

# Internet of Things

Module code: EEEM048/COM3023

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# Module Aims

- The main aim of this module is to introduce the fundamental concepts of the Internet of Things and its applications and architecture models;
- Introduction to the technologies and mechanisms for sensing, actuation, processing and cyber-physical data communication.
- Discussing semantic technologies, service oriented solutions and networking technologies that enable the integration of Internet of Things data and services into the cyber world (i.e. the Internet and the Web).
- To develop practical skills that can be transferred into a real-world environment.

Dr Payam Barnaghi, Dr Chuan H Foh  
Institute for Communication Systems  
Electronic Engineering Department  
University of Surrey



IBM Mainframe 360, source Wikipedia



Apollo 11 Command Module (1965) had 64 kilobytes of memory operated at 0.043MHz.

An iPhone 5s has a CPU running at speeds of up to **1.3GHz** and has **512MB to 1GB** of memory



Cray-1 (1975) produced 80 million Floating point operations per second (FLOPS)  
10 years later, Cray-2 produced 1.9G FLOPS

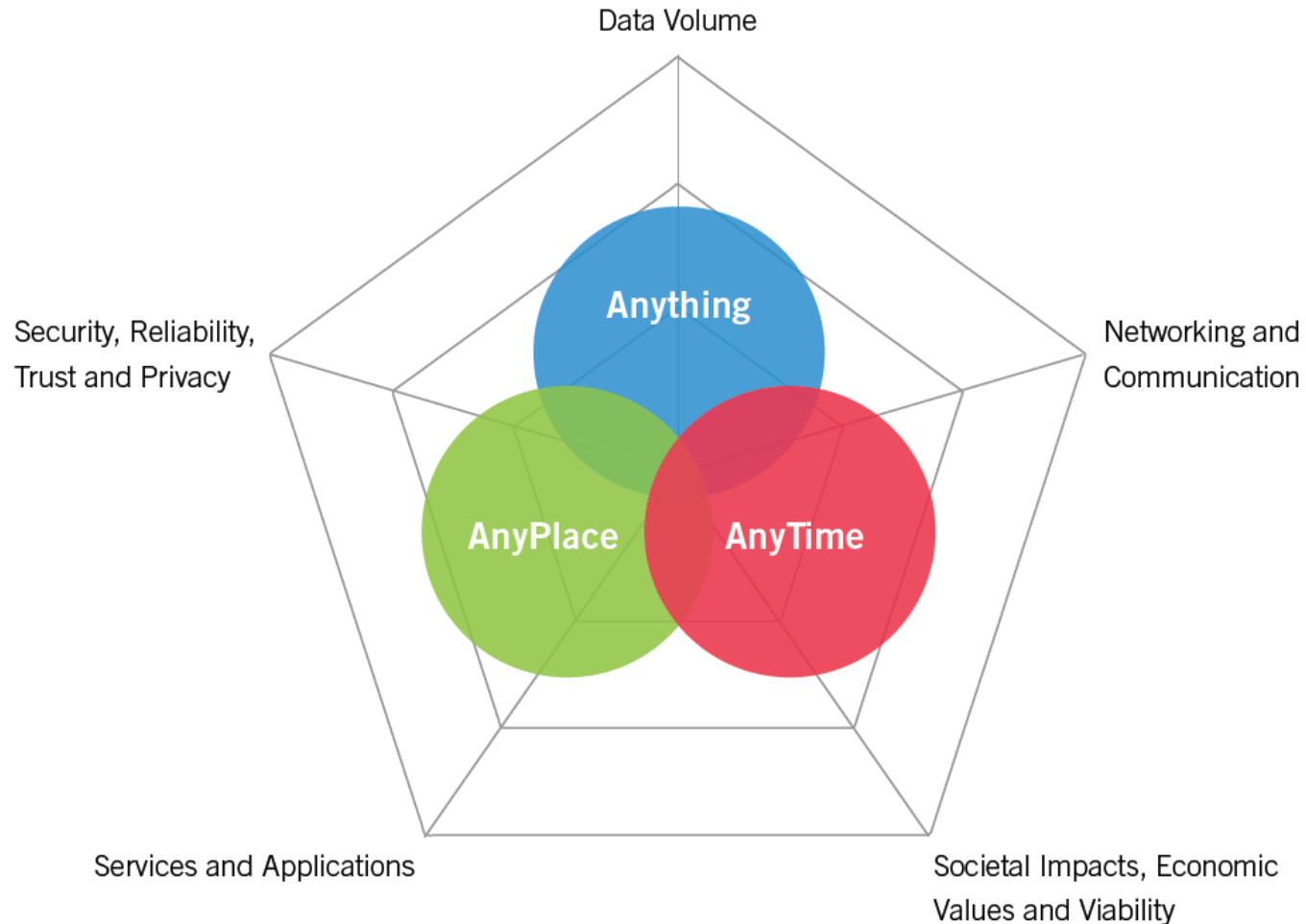
An iPhone 5s produces 76.8 GFLOPS – **nearly a thousand times more**

Cray-2 used 200-kilowatt power

# Computing Power

- Smaller size
- More Powerful
- More memory and more storage
- "Moore's law" over the history of computing, the number of transistors in a dense integrated circuit has doubled approximately every two years.

# Cyber-Physical-Social Data



IN  
**60**  
SECONDS...

1 **NEW**  
DEFINITION  
IS ADDED ON  
UPDAN

1,600+  
READS ON  
**Scribd.**

13,000+ HOURS  
**MUSIC**  
STREAMING ON  
PANDORA

12,000+  
NEW ADS  
POSTED ON  
craigslist

370,000+ MINUTES  
VOICE CALLS ON  
**skype**

98,000+  
TWEETS

20,000+  
NEW  
POSTS ON  
tumblr.

THE  
LARGEST  
SOCIAL READING  
PLATFORM (GOODREADS)

320+  
NEW  
twitter  
ACCOUNTS

100+  
NEW  
LinkedIn  
ACCOUNTS

THE  
WORLD'S  
LARGEST  
COMMUNITY  
CREATED CONTENT!!

1 **NEW**  
ARTICLE IS  
PUBLISHED

QUESTIONS  
ASKED ON THE  
INTERNET...

100+  
Answers.com  
40+  
YAHOO! ANSWERS

6,600+  
NEW  
PICTURES ARE  
UPLOADED ON  
**flickr**

600+  
NEW  
VIDEOS



50+  
WORDPRESS  
DOWNLOADS

25+ HOURS  
TOTAL  
DURATION

70+  
DOMAINS  
REGISTERED

60+  
NEW  
BLOGS

168 MILLION  
EMAILS  
ARE SENT

694,445  
SEARCH  
QUERIES

1,700+  
Firefox  
DOWNLOADS

695,000+  
facebook  
STATUS  
UPDATES

125+  
PLUGIN  
DOWNLOADS

1,500+  
BLOG  
POSTS

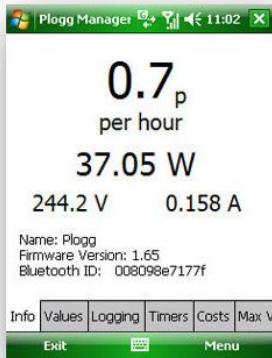
79,364  
WALL  
POSTS

510,040  
COMMENTS



# Sensor devices are becoming widely available

- Programmable devices
- Off-the-shelf gadgets/tools



**Linker Intel Group**



**Image Sensor Device**



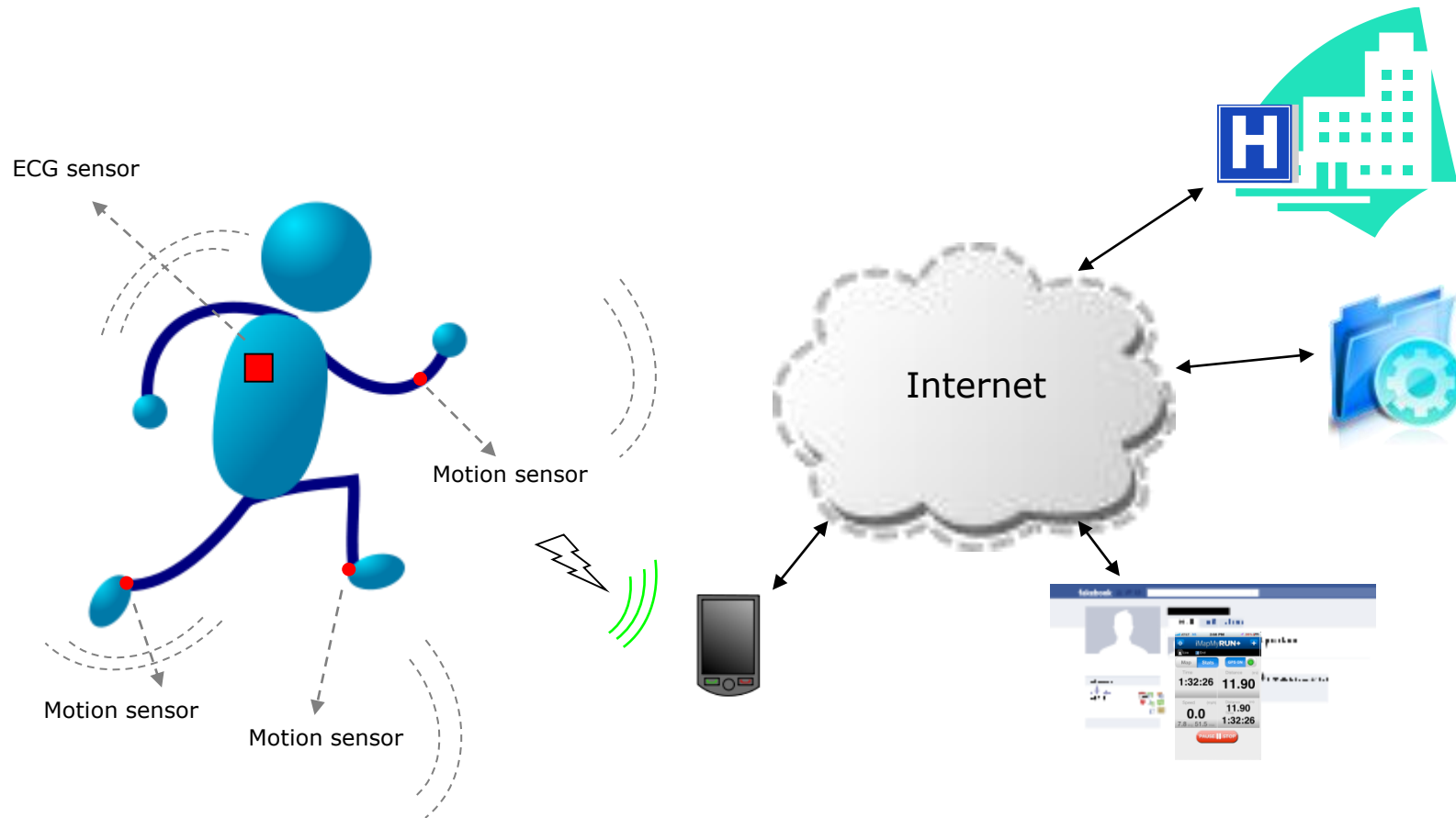
# More "Things" are being connected

Home/daily-life devices  
Business and  
Public infrastructure  
Health-care

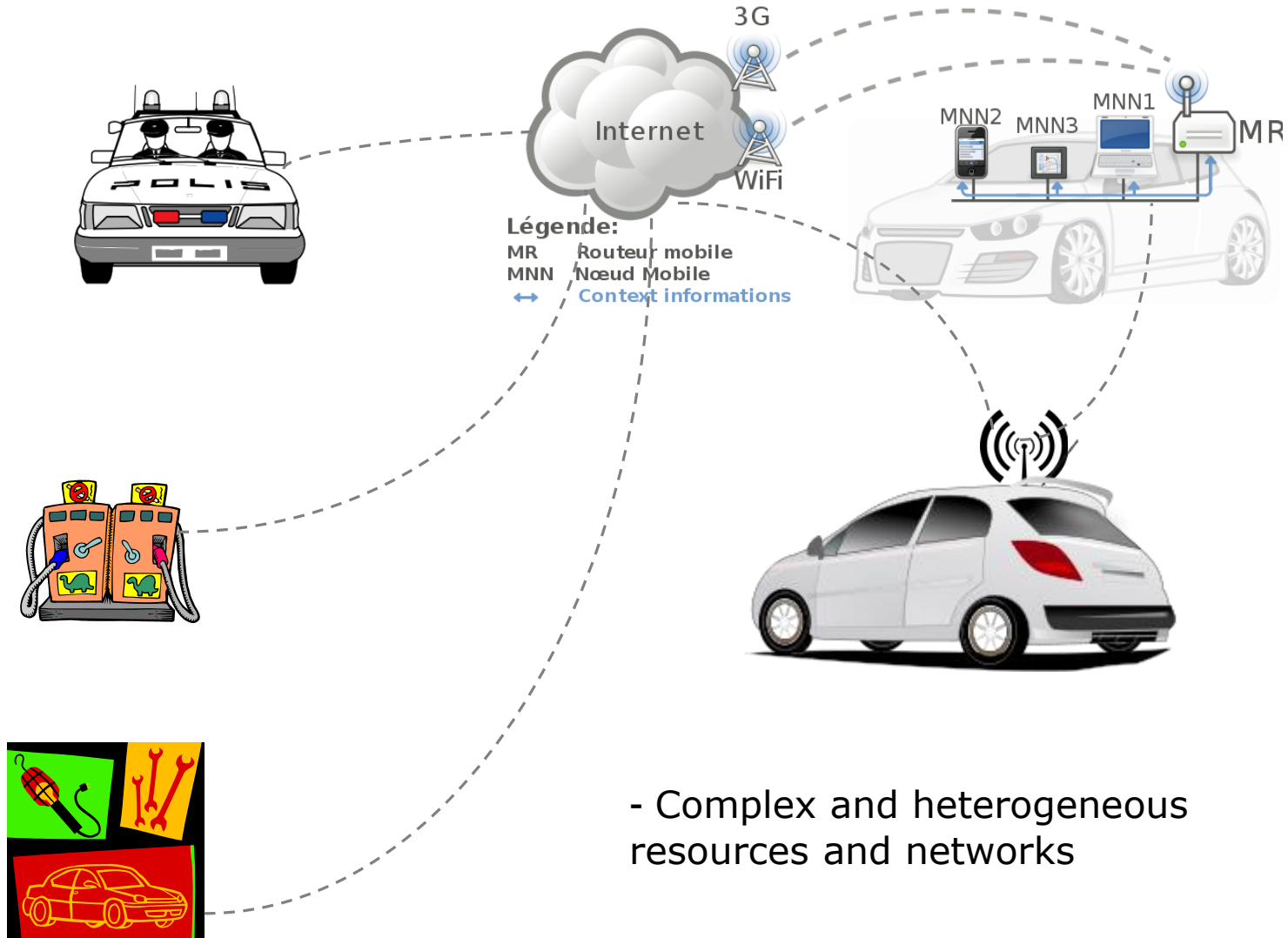
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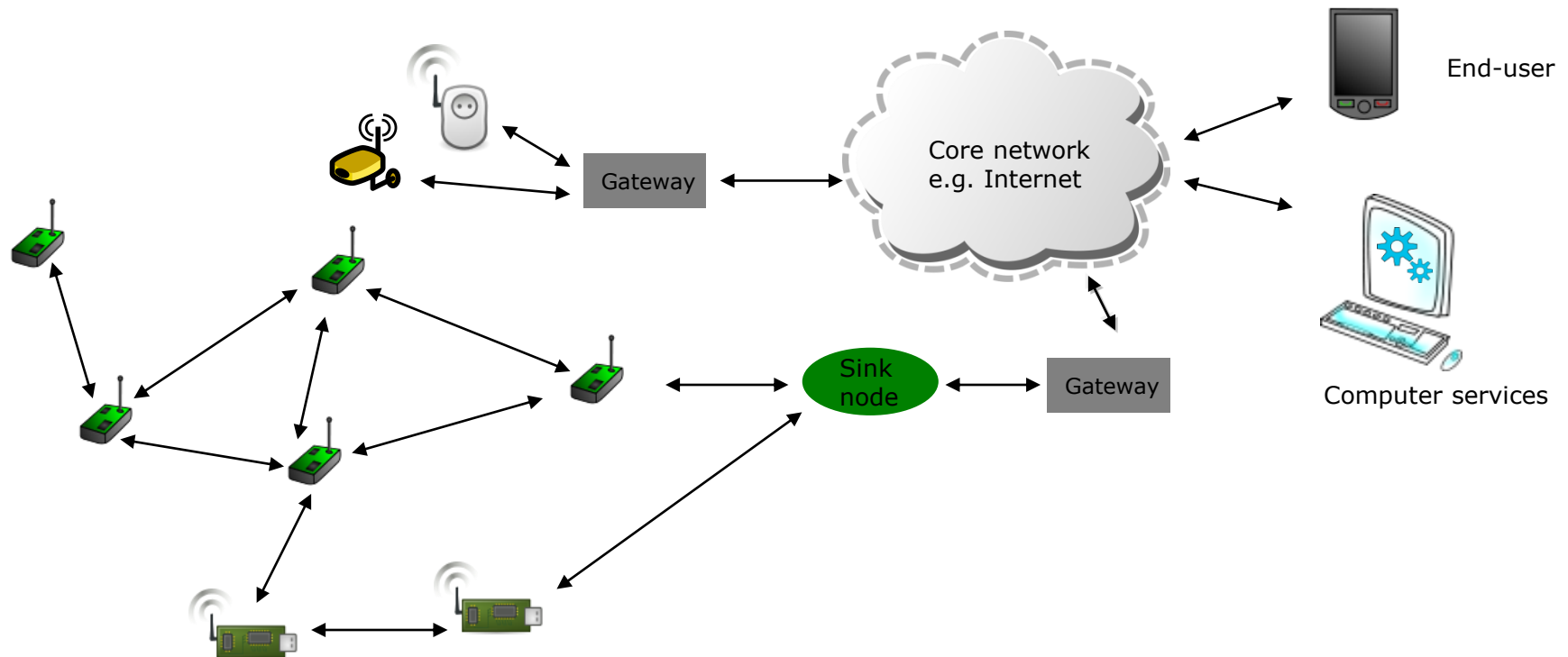
# People Connecting to Things



# Things Connecting to Things



# Wireless Sensor Networks (WSN)

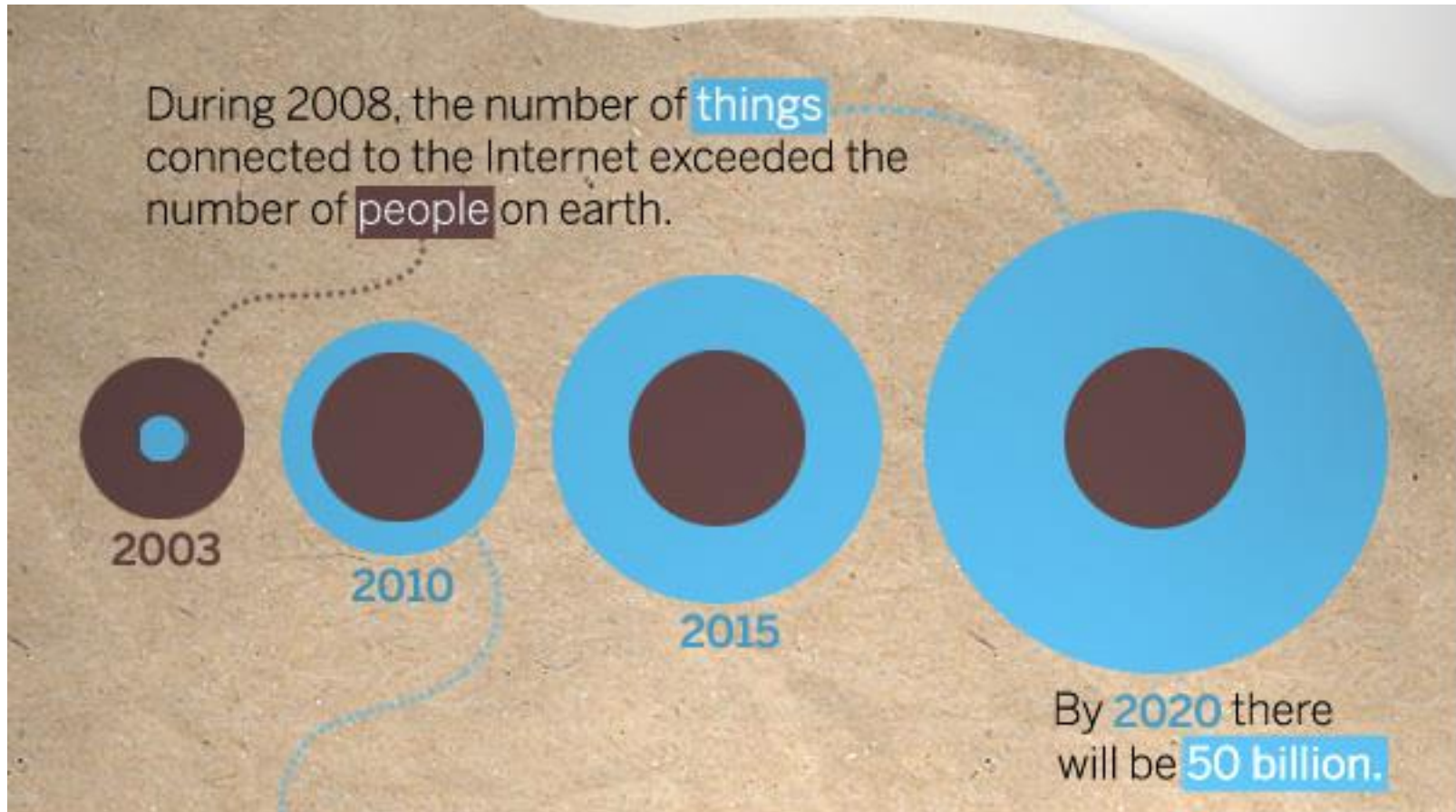


- The networks typically run Low Power Devices
- Consist of one or more sensors, could be different type of sensors (or actuators)

# How are the networks changing?

- Extensions
  - More nodes, more connections
  - Any **TIME**, Any **PLACE** + Any **THING**
  - M2M, IoT
    - Billions of interconnected devices,
    - Everybody is connected.
- Expansions
  - Broadband
  - LTE, 5G
- Enhancements
  - Smart networks
  - Data-centric and content-oriented networking
  - Context-aware (autonomous) systems

# “Thing” connected to the internet



Sources: Cisco IBSG, Jim Cicconi, AT&T, Steve Leibson, Computer History Museum, CNN, University of Michigan, Fraunhofer

Source: CISCO

# Internet of Things (IoT)

- Extending the current Internet and providing connection, communication, and inter-networking between devices and physical objects, or "Things," is a growing trend that is often referred to as the *Internet of Things*.
- “The technologies and solutions that enable integration of real world data and services into the current information networking technologies are often described under the umbrella term of the Internet of Things (IoT)”

# Why should I learn about IoT?

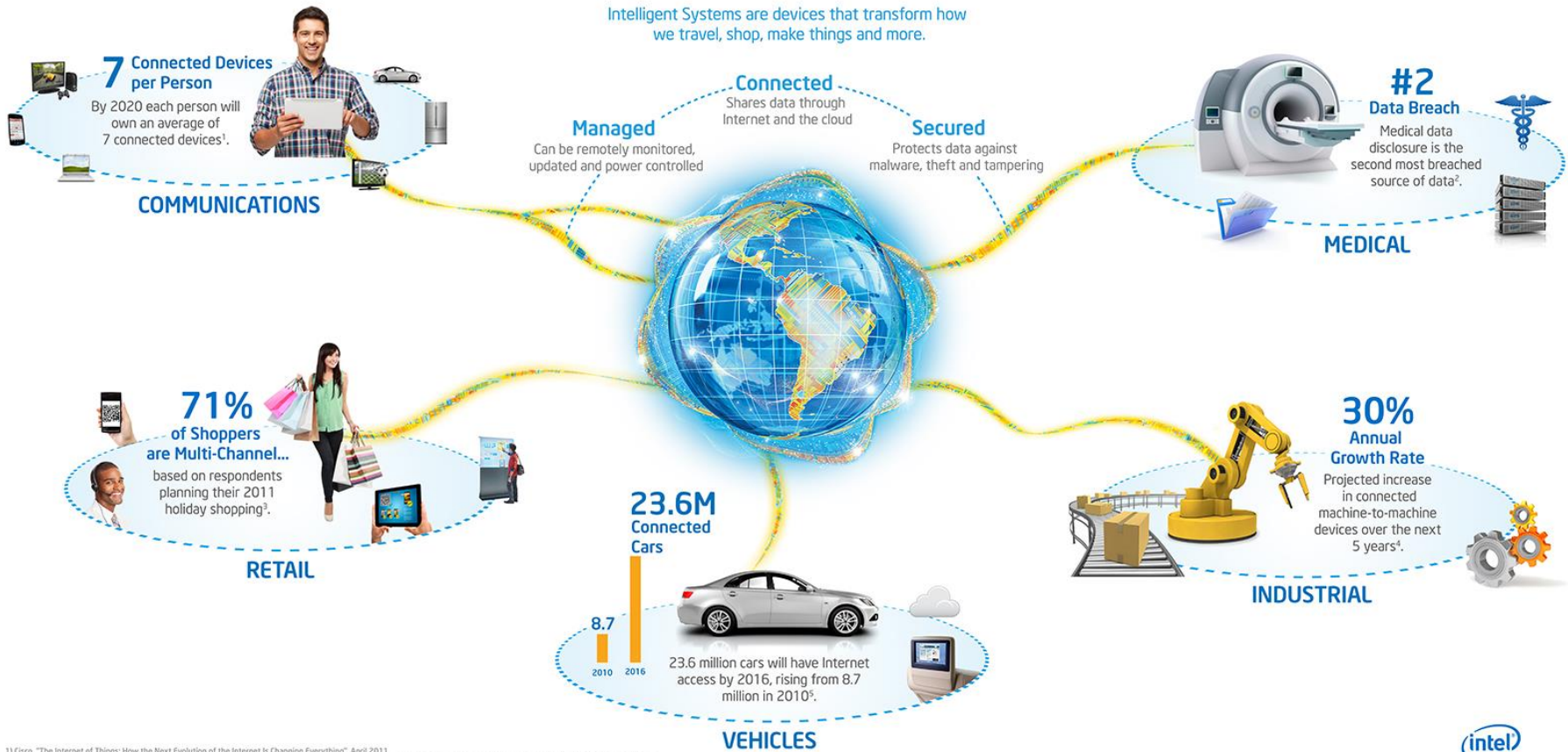
- Emerging technologies
- Growing IoT Services and Applications in various areas including smart cities, healthcare, transport, logistics, retail, safety and security, etc.
- Business trends and new opportunities

# Opportunities

## Intelligent Systems for a More Connected World

### WHAT ARE INTELLIGENT SYSTEMS?

Intelligent Systems are devices that transform how we travel, shop, make things and more.



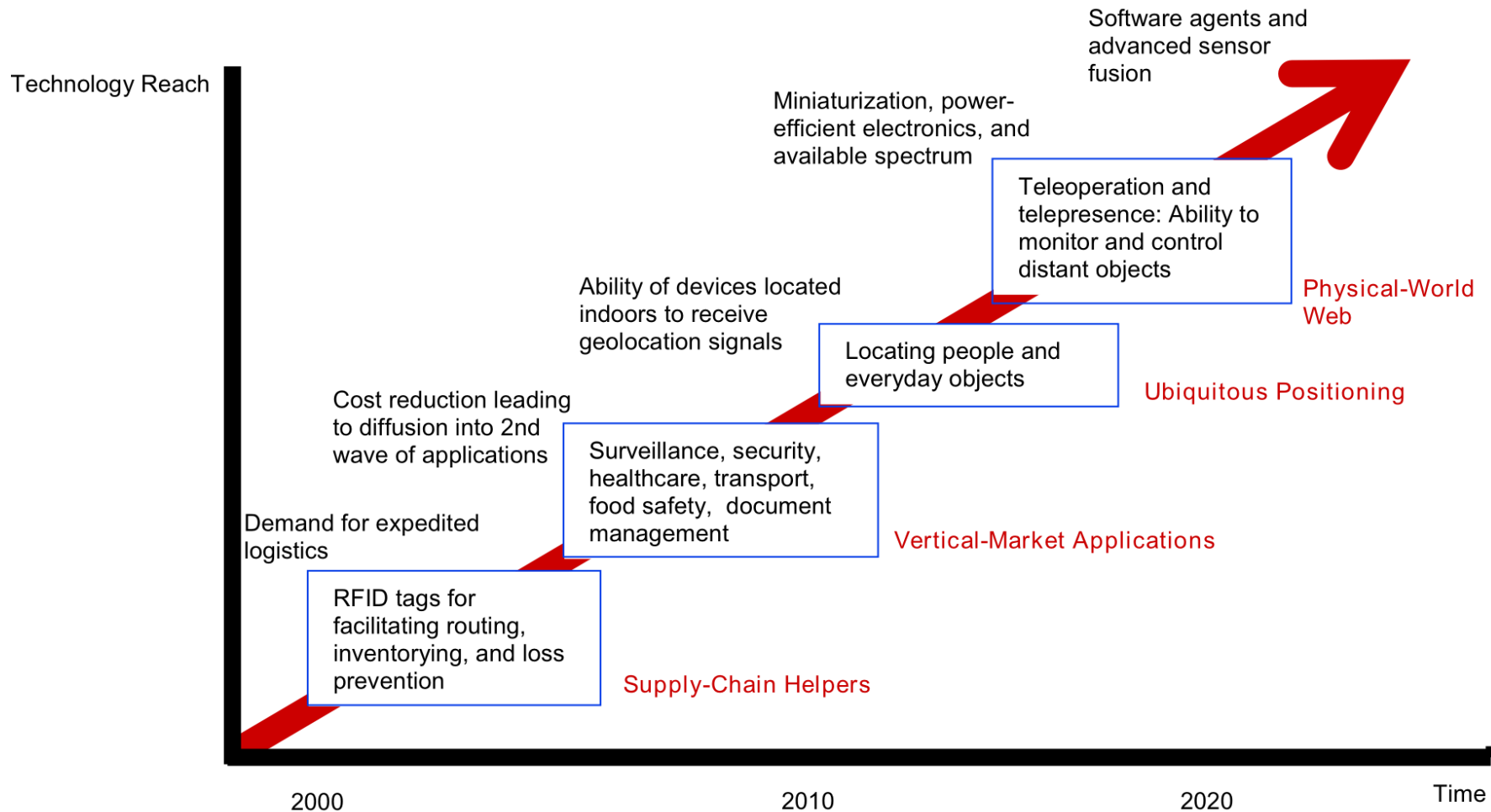
1) Cisco, "The Internet of Things: How the Next Evolution of the Internet is Changing Everything", April 2011  
 2) Bloor Research, "Security challenges in the US healthcare sector" White Paper, December 2010, <http://www.mcafee.com/us/resources/white-papers/wp-bloor-healthcare-security.pdf>  
 3) Deloitte U.S., 2011 Annual Holiday Survey, [http://www.deloitte.com/assets/Com-United-States/Local/20Assets/Documents/Consumer%20Business/us\\_retail\\_AnnualHolidaySurvey\\_2011\\_pr\\_102611.pdf](http://www.deloitte.com/assets/Com-United-States/Local/20Assets/Documents/Consumer%20Business/us_retail_AnnualHolidaySurvey_2011_pr_102611.pdf)  
 4) McKinsey Global Institute analysis, "Big data: The next frontier for innovation, competition, and productivity", June 2011  
 5) Wall Street Journal, <http://online.wsj.com/article/SB10001424052702304066504576349763614933844.html>, estimate from research firm, Frost & Sullivan

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# Technology trend

## TECHNOLOGY ROADMAP: THE INTERNET OF THINGS

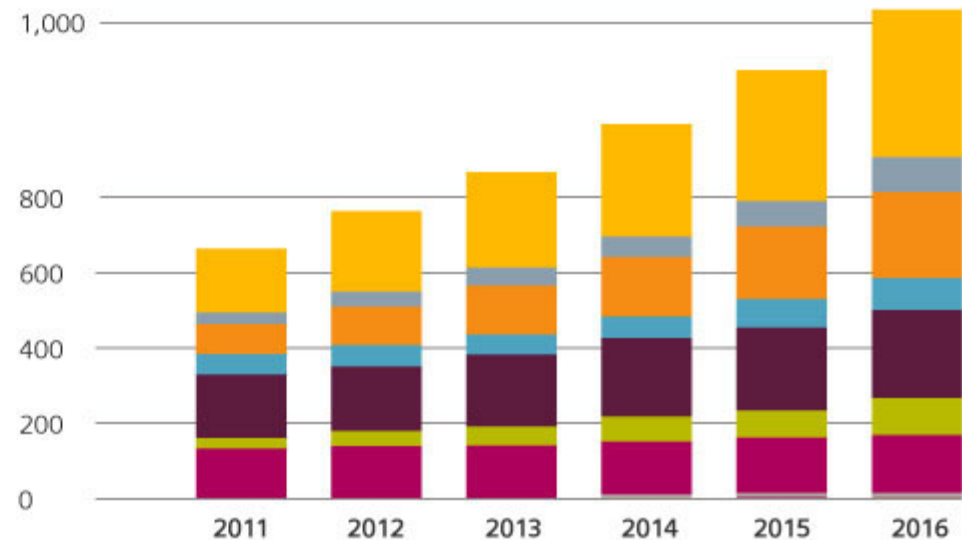


Source: SRI Consulting Business Intelligence

# Smart product sales

Smart Product Sales by Market in 2016 \$ billion

- Smart security
- Smart transportation
- Smart education
- Smart healthcare
- Smart industrie automation
- Smart energy (grid)
- Smart buildings
- Smart homes

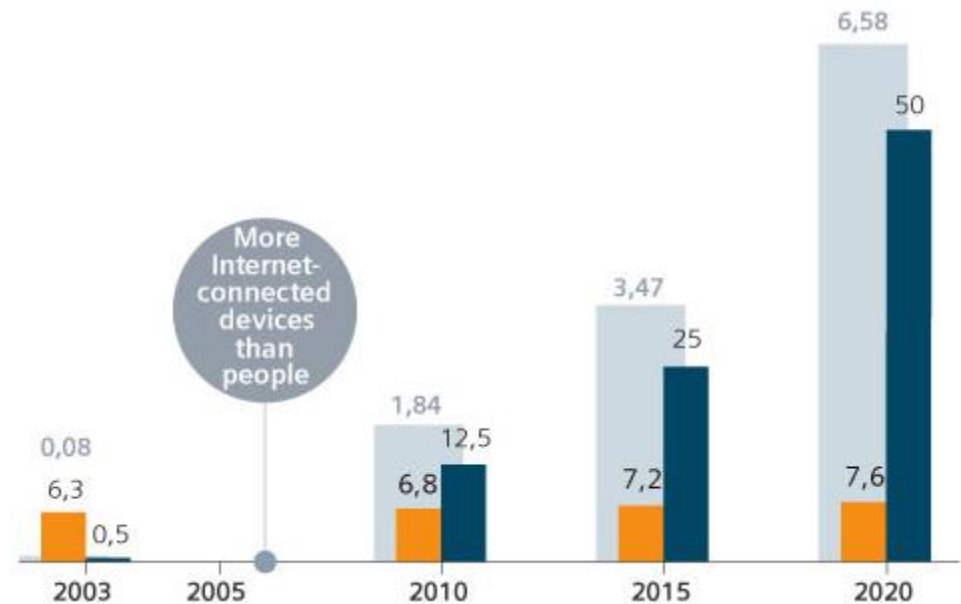


Source: MarketsandMarkets Analysis, 2012

# Internet Connected devices

## Growth in Internet-Connected Devices by 2020

- World population (in billions)
- Internet-connected devices in (billions)
- Internet-connected devices per person



Source: Cisco IBSG, April 2011

# Global Data Generation

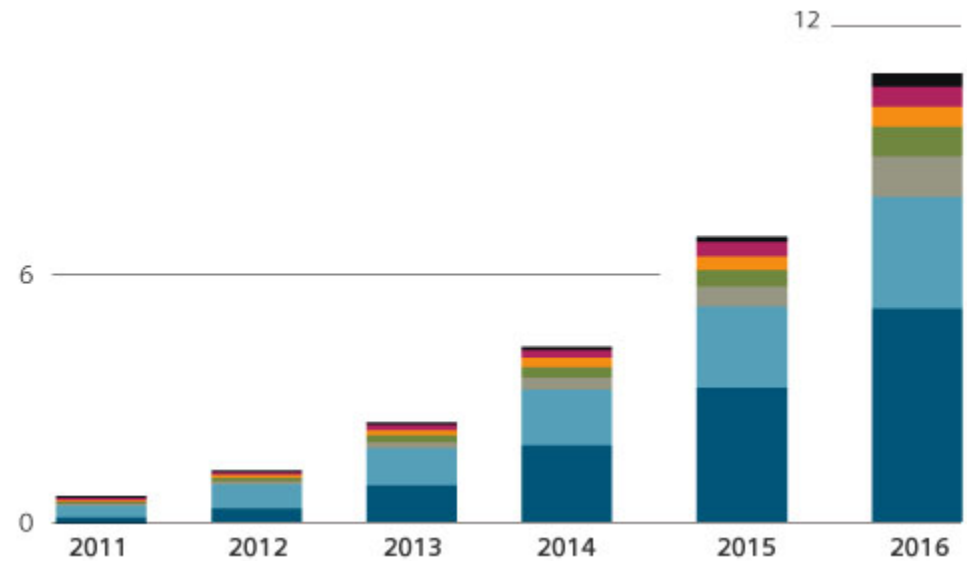
- Everyday around 20 quintillion ( $10^{18}$ ) bytes of data are produced (Source: <http://www-01.ibm.com/software/data/bigdata/>).
- This data includes textual content (unstructured, semi-structured, structured) to multimedia content (images, video and audio), on a variety of platforms (enterprise, social media, and sensors).

# Data Generation

## Global Data Generation

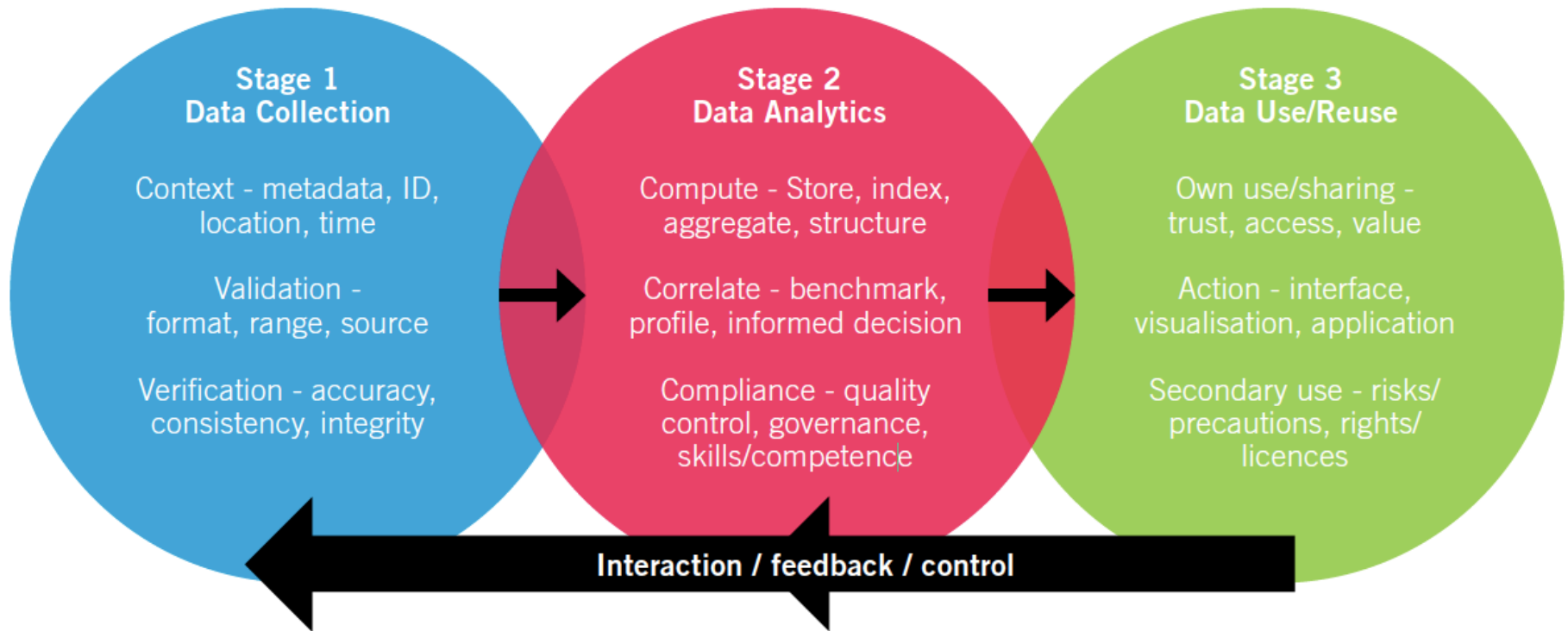
- Other mobile devices
- Machine-to-machine M2M
- Home gateways
- Non-smartphones
- Tablet PCs
- Laptop and netbooks
- Smartphones

## Extrabytes (quintillion bytes) per month



Source: Cisco VNI Mobile, 2012

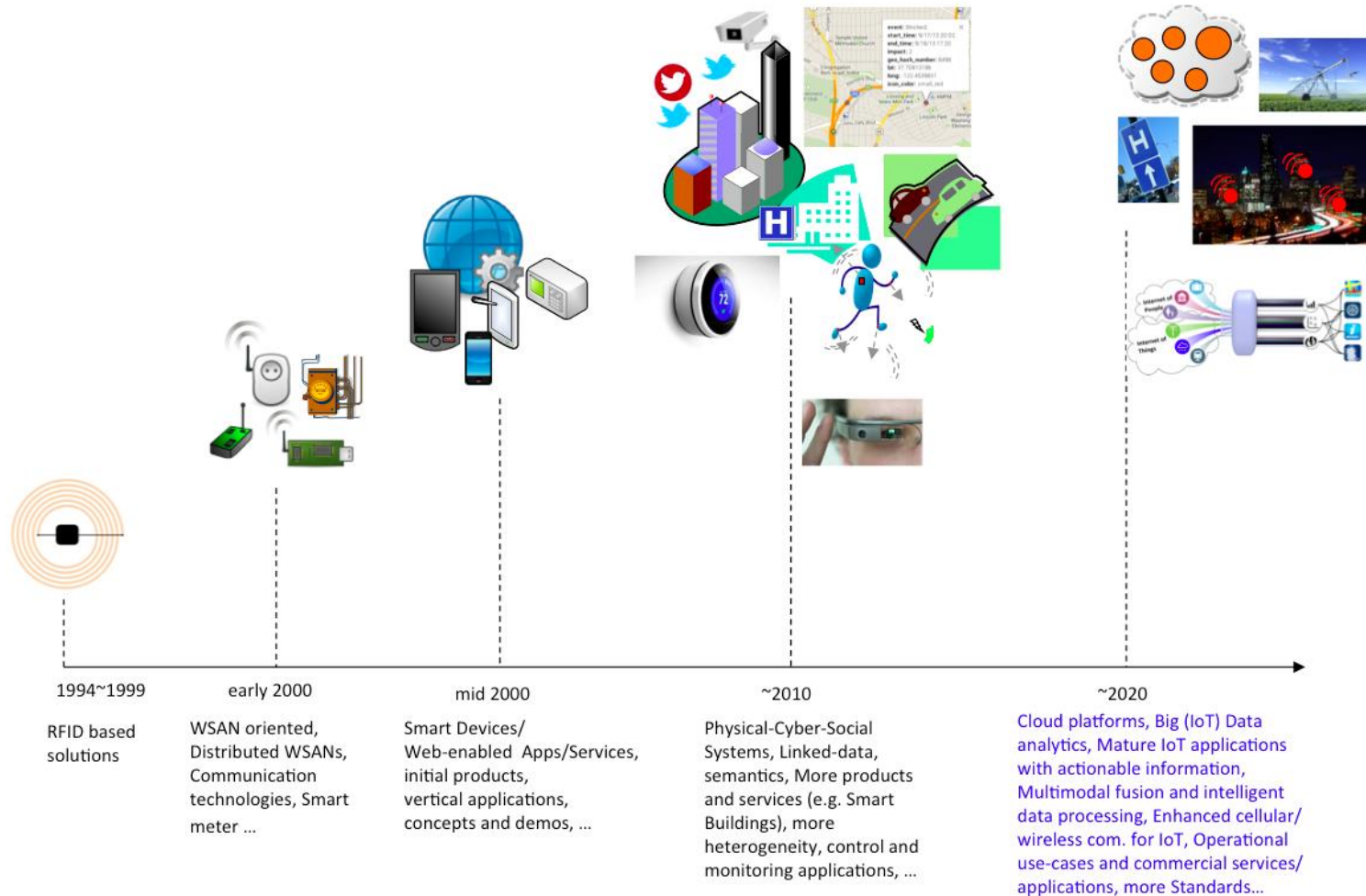
# Data Lifecycle



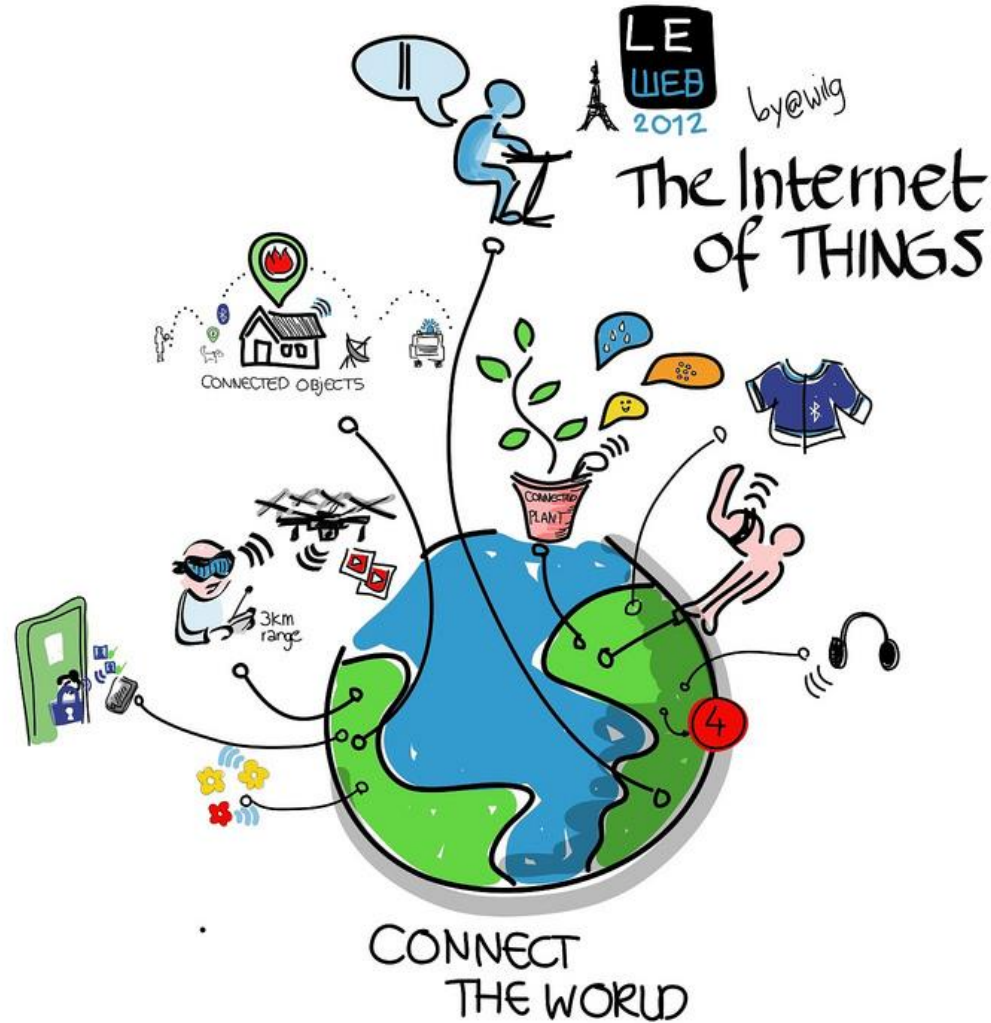
*“The ultimate goal is transforming the raw data to insights and actionable knowledge and/or creating effective representation forms for machines and also human users and creating automation.”*

*This usually requires data from multiple sources, (near-) real time analytics and visualisation and/or semantic representations.*

# Internet of Things



# Internet of Things Module



# Topics

- Cyber-Physical systems, smart devices, sensors and actuators
- Key applications, protocols and architectures
- Networks and Communications (Wireless Multi-hop Networks (WMN), Mobile Ad-hoc Networks (MANET), Wireless Sensor Networks (WSN))
- Reliability, Security, Privacy and Trust issues and solutions
- Software platforms and services
- Intelligent Data Processing and Semantic technologies
- Connecting Things to the Web (Web of Things)
- Applications, system models, Standards, and Physical-Cyber-Social systems (invited industry speaker?)

# Module Teaching

- Dr Chuan H Foh: Hardware Platforms, Networking and Security
- Dr Payam Barnaghi: Software and Services, Data Processing, Applications
- 3 hours (Lecture + Lab)
  - Lecture room: 35 AC 04
  - Lab: Duck/Swan/Whale Lab (2<sup>nd</sup>/3<sup>rd</sup> Floor, BB Building)
  - Tuesdays, 9:00am to 12:00noon

# Assessment

- Written Exam (60%)
- Coursework (40%)
  - Coursework
    - Lab exercises
      - Lab exercises will be done during the lab hours
    - Written report
      - Will include an essay (details will be provided)- the essay will be maximum 3 pages (including references).

# Pre-requisites

- We expect you are familiar with hardware systems.
- We expect you know about basic communication and networking.
- We expect you have a knowledge of the object oriented programming (especially C).

# Module Web Link

- All the slides and additional material will be uploaded to SurreyLearn
  - <http://surrylearn.surrey.ac.uk>

# Some of the related material

## – Reading List:

- <http://aspire.surrey.ac.uk/lists/35640FC8-892D-E309-E66C-F07C3D9BCB28.html>

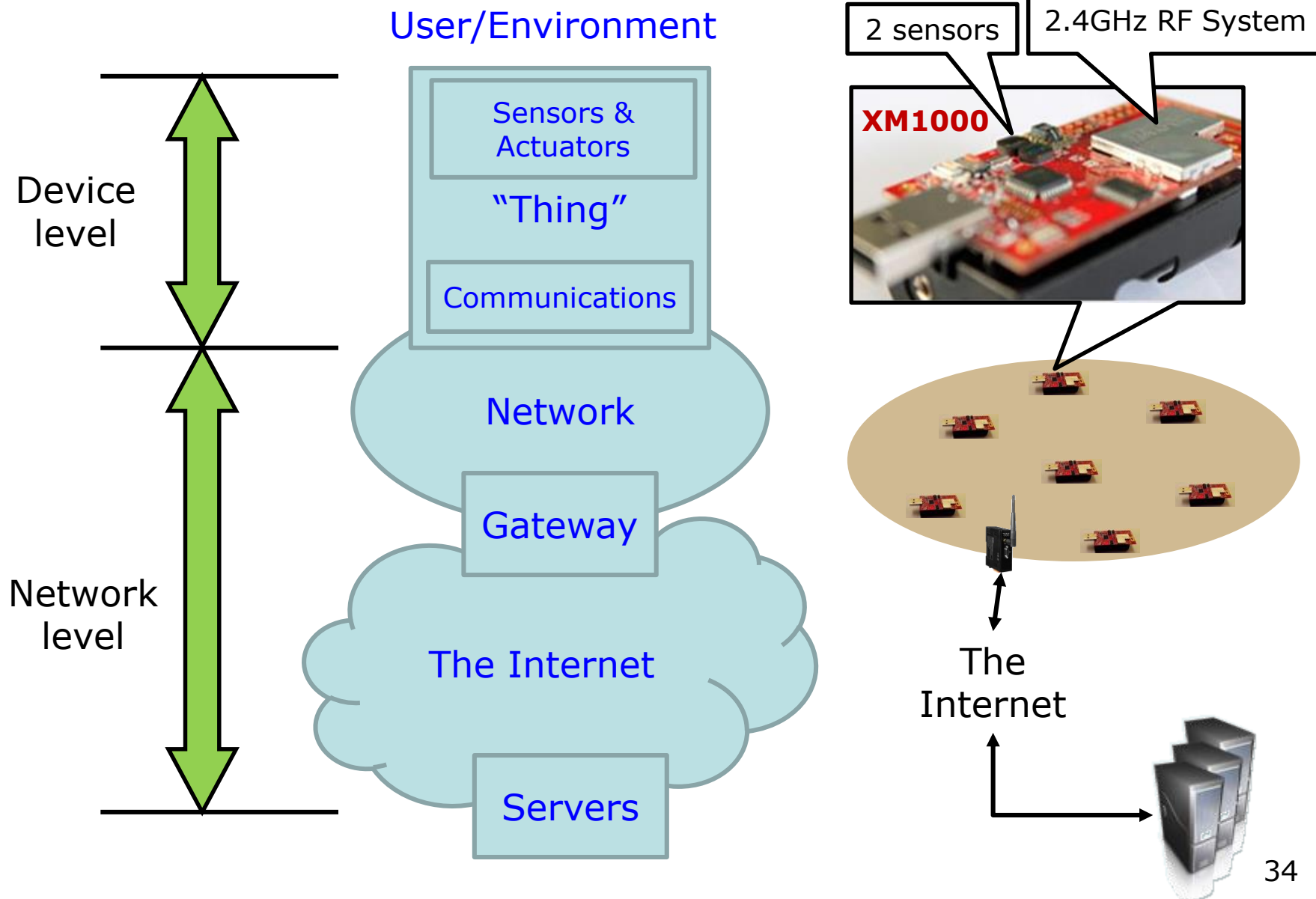
## Topics to be covered

Dr Chuan H Foh: Hardware Platforms,  
Networking and Security

Office: 5GIC Building- 07-CII-02

Email: [c.foh@surrey.ac.uk](mailto:c.foh@surrey.ac.uk)

# Overview: Hardware Platform



# Sensors & Actuators

- Sensors:
  - They are mainly input components
  - They sense and collect surrounding information
  - Basically three types:
    - Passive, omnidirectional (e.g. mic)
    - Passive, narrow-beam sensor (e.g. PIR)
    - Active sensors (e.g. sonar, radar, etc.)
- Actuators:
  - They are mainly output components
  - They alter the surrounding. Some examples:
    - Adding lighting, heat, sound, etc.
    - Controlling motors to move objects
    - Displaying messages
    - and others...

# Things

- We can turn almost every object into a “thing”.
- A “thing” still looks much like an embedded system currently.
- A “thing” generally consists of four main parts:
  - Sensors & actuators
  - Microcontroller
  - Communication unit
  - Power supply
- A “thing” has the following properties:
  - It’s usually powered by battery. This implies limited source of energy.
  - It’s generally small in size and low in cost. This limits their computing capability.
  - It doesn’t usually perform complicated tasks.
- Power consumption is the main design issue.

# Communications

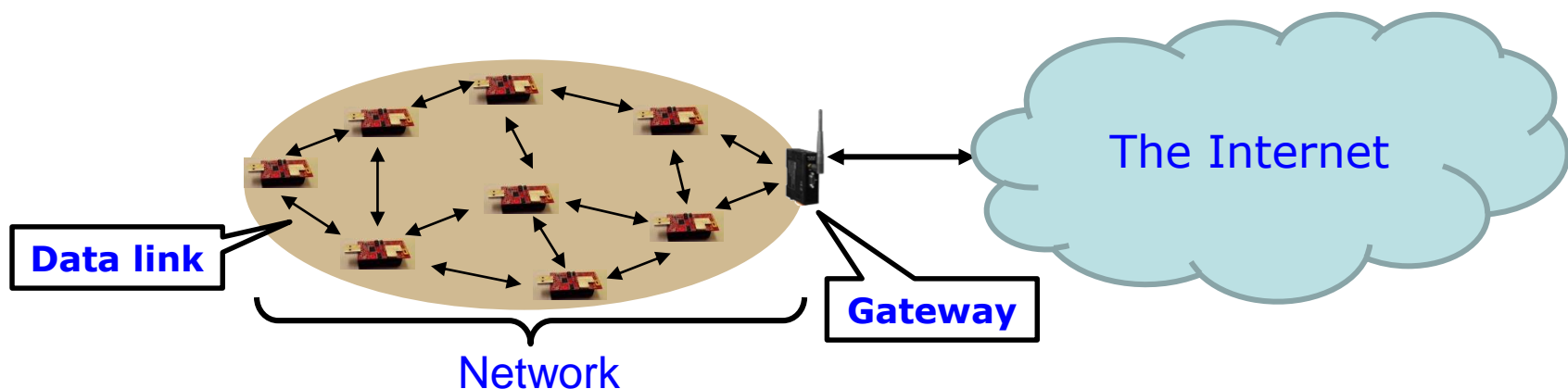
- A “thing” always feature communications for “team working”
- The Role of Communications
  - Providing a data link between two nodes
- Communication type:
  - Wireline (e.g. copper wires, optical fibers)
  - Wireless (e.g. RF, IR). RF-based communication is the most popular choice (and also our focus)
- Popular RF-based communication solutions:
  - IEEE 802.15.4 ← used in XM1000
  - IEEE 802.11 (or Wifi)
  - Bluetooth
  - Near Field Communication (NFC), e.g. RFID

# Networks

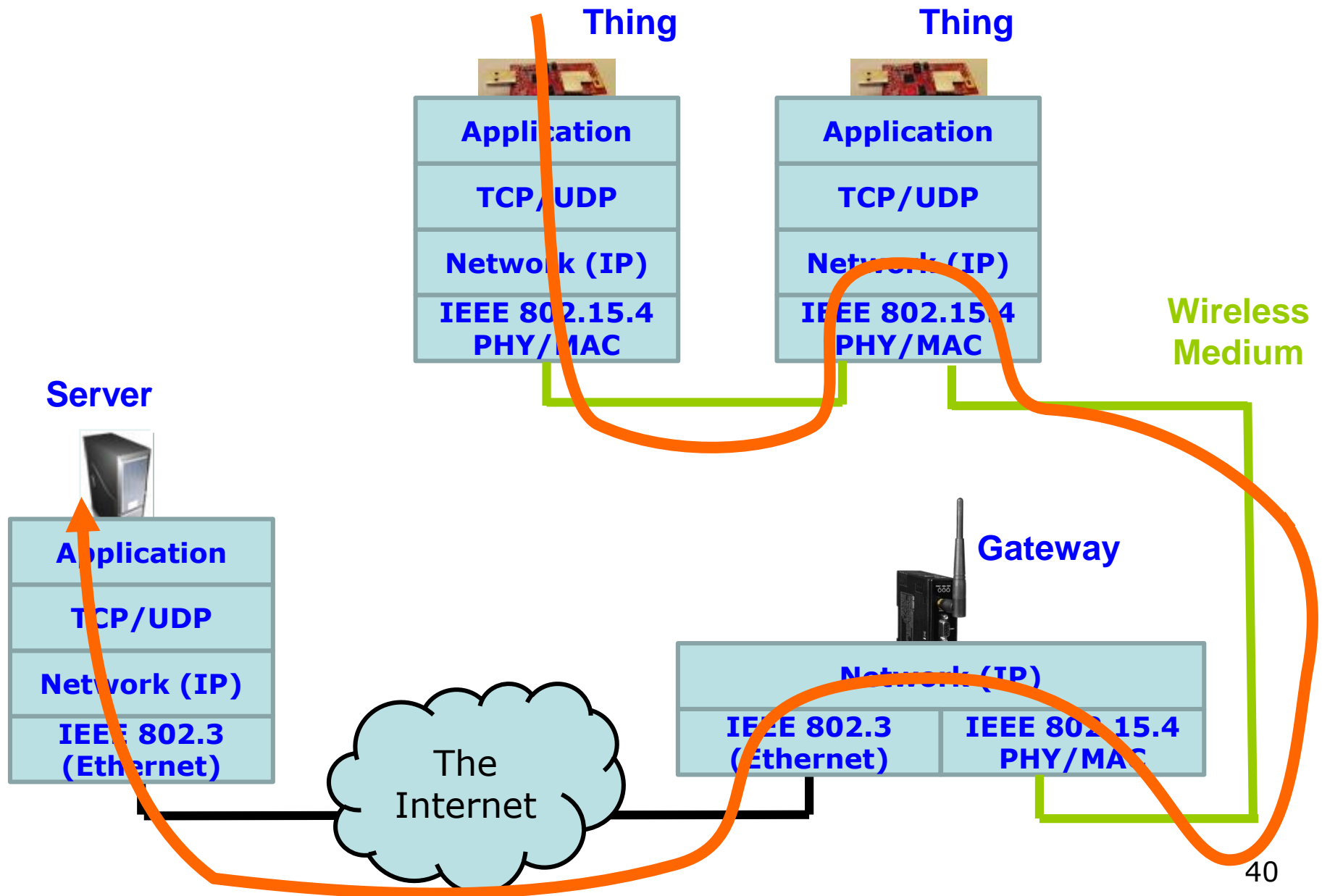
- The Roles of Networks
  - Managing nodes (discovery, join, leave, etc).
  - Relaying data packets from the source to the destination node in the network.
- Networks are a distributed system. All nodes need to perform networking related tasks.
- RF-based Network in IoT is usually a Wireless Multi-hop Network. Some examples:
  - Wireless Sensor Networks (WSNs)
  - Mobile Wireless Ad hoc Networks (MANETs)
  - Wireless Mesh Networks (WMNs)
  - Vehicular Ad Hoc Networks (VANETs)
  - and others...
- Main concern: Reliability & Performance

# The Internet

- The Internet serves as a wide area networking for a local network.
- The Internet uses TCP/IP. This implies that things must also support TCP/IP.
- Gateway (or sink)
  - For a practical deployment, a gateway is often needed in a network.
  - It offers relaying packets between the network and the Internet.



# Protocol Stack



# Security & Privacy

- Are they important?
- What is the risk?
- What are the challenges?
  - Device level
  - Network level
  - System level
  - User level
- Solutions?

## Topics to be covered

Dr Payam Barnaghi: Software and  
Services, Data Processing and  
Applications

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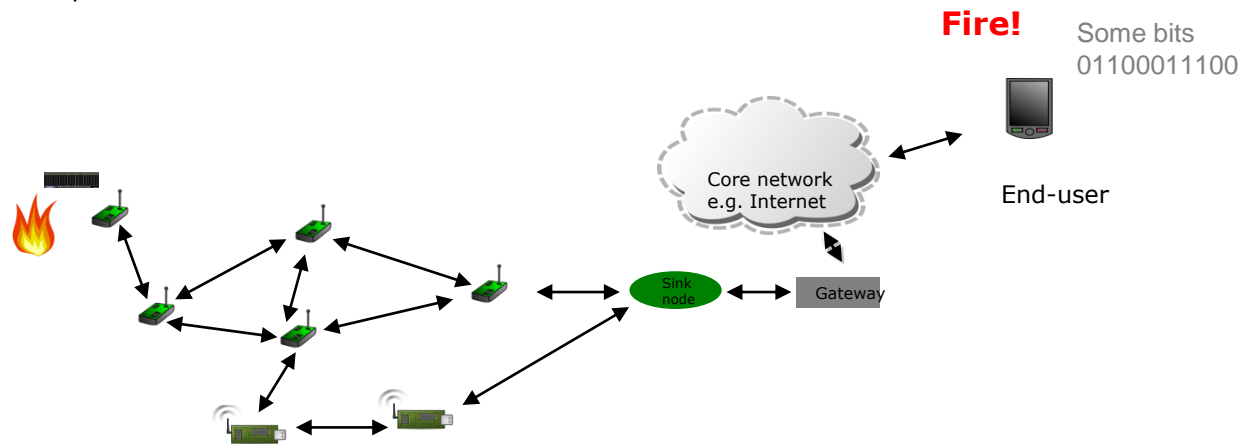
# Software Platforms and Services

- Operating Systems and execution environments
  - Contiki, TinyOS
- Relevant protocols and standards
  - 6LoWPan, CoAP
- Architecture reference models
- ETSI M2M architecture and components
- Gateway/middleware
  
- Types of services
  - In conventional communication networks the target is moving bits from one place to another
  - In the IoT moving the data is not the actual goal.
    - The IoT is expected to facilitate providing meaningful information/actions.

# Example: Type of Services in IoT



A sample data communication in conventional networks



A sample data communication in WSN

# Intelligent Data Processing

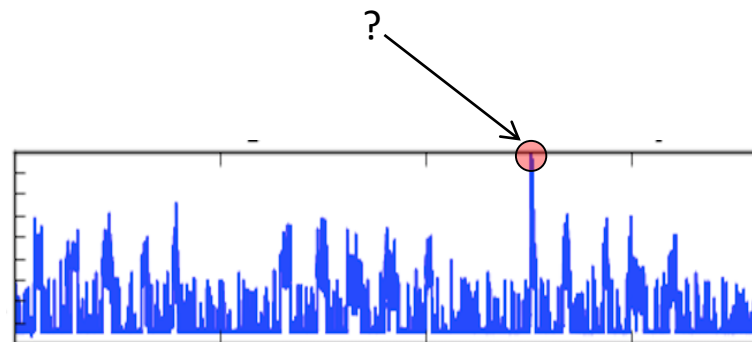
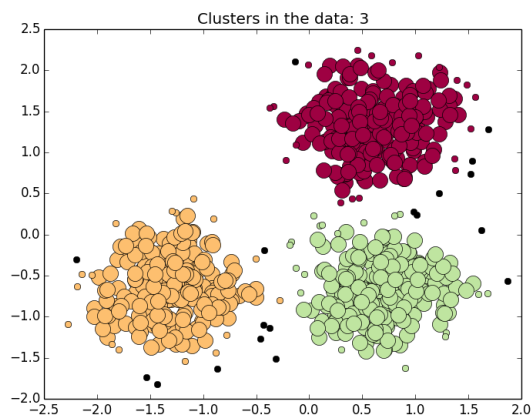
- Sensing and data collection, sensor data and data-centric networks
- Access, subscription and integration
- Data processing and stream data analysis
- Query and discovery
- Data classification and clustering

# Things, Data, and lots of it



*“Each single data item is important.”*

*“Relying merely on data from sources that are unevenly distributed, without considering background information or social context, can lead to imbalanced interpretations and decisions.”*

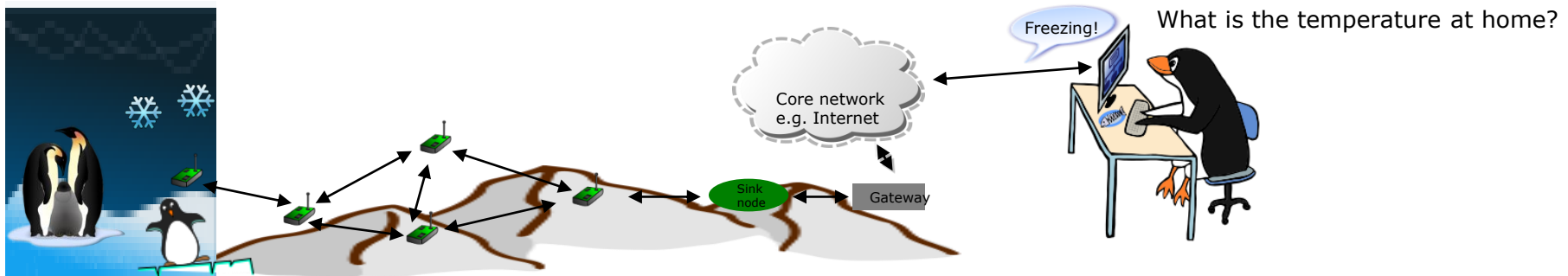


# IoT Data- Challenges

- Multi-modal and heterogeneous
- Noisy and incomplete
- Time and location dependent
- Dynamic and varies in quality
- Crowded sourced data can be unreliable
- Requires (near-) real-time analysis
- Privacy and security are important issues
- Data can be biased- **we need to know our data!**

# "People want answers, not numbers"

(Steven Glaser, UC Berkley)



# Storing, Handling and Processing the Data

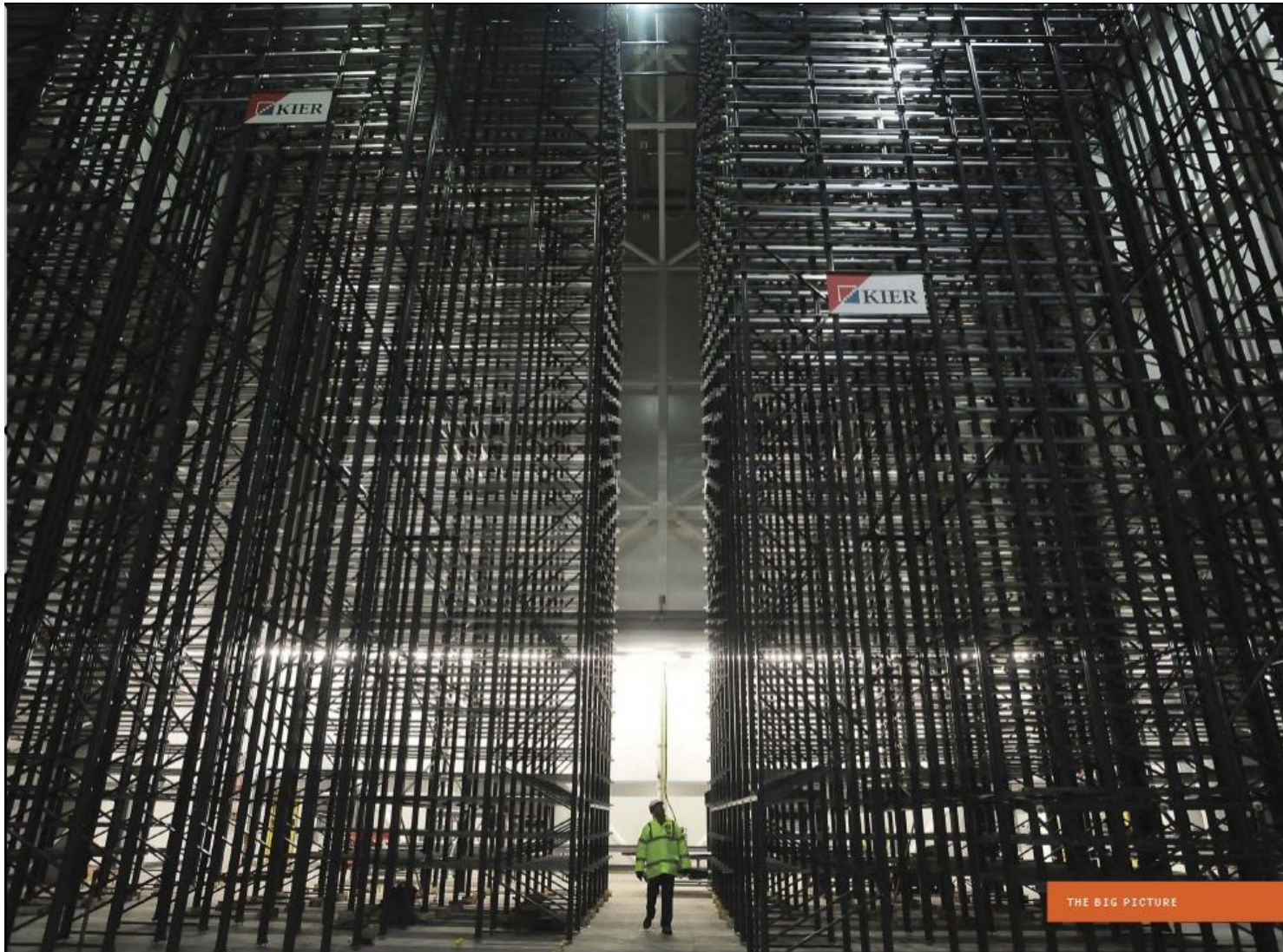


Image courtesy: IEEE Spectrum

# Semantic technologies and connecting Things to the Web

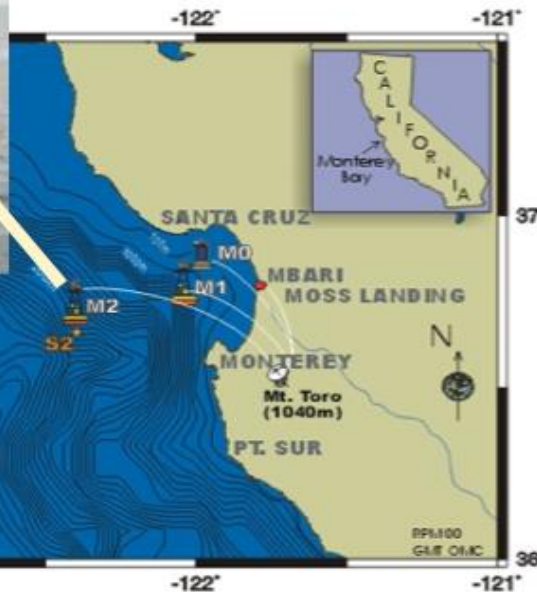
- Meta-data models and schemas
- Linked data and Linked IoT data concepts
- Semantic technologies and semantic sensor networks
- Interoperability issues
- Web of Things

# Device/Data interoperability

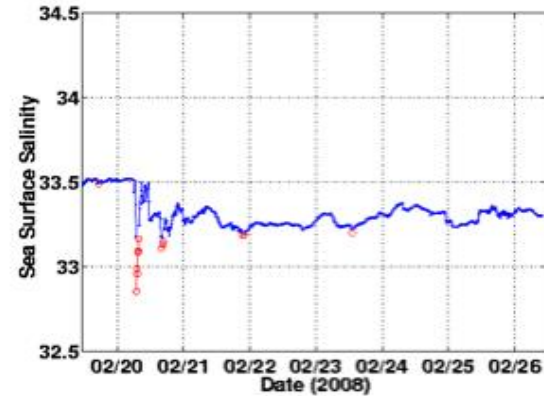


# Observation and measurement data

## Procedure



Feature of Interest =  
Monterey Bay



Estimation value  
of a property

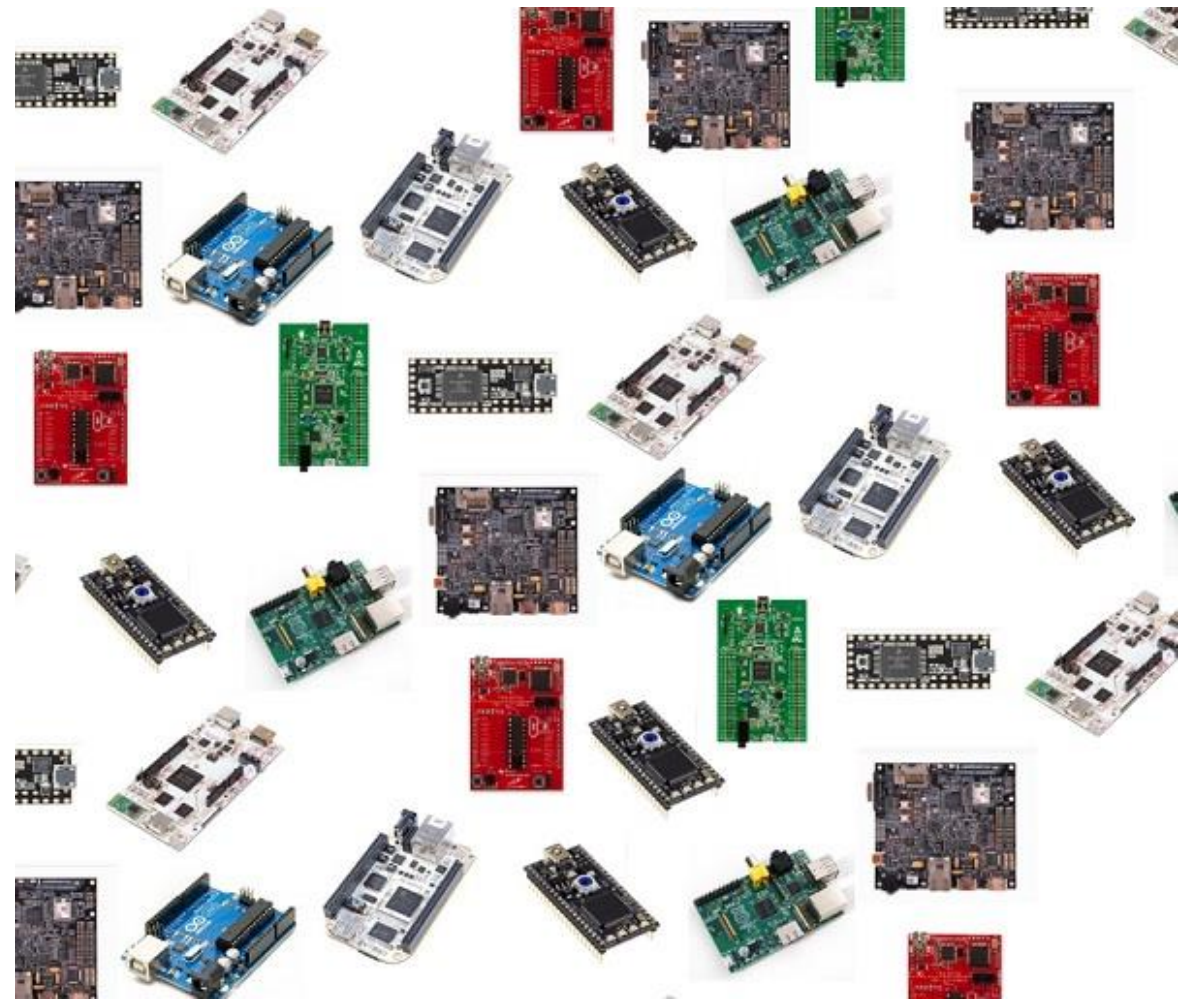
Salinity = property  
related to the feature  
of interest

# System models, Applications and Standards

- Applications: Smart City, Smart Homes, Healthcare, Smart Grid,
- Physical-Cyber-Social Systems
- Machine-to-machine communications
- System models and Standards

# Platforms

- Arduino
- Raspberry Pi
- Intel Galileo
- Adafruit
- SparkFun
- ARM mbed
- Particle
- Etc..



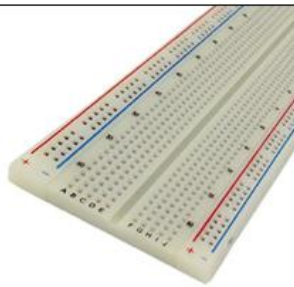
# What will we use?

- Books
  - Arduino Cookbook, 2nd edition (Michael Margolis)
  - Arduino Programming Notebook (Brian W. Evans)
  - Introduction to Embedded Systems (David Russell)
- Hardware
  - Arduino UNO + USB cable
  - LEDs + resistors(220, 1K, 10K) + breadboard + wires
  - Potentiometers (variable resistors), buttons
  - Light dependant resistor, piezo buzzer, tilt sensor, temperature sensor, IR and sonar distance sensors
  - servo-motor, dc-motor, stepper-motor(and driver)
  - LCD display, 8x8 led matrix, 7 segment displays, remote IR control
  - ESP8266 WiFi module
- Software
  - Arduino IDE (software)
  - Proteus ISIS simulation tool

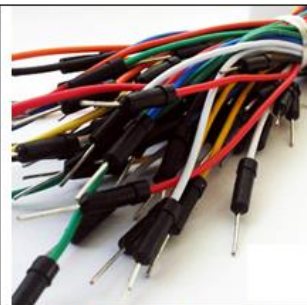
# Part List



1x Arduino UNO (with USB cable)



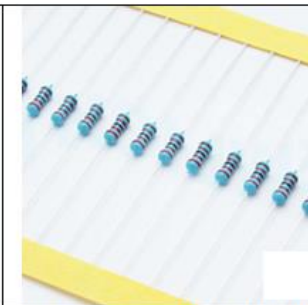
1x Breadboard



30x Wires (M-M, M-F)



30x LEDs (Red, Green, Yellow)



30x Resistors (220Ω, 1kΩ, 10kΩ)



1x Potentiometer (10k)



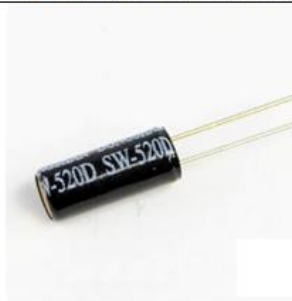
4x Buttons



3x Light Dependant Resistors



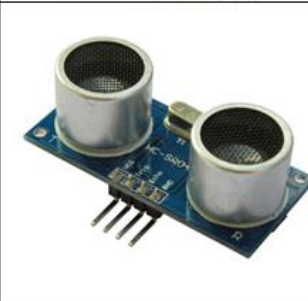
1x Piezo buzzer



1x Tilt Sensor



1x LM35 Temperature Sensor



1x Sonar Distance Sensor



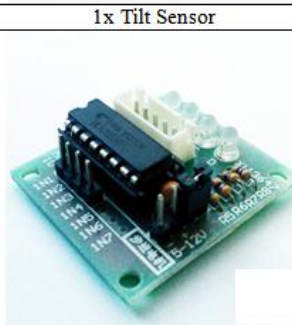
1x Servomotor



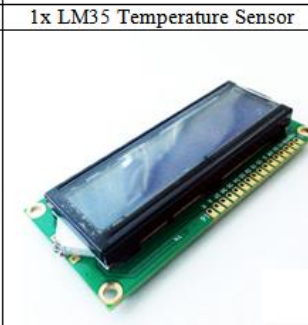
1x DC motor



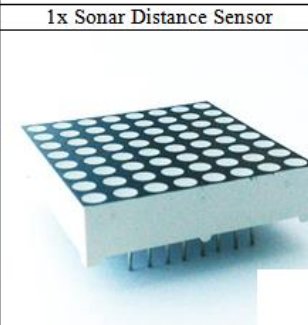
1x Stepper Motor



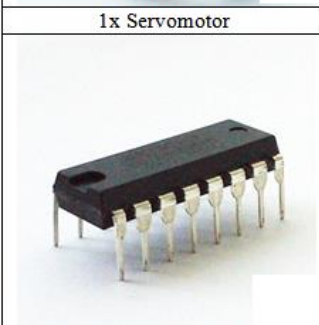
1x Stepper Motor Driver



1x LCD Display (header pins)



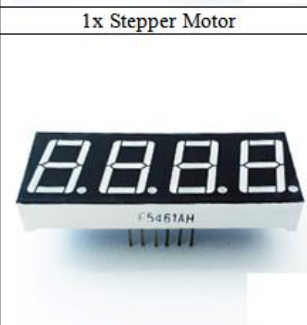
1x LedMatrix (8x8)



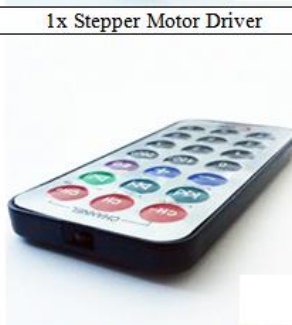
1x 8-bit Shift Register



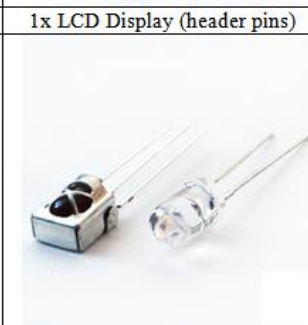
1x 7-segment Display



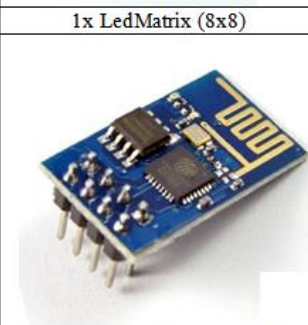
1x 4-digit 7-segment Display



1x IR Remote Controller

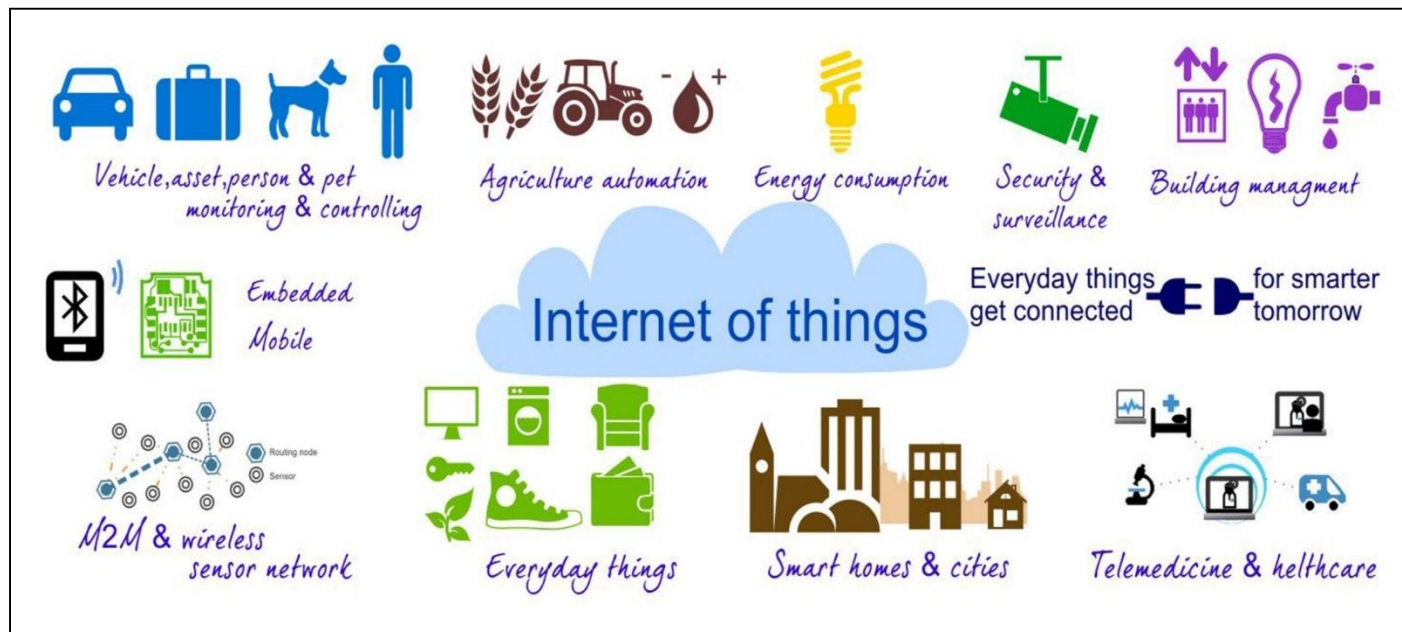
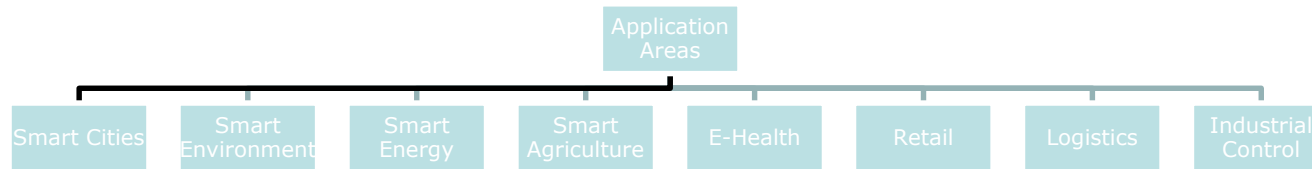


1x IR Receiver and Transmitter

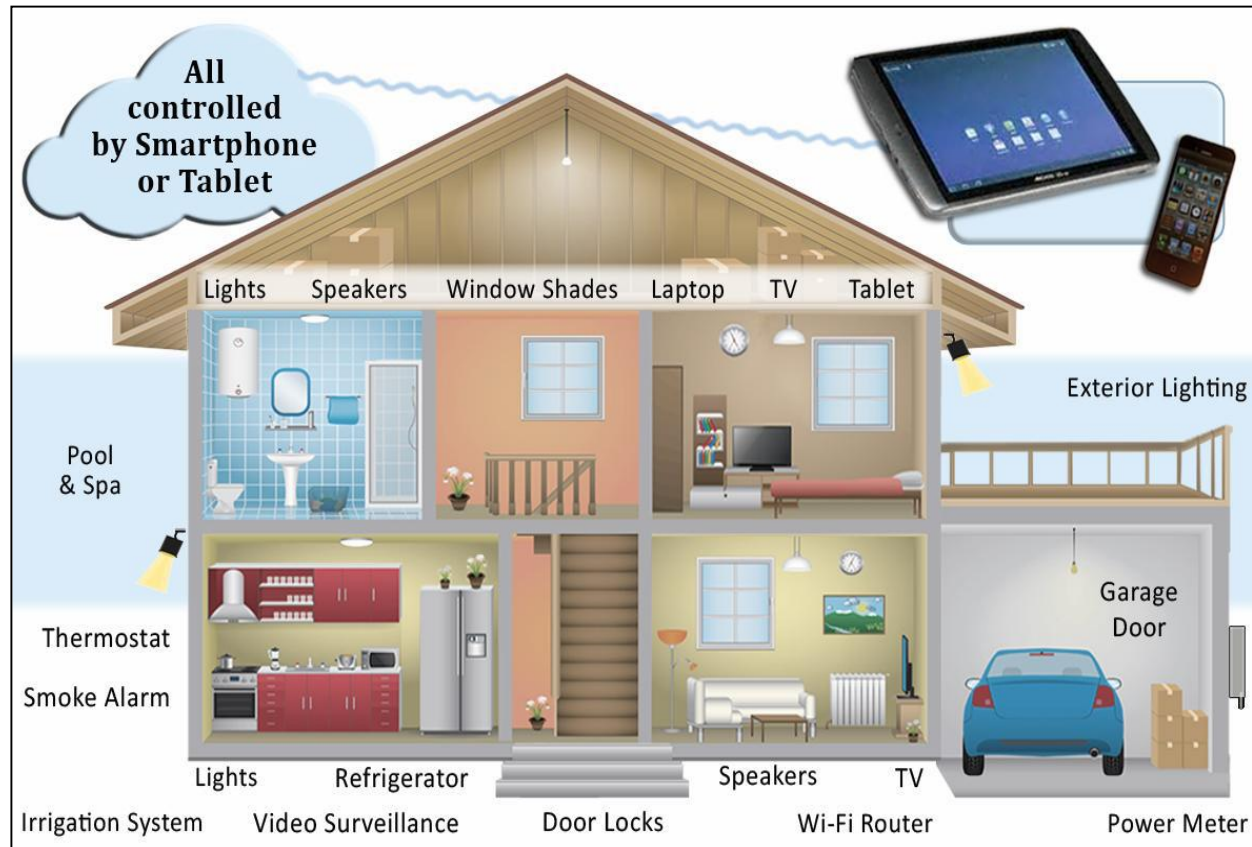


1x ESP8266 WIFI module

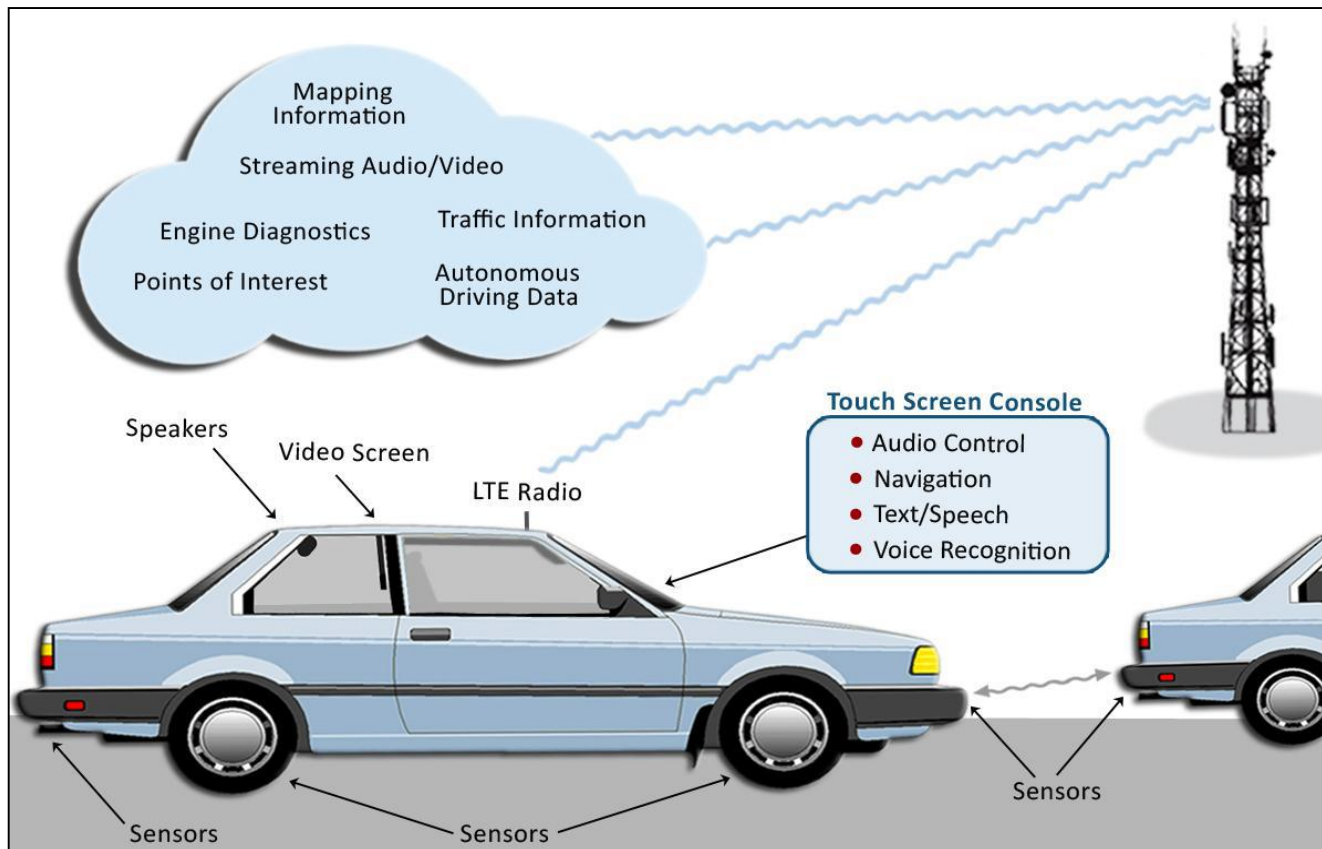
# APPLICATIONS



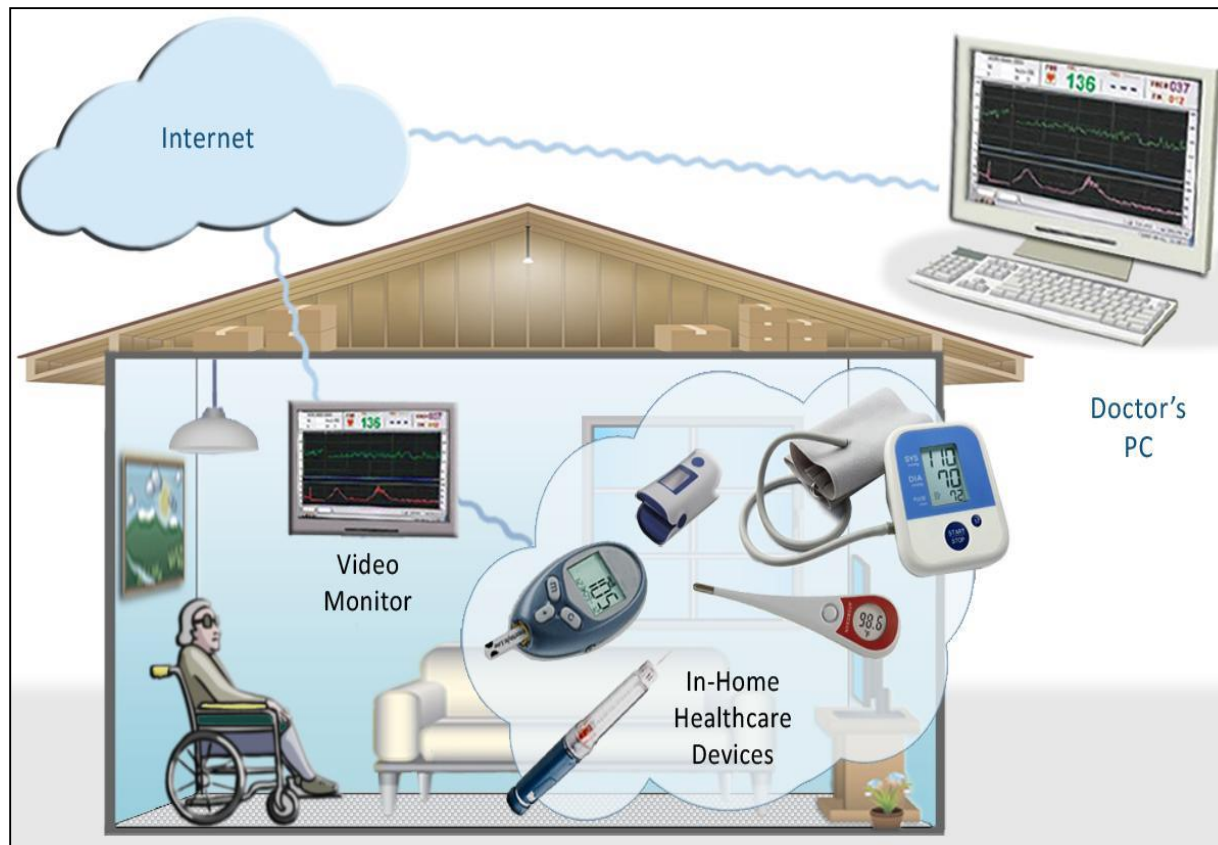
# Smart Home



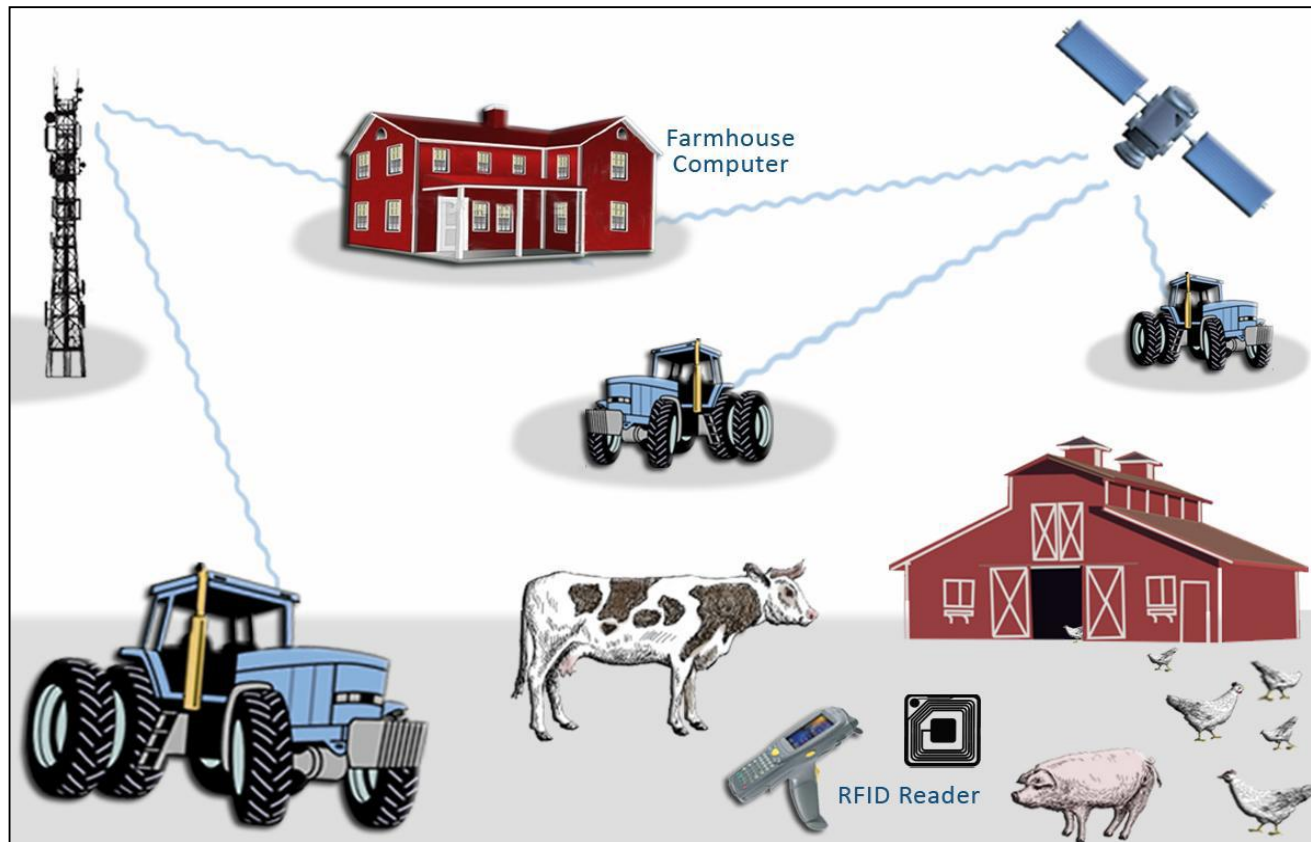
# Smart Cars



# E-Healthcare



# Smart Farms



# Scenario: shopping

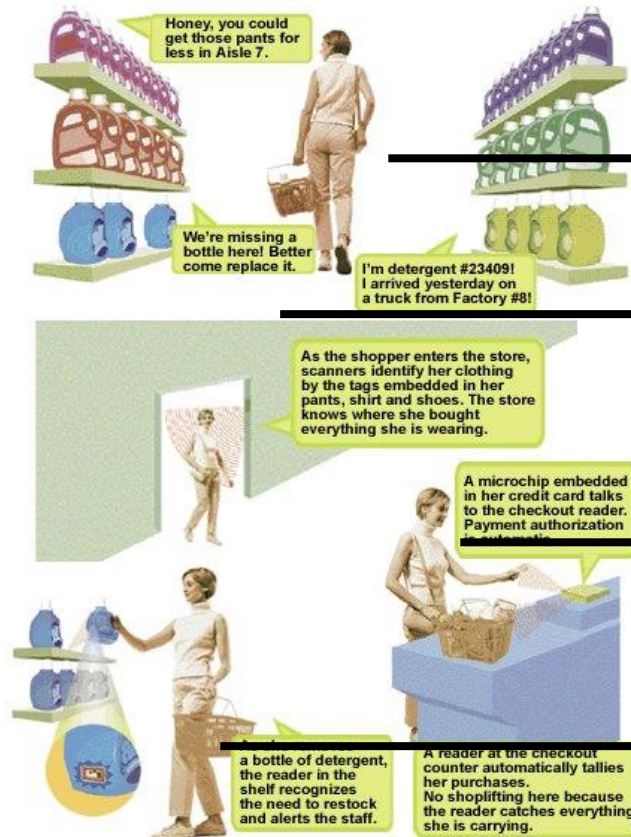


Illustration by Lisa Knouse Braiman for Forbes

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

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

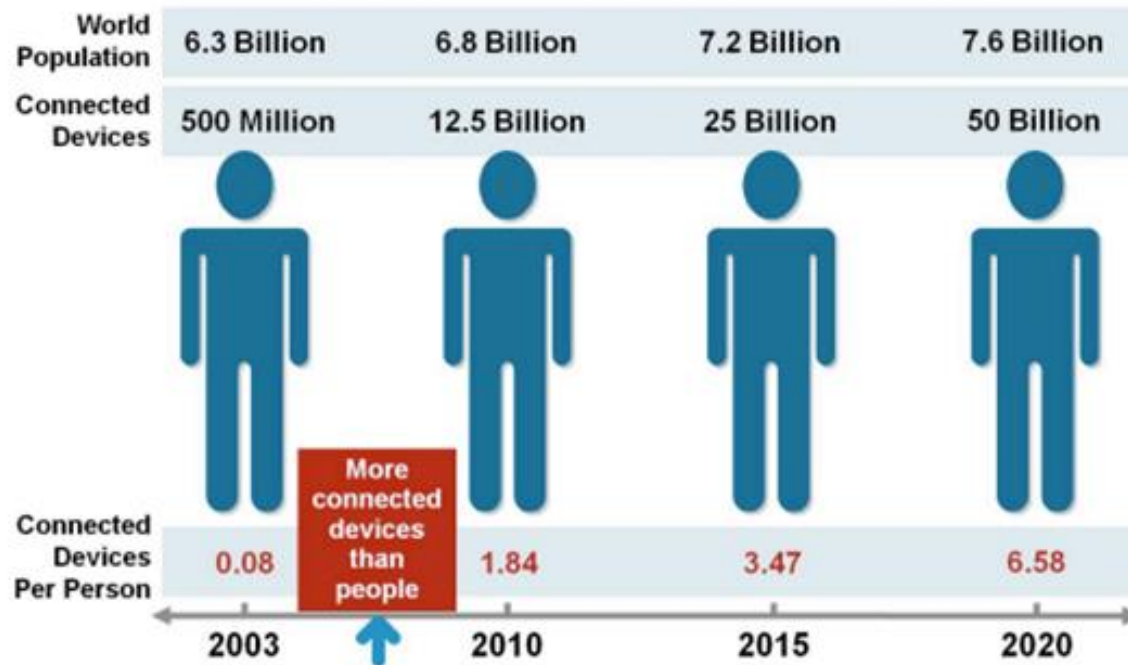
(4) When paying for the goods, the microchip of the credit card will communicate with checkout reader.

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

# SMART JAR



# Internet Usage and Population Statistics



Source: Cisco IBSG, April 2011

# Questions?

