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Internet of Things (IoT): An Introduction

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Definition

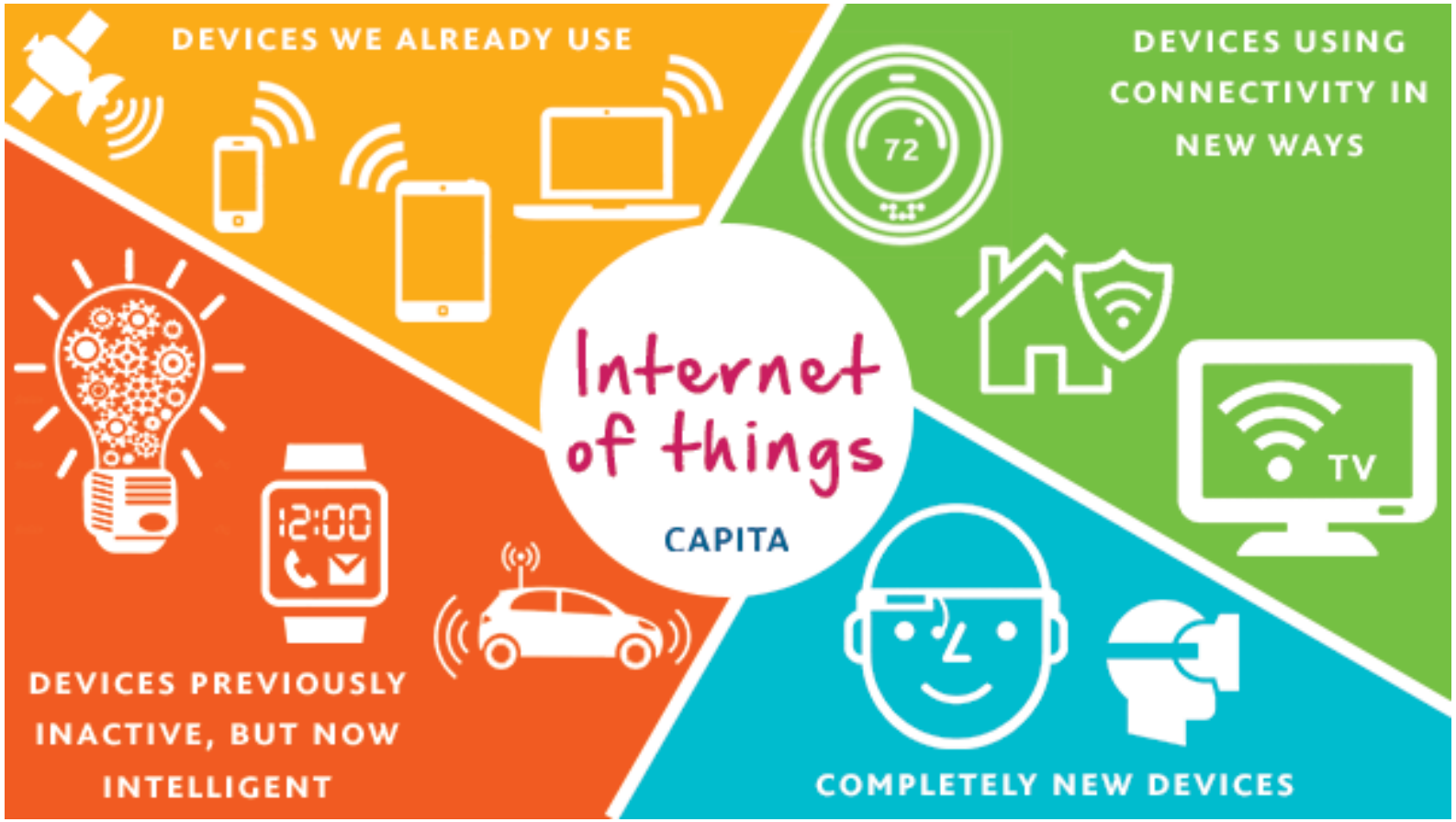
Internet → The worldwide network of interconnected computer networks, based on a standard communication protocol (TCP/IP).

Thing → An object not precisely identifiable.

Internet of Things (IoT) → A worldwide network of interconnected objects uniquely addressable, based on standard communication protocol.

Definition (cont.,)

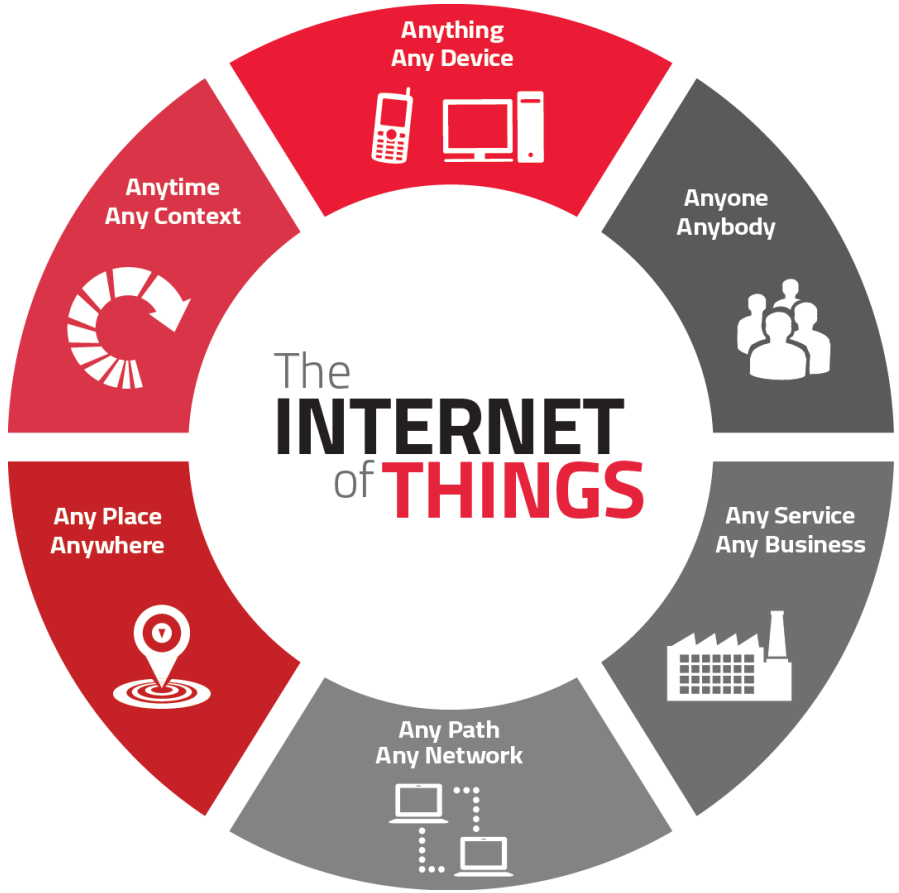
- Extending the current Internet and providing connection, communication, and inter-networking between devices and physical objects, or "Things,".



https://www.capitatranslationinterpreting.com/the-internet-of-things/

IoT Vision

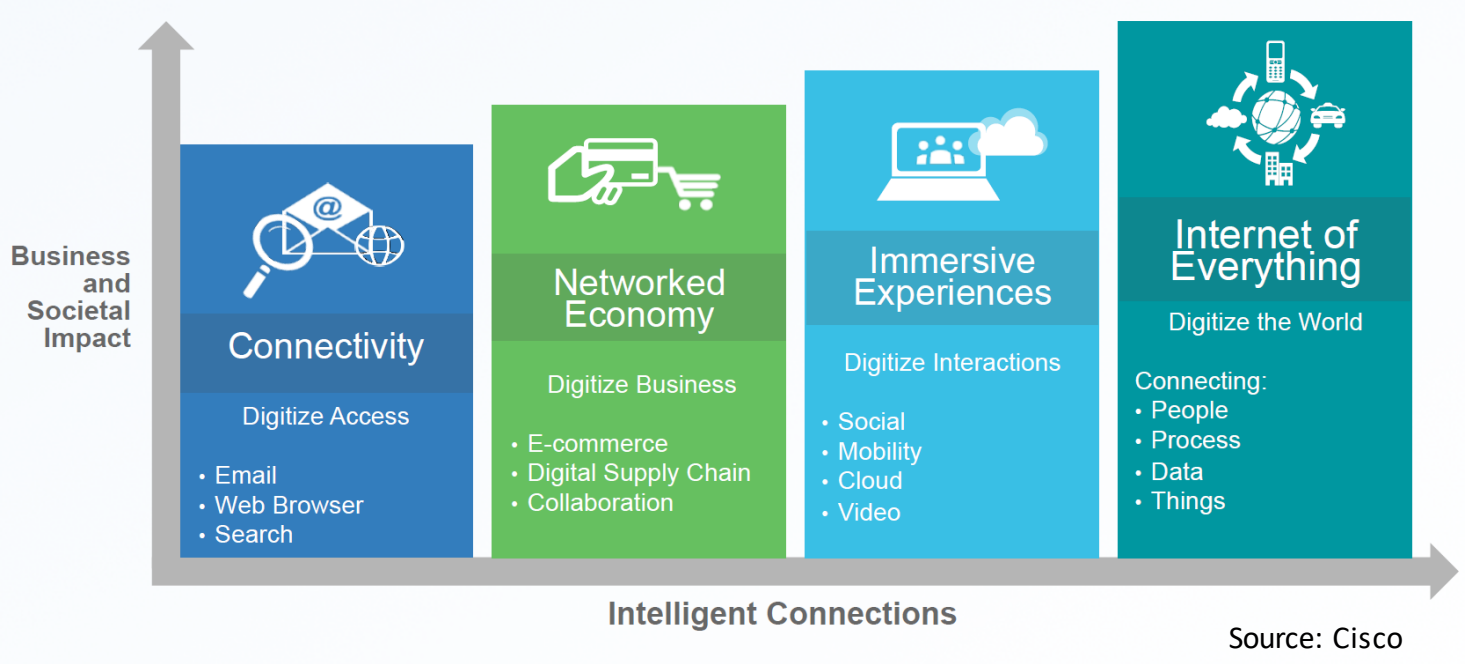
- The vision of the IoT is to fuse the physical and digital worlds by bringing the different concepts and technical components together.
- Create a seamless network of billions of wireless identifiable objects that communicate with one another.
- Crate a new ecosystem in which the devices can be able to direct their transport, adapt to their respective environments, self-configure, self-maintain, self-repair as necessary.



http://iotworm.com/biggest-challenges-for-the-internet-of-things/

IoT Evolution

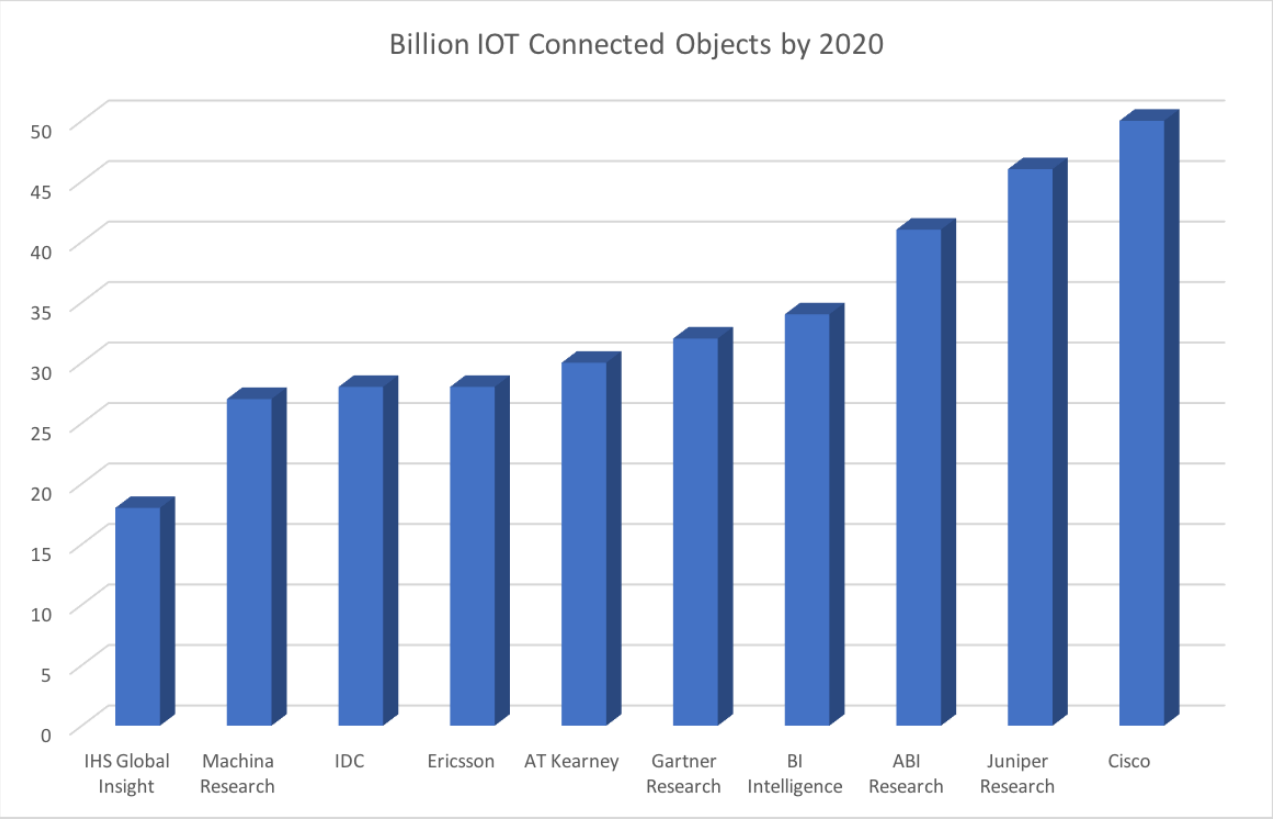
- Started with connectivity among people for sharing information.
- Led to a “flat-world” where everyone across the world is connected.
- Advancement in cloud computing and immersive experience led towards universal accessibility of data.
- Combination of immersive experiences, connectivity and advancement in electronics further leading to Internet of Everything (IoE)



Source: Cisco

IoT Market

- As of 2015, 25 billion IoT units
- Expected to grow to 50 billion IoT devices by 2020
- Revenue growth from $1.9 trillion in 2013 to $7.1 trillion in 2020

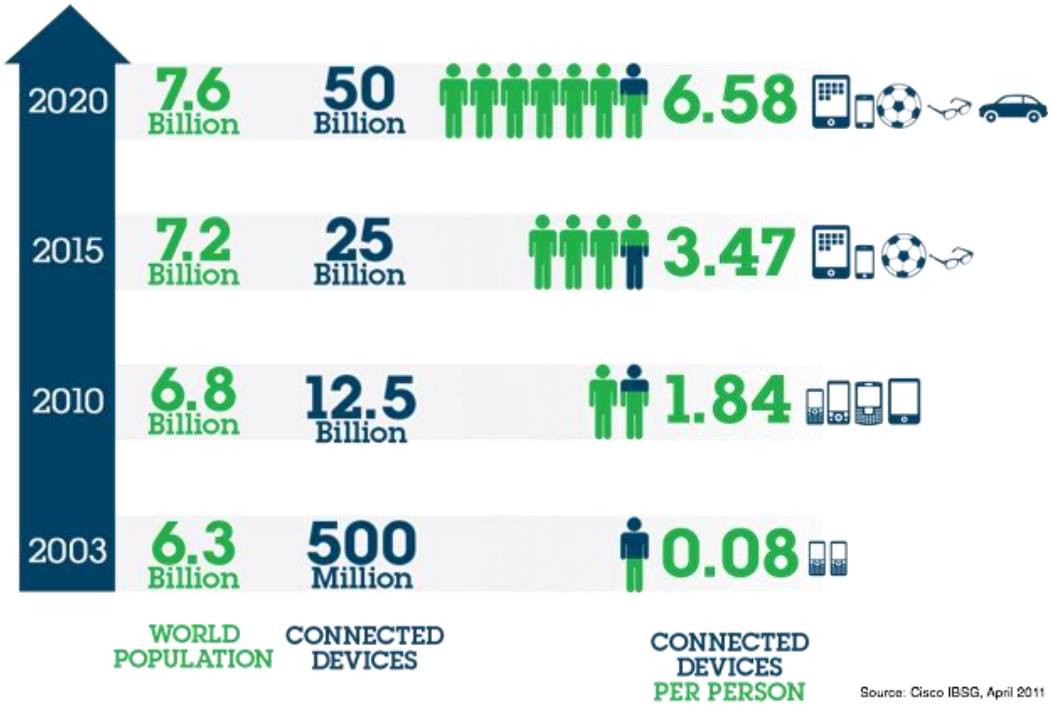


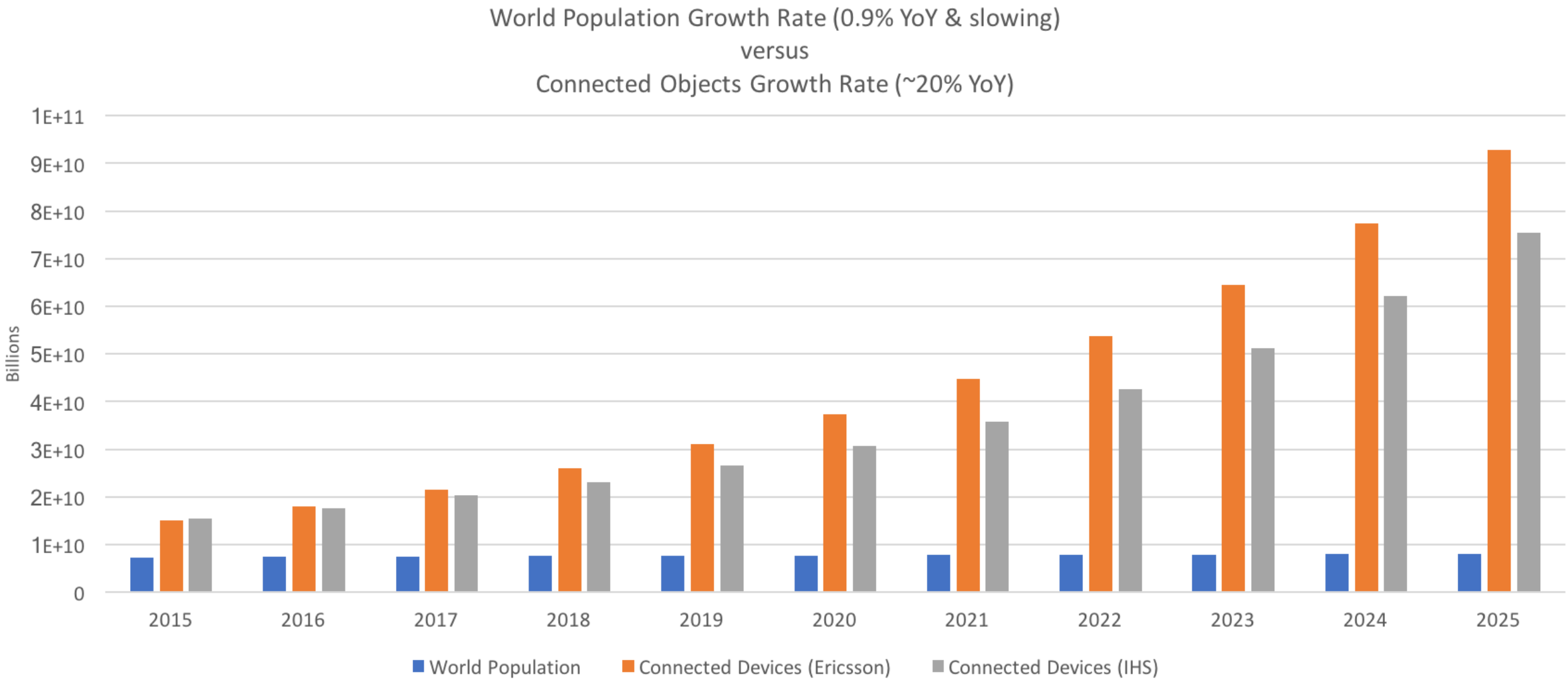
IoT Potential

- Conservatively → 20 billion newly connected devices will be deployed.
  - 211 new internet connected objects will come online every second.

- First public website went live at CERN in 1990.
  - It took 15 years to reach 1 billion people on earth over the internet.
  - IoT is looking to add 6 billion connected devices per year.

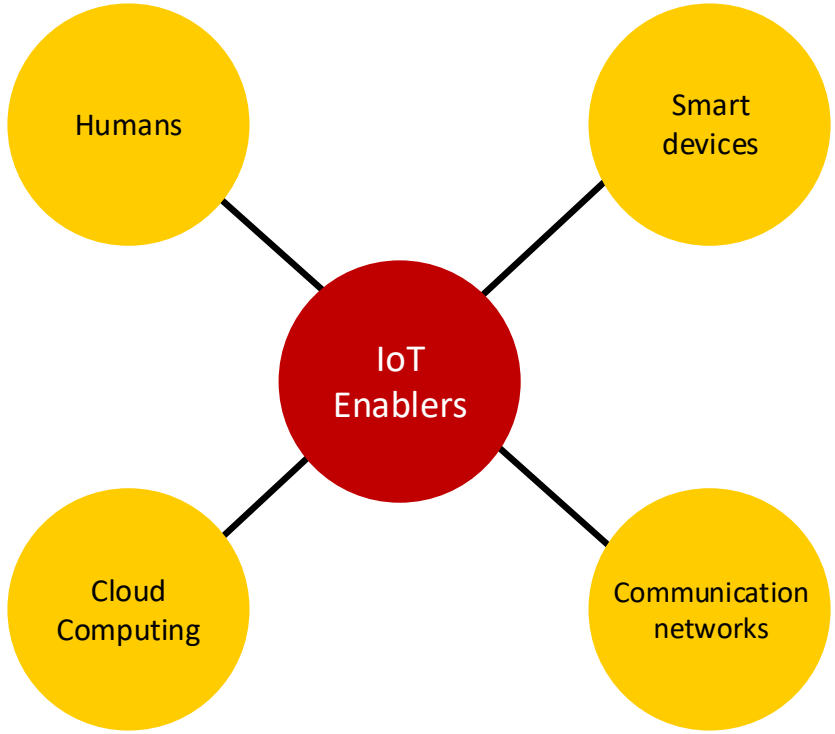
- Economic impact
  - New revenue streams
  - Reducing costs
  - Reducing time to market
  - Improving supply chain
  - Reducing production loss
  - Increasing productivity




World Population Growth Rate (0.9% YoY & slowing)
versus
Connected Objects Growth Rate (~20% YoY)
Billions
1E+11
9E+10
8E+10
7E+10
6E+10
5E+10
4E+10
3E+10
2E+10
1E+10
0
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
World Population
Connected Devices (Ericsson)
Connected Devices (IHS)

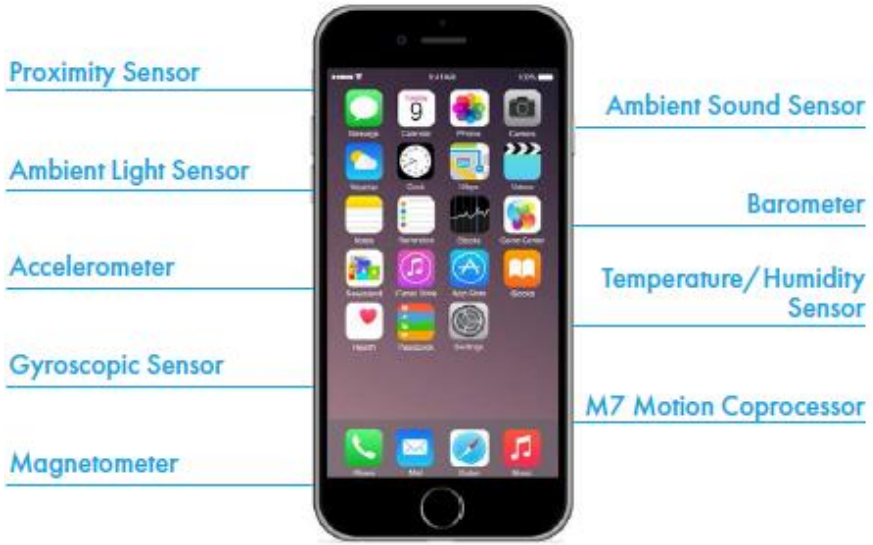
IoT Enablers

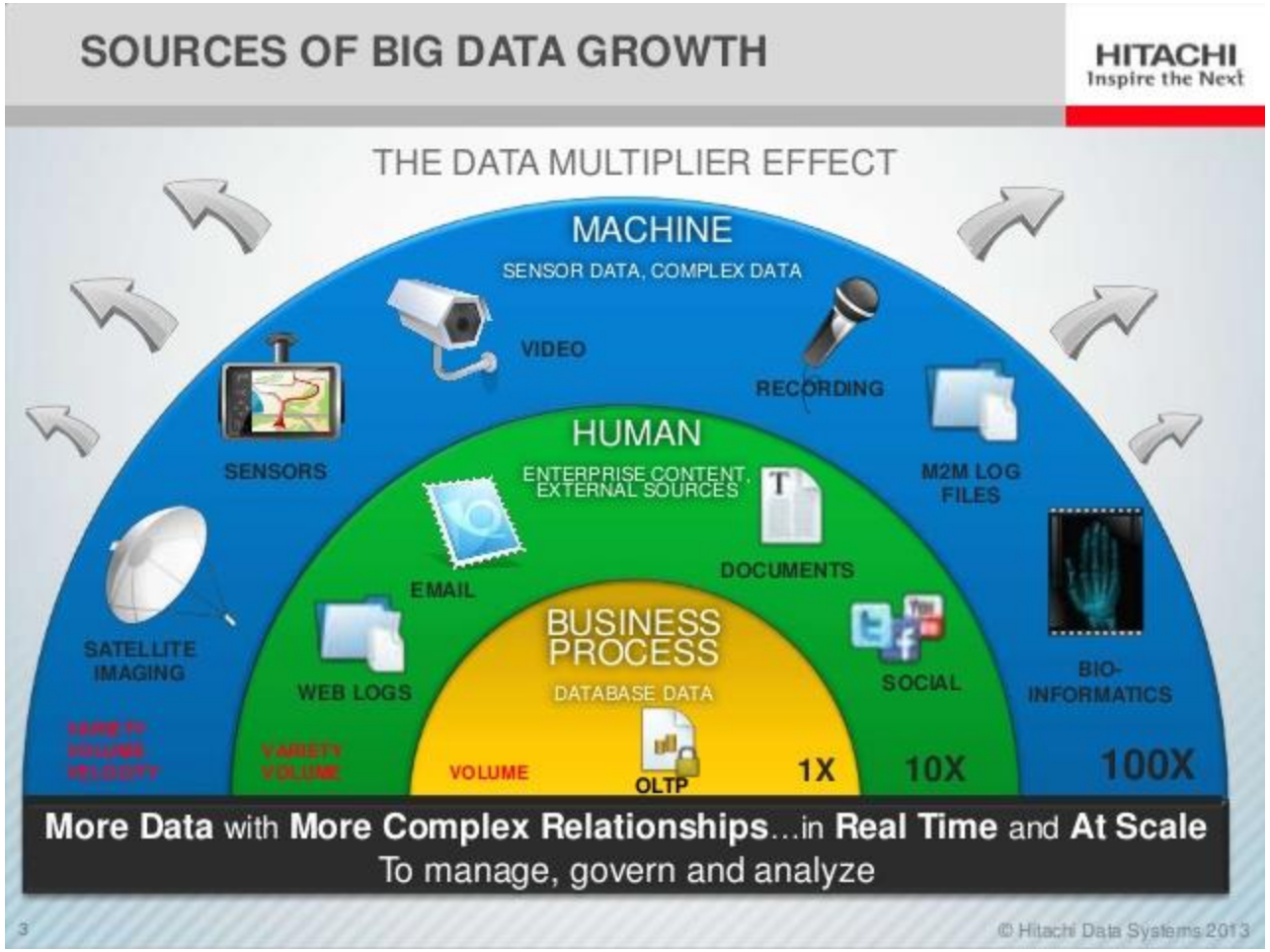
- Humans
  - They can act both as consumers and producers of data
- Smart devices
  - Technological advances and reduction in the cost of manufacturing has enabled widespread adoption of smart devices
- Communication Networks
  - Diverse method such as Wi-Fi, Bluetooth LE, Zigbee, ANT+, GPRS, 3G are the key denominator as they make a lot more options available to the IoT
- Cloud Computing
  - Scaling rapidly to meet the growing demand resulting from the IoT in terms of storage and computational power



Big Data - Enablers

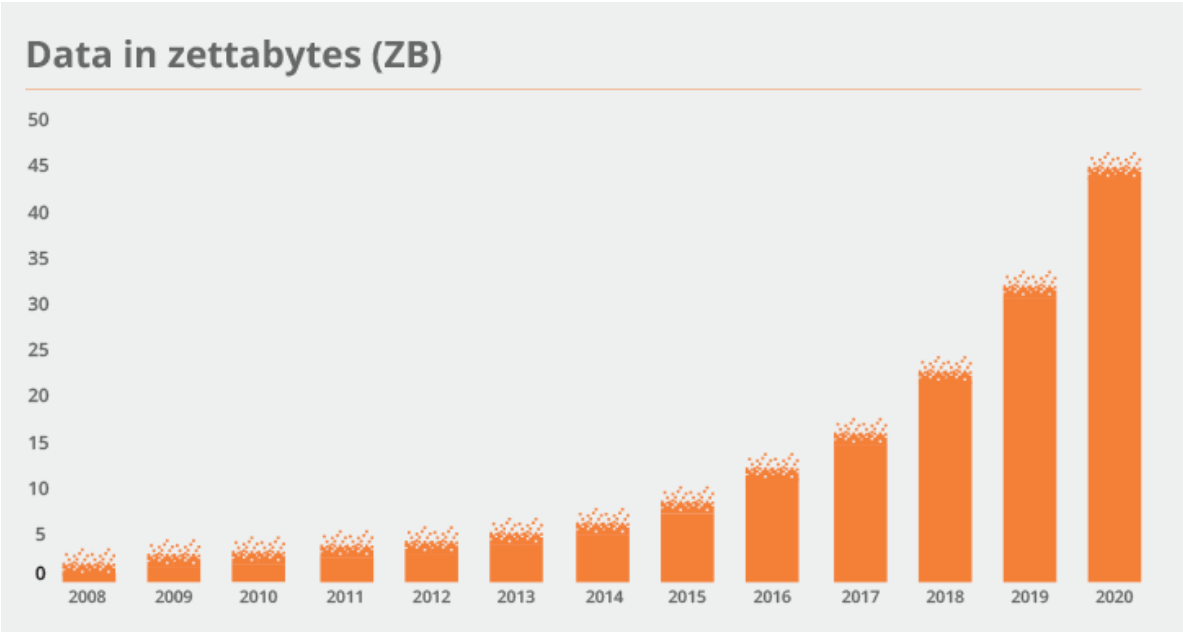
- A full 90% of all the data in the world has been generated over the last two years.
- Sources
  - Physical Environment
  - Smartphones & wearables
  - Online presence





Big Data

- It is estimated by IDC, that by 2020 the number will reach 45 Zettabytes (ZB).
- By 2020, there will be 5,200 GB of data for every person on Earth.
- By 2020, 40% of all data will come from sensors.

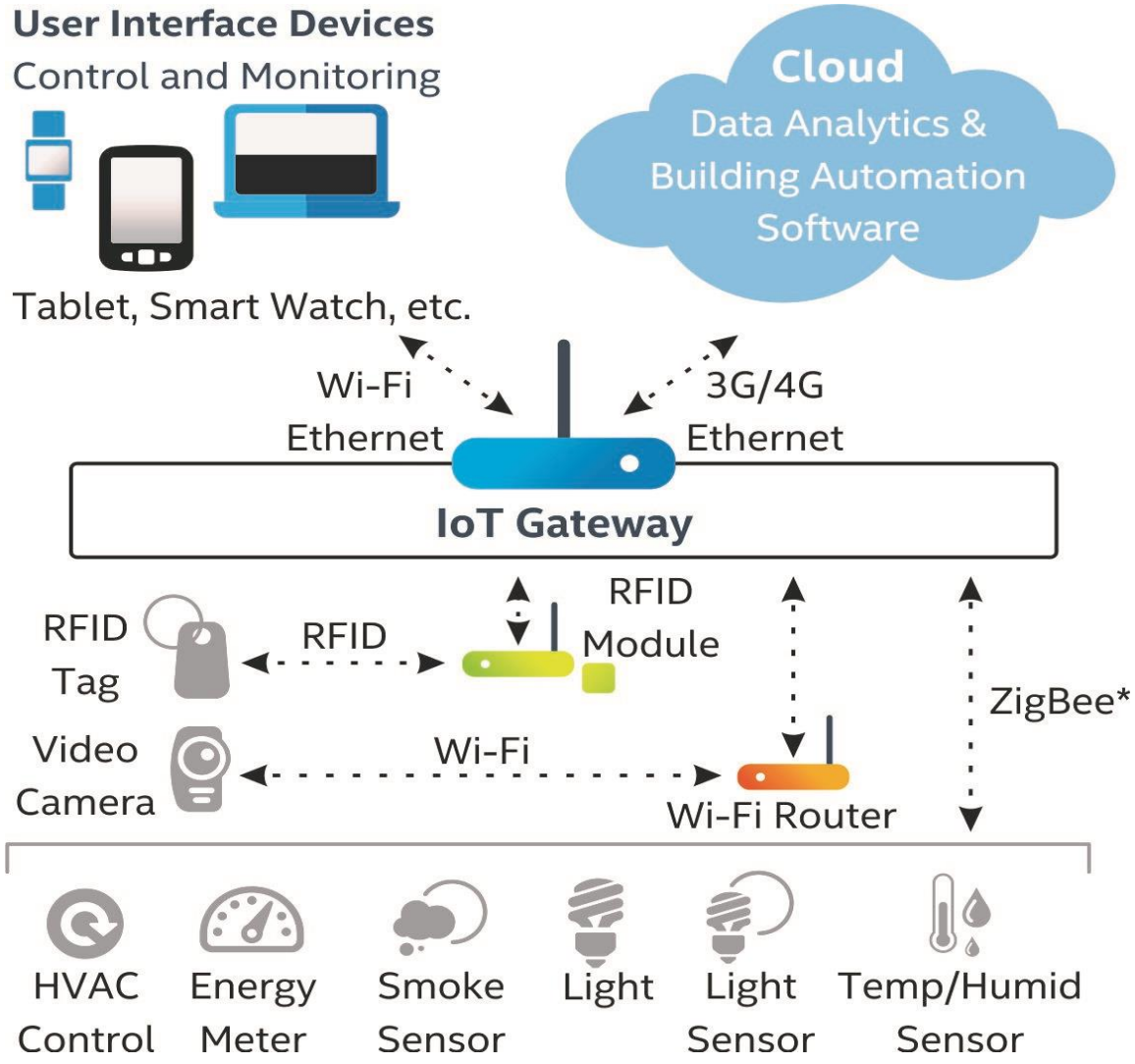


http://blog.datasift.com/2014/10/08/resolving-the-big-data-paradox/

1024 Terrabytes = 1 Petabyte
1024 Petabytes = 1 Exabyte
1024 Exabytes = 1 Zettabyte

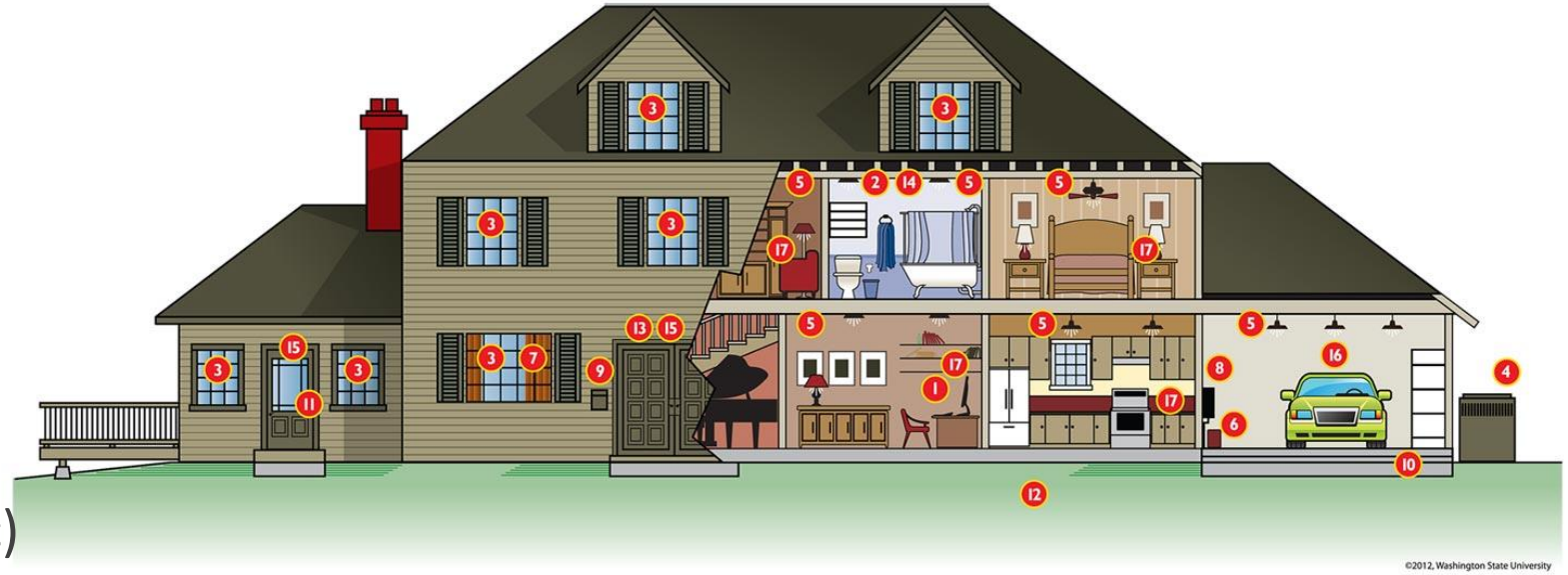
Building Blocks of an IoT System

- Sensing
- Connectivity
- Gateways
- Processing
- Software
- Power



Sensors – Healthy Independent Living

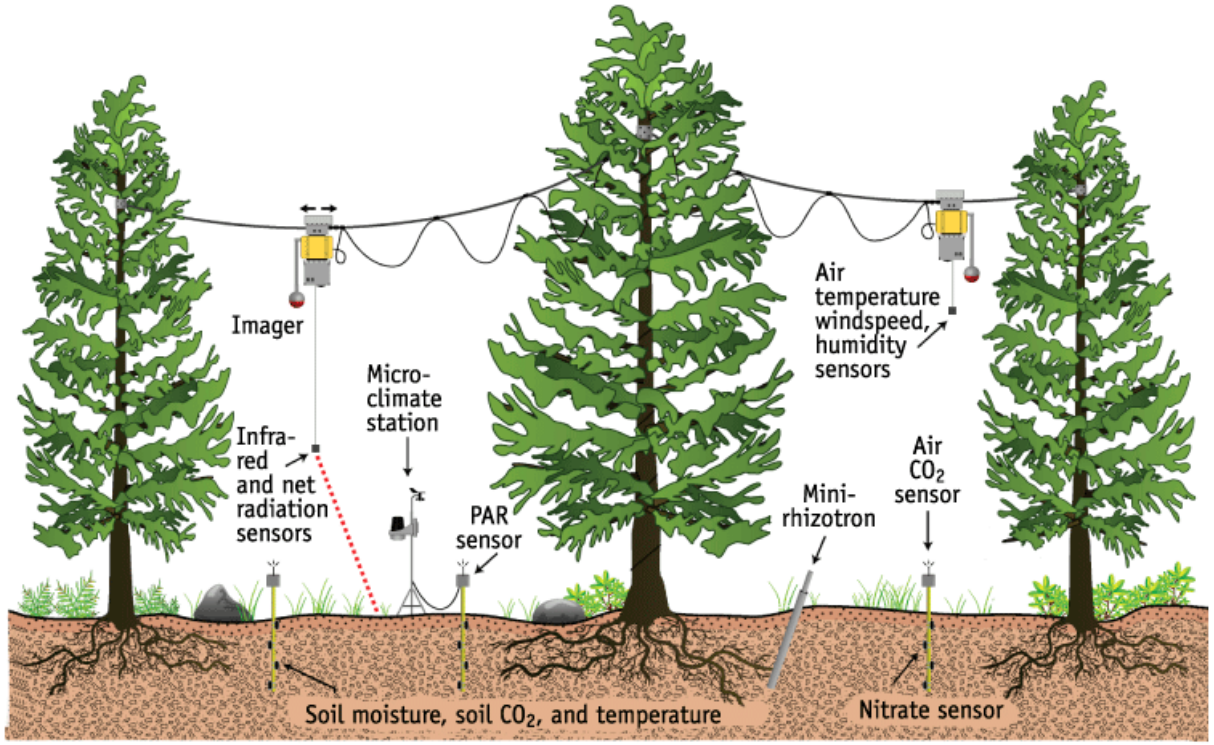
- They are mainly input components
- They sense and collect surrounding information
- Basically three types:
  - Passive, omnidirectional (e.g. mic)
  - Passive, narrow-beam sensor (e.g. PIR)
  - Active sensors (e.g. sonar, radar, etc.)



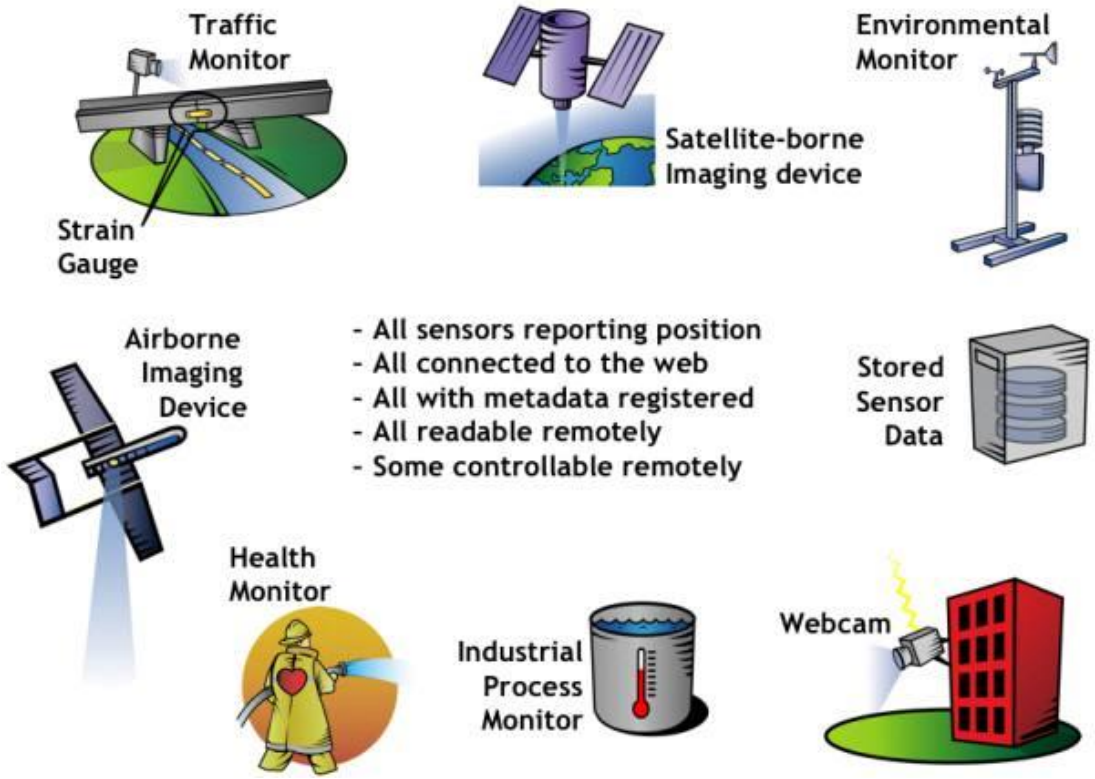
1	Ambient Intelligence Agent (AmI) Control	6	Automatic Pet Feeder	12	Lawn Moisture Sensor
2	Light Sensor	7	Motorized Drapes	13	Face Recognition Sensor
3	Windows and Door Control	8	Automatic Watering	14	Motion Sensors
4	HVAC Control	9	Mailbox Sensor	15	Door Sensors
5	Lighting Control	10	Driveway Sensor	16	AmI Interface with Car
		11	Security System	17	AmI Interface with Smart Phone

http://www.nibib.nih.gov/sites/default/files/SMART-HOUSE_2_DCook.jpg

Sensors – Environmental Monitoring



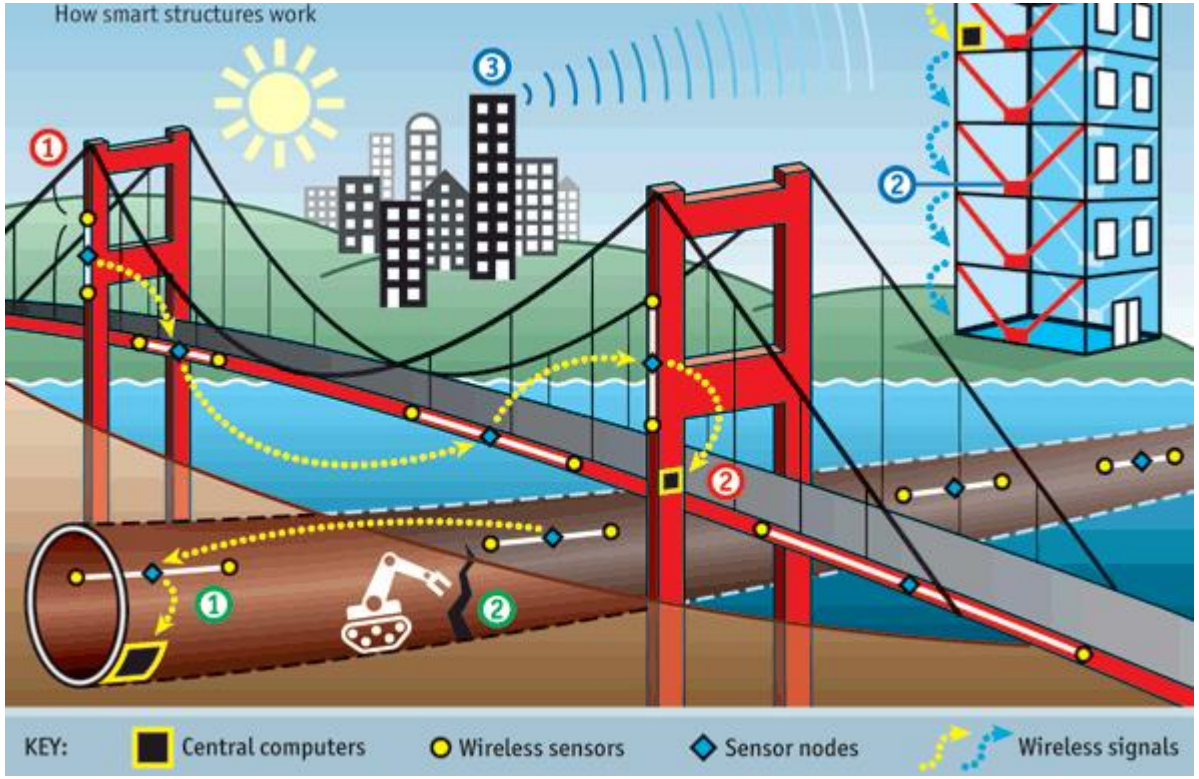
http://www.environment.ucla.edu/media/images/Fig1_NIMS-lrg.gif



http://www.opengeospatial.org/pub/www/files/images/SWE%20Overview_0.jpg

Sensors – Infrastructure Health Monitoring

- Smart Building
  - Sensor to detect strong wind or earthquake
  - Shock absorbers can react to minimize the damage
  - Building could warm other building to prepare for the event
- Smart Bridge
  - Sensors to monitor vibrations, displacement, and temperature
  - If problem is detected, a warming can be sent by SMS
- Smart Tunnel
  - Sensors to monitor humidity, displacement, and temperature
  - If problem is detected, appropriate maintenance can be carried out



www.rfwirelesssensors.com/2010/12/energy-harvesting-wireless-sensor-networks-for-smart-structures

Embedded Processing Units

- Reliance on communication to create cohesion between the physical and the technological realms places importance on the microprocessors and/or microcontrollers.
- Used either to allow objects sense their surroundings, or exchange data with other systems, or interact with the cloud, they are integral in an IoT system.
- Given the changing nature of the landscape, microprocessors that are low power, cost-effective and leave a smaller imprint will be those that are favored within the IoT.

Embedded Processing Units

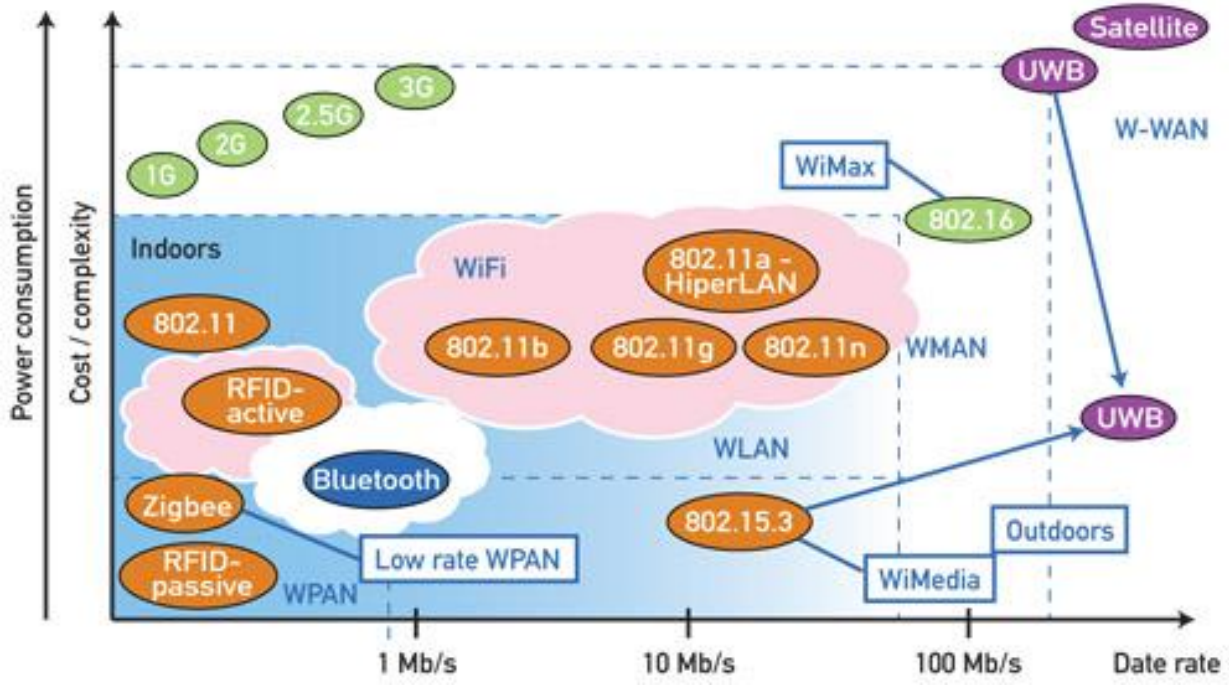
- Selection Criteria
  - Physical size
  - Power management
  - Interface requirements
  - Performance requirements
  - Security needs
  - Safety and fault tolerance
  - Debugging capabilities
  - Cost
  - Architecture (x86, ARM, etc.,)
  - Feedback required

Communications

- 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
- Popular RF-based communication solutions:
  - IEEE 802.15.4
  - IEEE 802.11 (or Wi-Fi)
  - Bluetooth
  - Near Field Communication (NFC), e.g. RFID

Communications - Current Wireless Landscape

- Each protocol is targeted at different types of applications.
- In addition to these protocols, there are also a number of different license-free frequencies, such as 900 MHz, 2.4 GHz and 5.8 Ghz, used as the carriers for these signals.
- Each frequency has its advantages and challenges regarding distance and bandwidth



http://www.controlglobal.com/articles/2013/verhappen-wireless/

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.
  - Wireless Sensor Networks (WSNs)
  - Mobile Wireless Ad hoc Networks (MANETs)
  - Wireless Mesh Networks (WMNs)
  - Vehicular Ad Hoc Networks (VANETs)

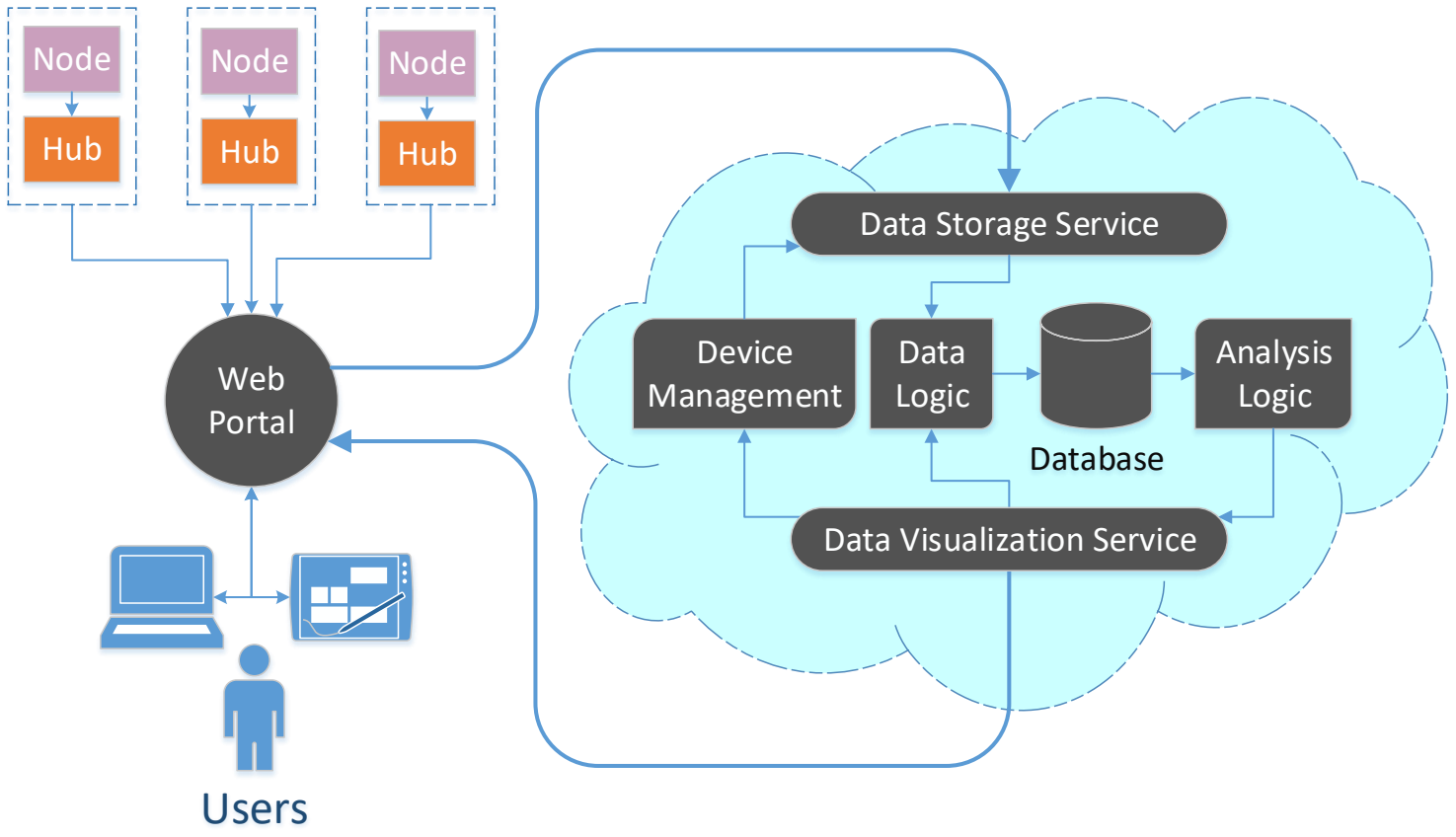
- Main concern: Reliability & Performance

http://www.psemi.com/markets/industrial/internet-of-things

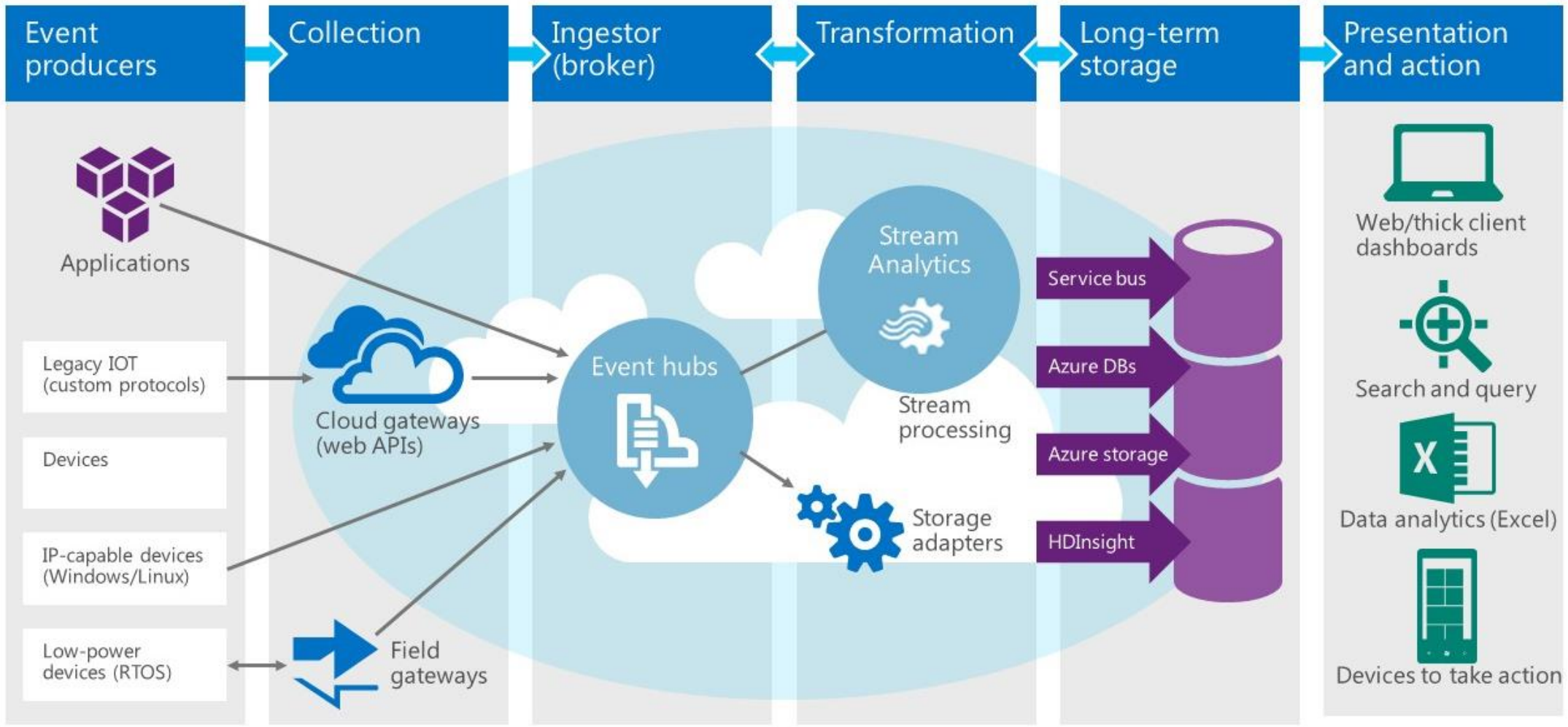
Data Management on Cloud

Data management applications are potential candidates for deployment in the cloud

- Industry: enterprise database system have significant up-front cost that includes both hardware and software costs
- Academia: manage, process and share mass-produced data in the cloud



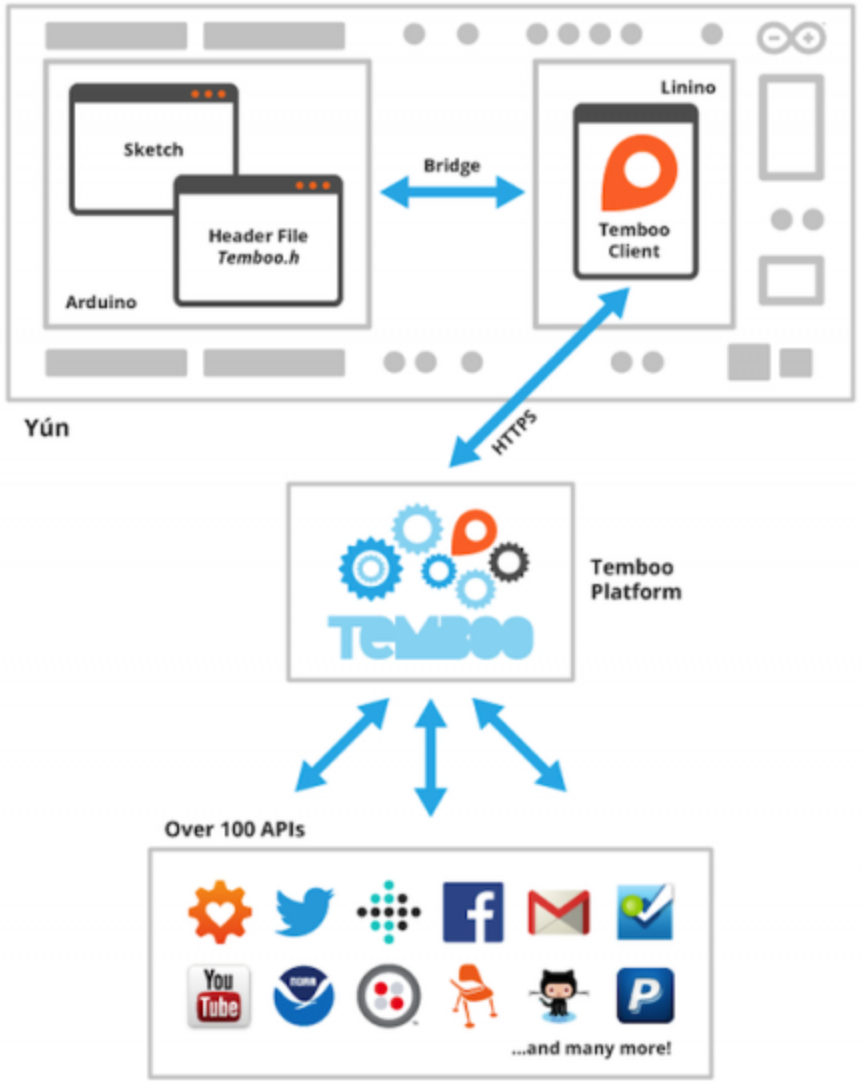
Microsoft Azure – IoT Sensor Data Platform



https://dzone.com/articles/pushing-realtime-sensors-data-into-asa-visualize-i

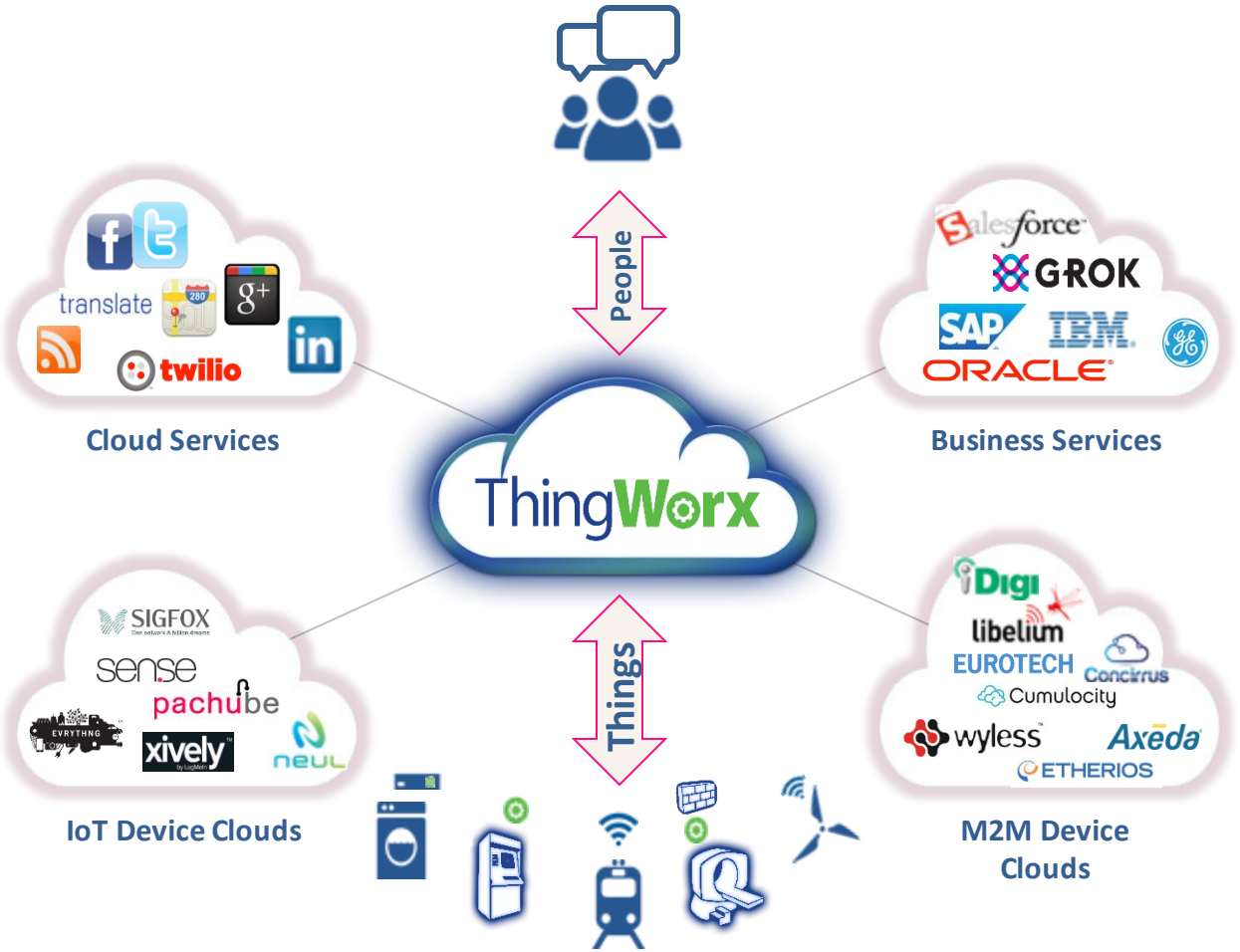
Services – IoT & M2M

- Code Generator with scalable, fault-tolerant environment for running and managing code snippets.
- Several APIs available to interface with diverse range of devices and applications
  - Arduino Yun & Arduino Uno
  - TI CC3200
  - Facebook
  - Twitter
  - Gmail
  - Google Sheets
- Can interface with databases and devices to create custom processes
- Educational plan available for easy integration into classroom



Services – IoT & M2M

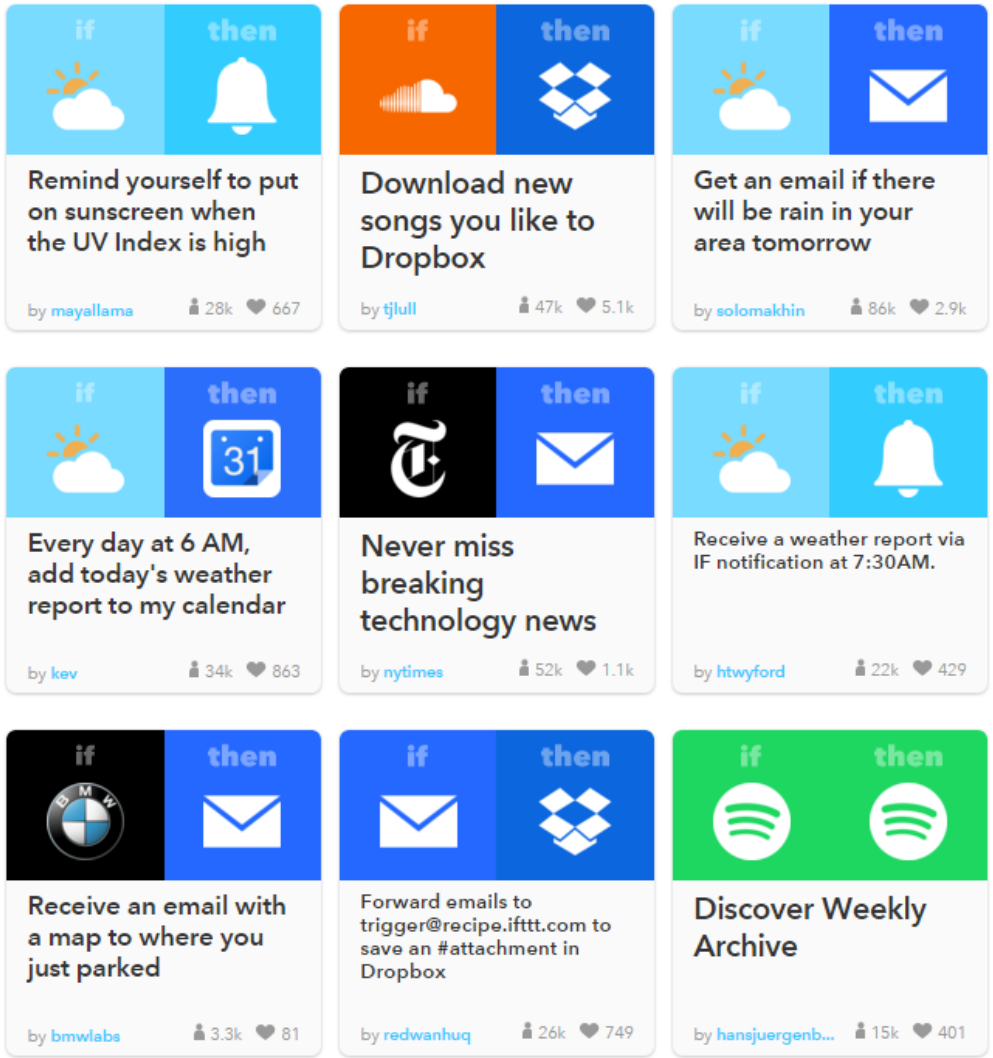
- Code Generator with scalable, fault-tolerant environment for running and managing code snippets
- Dynamic collaboration & system administration
- Has connectivity to broad range of services and devices
  - Business Enterprise Systems (Oracle, SAP)
  - Memory intensive computational devices (Raspberry Pi, Intel Edison)
  - Big Data Analytics



http://www.slideshare.net/marklittlewood/thingworx

Services - IoT

- Web-based service that allows users to create chains of simple conditional statements.
- Example
  - Sending an email if a condition evaluates to true
  - Tweet using a certain hashtag
- Can integrate with diverse services
  - Blogging – Blogger, Tumblr, Weebly
  - Business – LinkedIn, Square, Stocks
  - Commerce – Craigslist, Home Depot
  - Connected Home – D-Link, Amazon Alexa, Nest Thermostat, Wemo devices (coffeemaker, heater, humidifier,)
  - Mobile – Android Phone call, photos, SMS
  - Productivity – Google Drive, Dropbox, OneNote, Evernote
- Easy to integrate with hardware devices



https://ifttt.com/recipes

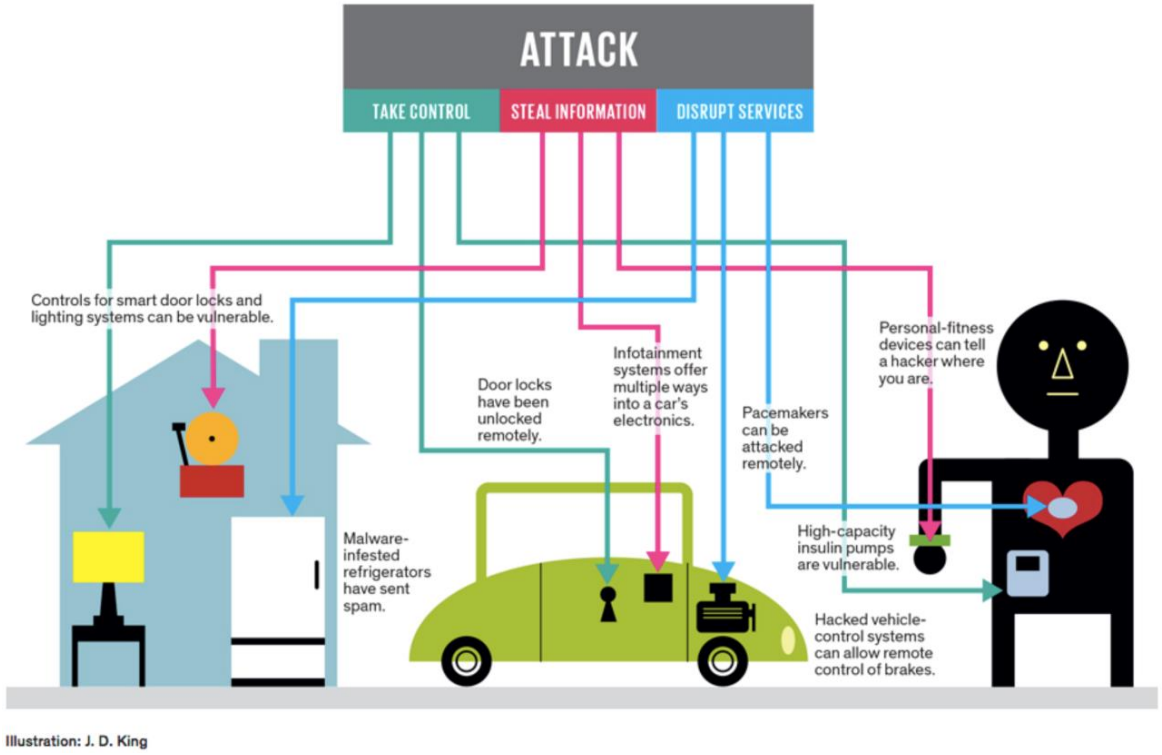
IoT Challenges – Big Data

- Data privacy, governance, and compliance issues
- Data complexity
- Defining what Big data is and how can it help the business
- Integrating legacy system with big data technology
- Lack of big data skills (internally, or ability to hire)
- The cost of big data tools

https://jaxenter.com/actian-112215.html

IoT Challenges - Security

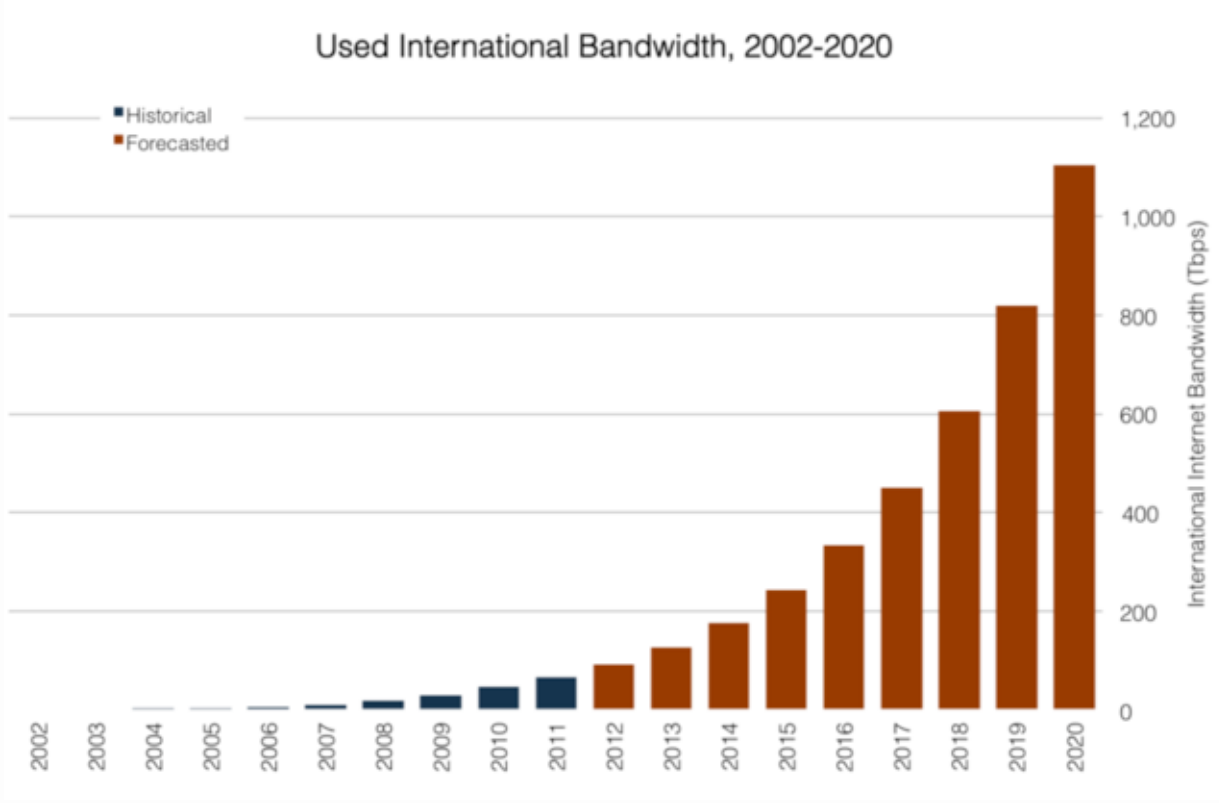
- Usable Security
  - How do we make security solutions usable, scalable, manageable and non-intrusive?
- Privacy
  - How we do we make users feel comfortable using network services?
- Infrastructure & Service Protection
  - Technical security solutions for the networked society's "threat landscape"



www.pubnub.com/blog/2015-05-04-10-challenges-securing-iot-communications-iot-security/

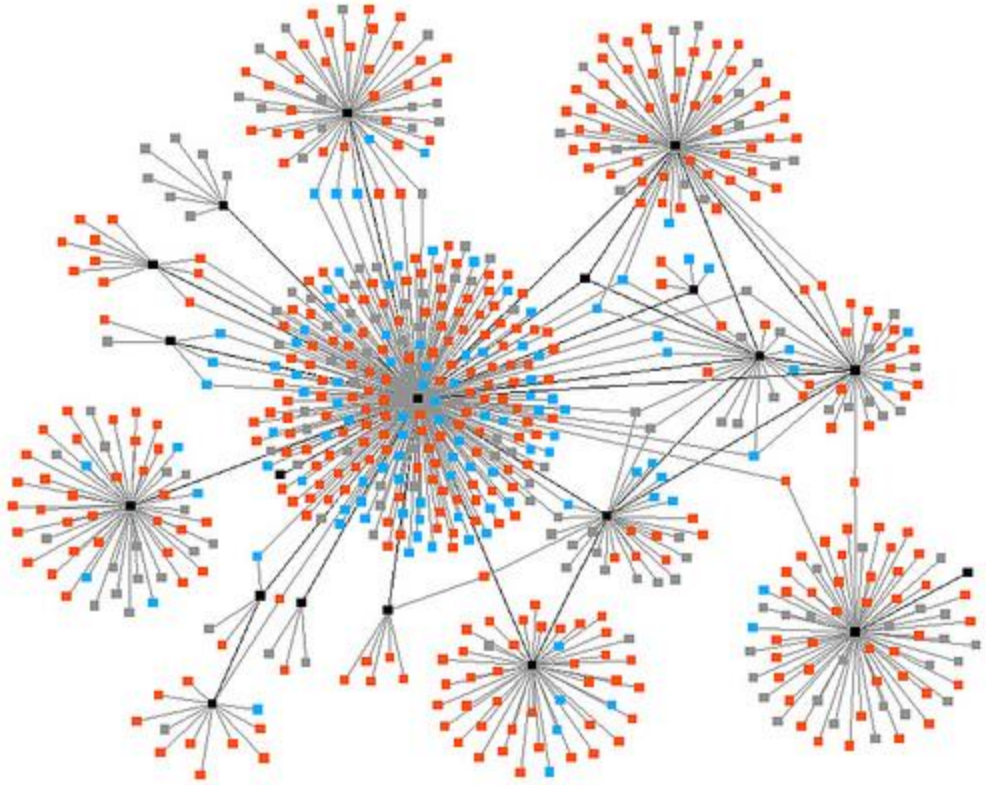
IoT Challenges – Bandwidth & Power Consumption

- International bandwidth availability has soared
- From 1.4 Tbps in 2002, it steadily climbed to 6.7 Tbps in 2006 and has now reached 92.1 Tbps.
- TeleGeography expects that number to hit 606.6 Tbps in 2018 and 1,103.3 Tbps in 2020.

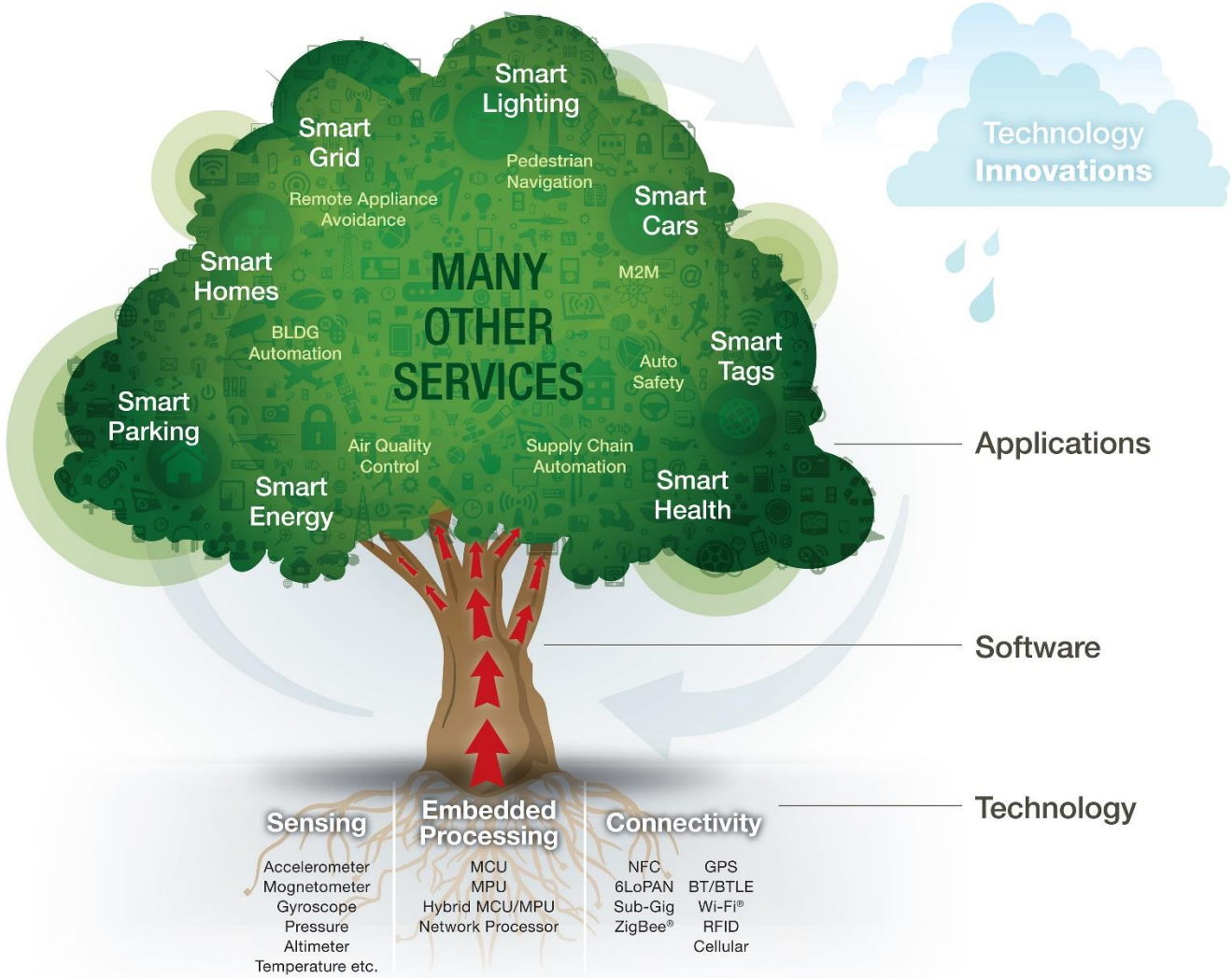


IoT Challenges - Complexity

- The maintenance of central control over all the resources, goals and behaviors becomes complex to manage.
- Adding the new opportunities and features of social, mobile, big-data, poly-analytics and cloud, the complexity starts increasing faster than ones ability to manage it centrally.
- There will be 6.4 billion connected things in use during 2016, a 30% increase on the previous year.



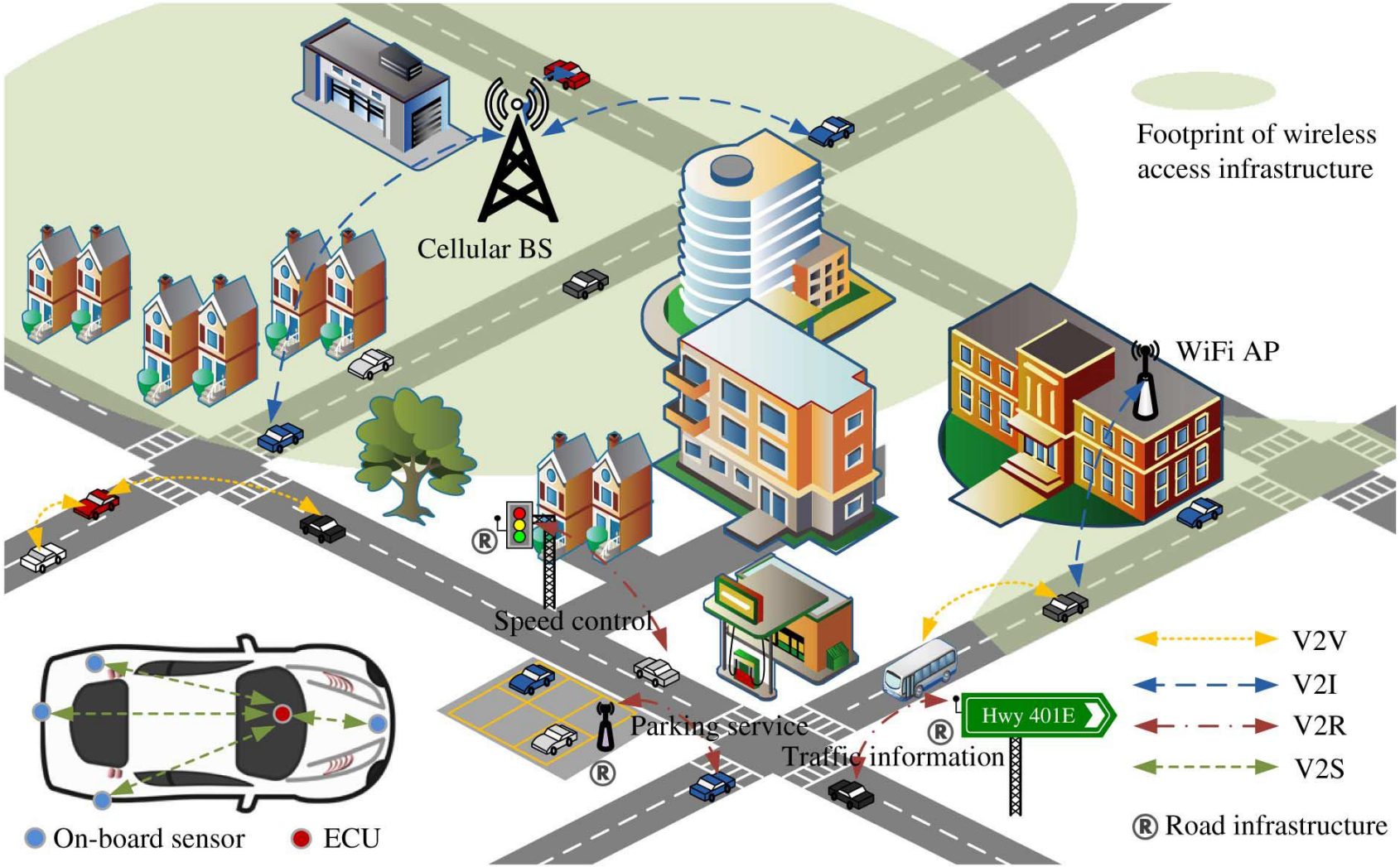
IoT - Opportunities



IoT Applications - Infrastructure

- Improving infrastructure
- Creating more efficient and cost effective municipal services
- Enhancing public transportation
- Reducing traffic congestion
- Keeping citizens safe and more engaged in the community.

IoT Applications – Connected Vehicles



Source: Connected Vehicles: Solutions and Challenges

IoT Applications - Healthcare

- Patient monitoring and diagnostics
- Information and data transfer, storage, and collaboration
- Intelligent healthcare devices and tools (smart wheelchair, RFID, sensors)
- Connected emergency units, response vehicles, and hospitals

IoT Applications – Smart World