Digital Economy Papers, No. 192, OECD Publishing*. http://dx.doi.org/10.1787/5k9gsh2gp043-en

New Networking Technologies

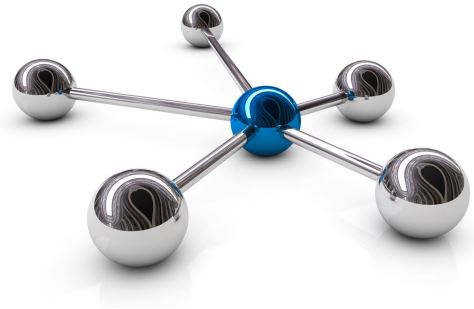
dispersed	PSTN Broadband 2G/3G/4G/5G Power line communications	2G/3G/4G/5G satellite
concentrated	wireless personal area networks wired networks indoor electrical wiring WiFi	WiFi LPWPAN
	fixed	mobile

Source: OECD (2012), "Machine-to-Machine Communications: Connecting Billions of Devices", *OECD Digital Economy Papers, No. 192, OECD Publishing*. http://dx.doi.org/10.1787/5k9gsh2gp043-en

Current IoT Ecosystems

- 3 Tiers:
  - Low-power IoT devices
  - Gateway (edge, fog)
  - Cloud

Centralization does not scale



- Centralised brokered communication models based on the client-server paradigm

- All devices are identified, authenticated and connected through cloud servers

- Often, two IoT devices sitting next to each other will communicate through the Internet

Why be concerned about IoT?

- It's just another computer, right?
  - All of the same issues we have with access control, vulnerability management, patching, monitoring, etc.
  - Imagine your network with 1,000,000 more devices
  - Any compromised device is a foothold on the network

Attacking IoT

- Default, weak, and hardcoded credentials
- **Difficult to update firmware and OS**
- Lack of vendor support for repairing vulnerabilities
- Vulnerable web interfaces (SQL injection, XSS)
- Coding errors (buffer overflow)
- Clear text protocols and unnecessary open ports
- DoS / DDoS
- **Privacy issues**
  - **Machine/deep learning**
- **Physical theft and tampering**

The DDoS Attack On Dyn DNS Was Carried Out Using Mirai Malware Botnet — Mirai Is A DDoS Nightmare Turning Internet Of Things (IoT) Into A Botnet Of Things.

Yesterday's DDoS attack on Dyn's DNS was like an earthquake that was felt worldwide when the top and most visited sites on the Internet went offline for hours. Although it is unclear who was behind this attack the security researchers are linking the Mirai DDoS botnet malware to this attack.

If you don't know what Mirai is then let us tell you. It is the same botnet that was behind the DDoS attacks on Krebs on security blog and the OVH hosting website a couple of weeks back. The attack on Krebs's website was 665 GBPS whilst OVH suffered Internet's largest ever DDoS attacks of 1 TBPS in which 145,000 hacked webcams were used.

Mirai uses Internet of Things (IoT) devices like routers, digital video records (DVRs), and webcams/security cameras, enslaving vast numbers of these devices into a botnet, which is then used to conduct DDoS attacks.

Source: Hackread, Oct 2016

Outline

- How IoT will improve the world
- How IoT will break the Internet
  - (…and what we are doing to fix it)
- **What to expect in this class**

Course Topics

- **Interfacing with the physical world:** sensors and actuators
- **Embedded systems:** MCU, sleep modes, interrupts, timers, clocks, event handlers, schedulers.
- **Networking:** Zigbee, Bluetooth Low Energy, RPL,6LowPAN, LPWAN
- **Web services:** CoAP, MQTT
- **Components:** time and location.
- **Data analytics**: signal processing, machine learning and data fusion.

Ground Rules

- No cheating
  - Failing grade for the class
  - Conform to academic honesty policies
  - No exceptions for group projects

Software for sensor programming

- Micropython on Arduino Nano 33 BLE sense

- Java on Android smartphones/glasses/watches
  - https://youtu.be/BjlPbqgBSuc?t=22

IoT - What's next

- You have learnt about
  - What is IoT
  - Applications
- We will take a bottom-up approach
  - Week 2, 3: Low power communications
  - Week 4: CoAP
  - …
- Some recurrent themes that you will see
  - Distributed cooperation
  - Energy efficiency
  - Dealing with resource constraint environment