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BIG DATA and AI
for business

Internet of Things

Decisions, Operations & Information Technologies
Robert H. Smith School of Business
Fall, 2020

Internet of Things

Introduction, History, and Technology

Why Internet of Things?

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- https://www.youtube.com/watch?v=x-tgoXncKh4
- https://nest.com/smoke-co-alarm/overview/#meet-nest-protect

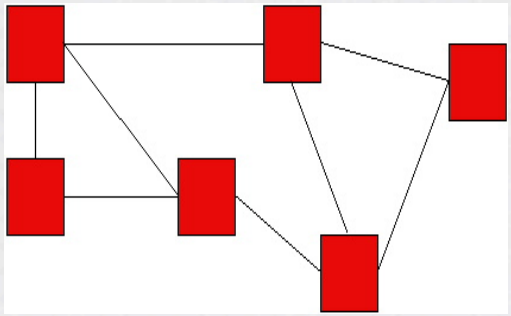
Basics of Network

- How data get transferred over the net
- What is TCP/IP
- Difference between Internet and the Web
- Network neutrality

Data Communication and Networking

- With only two nodes, mostly EE issues.

- With more than two nodes, more complex



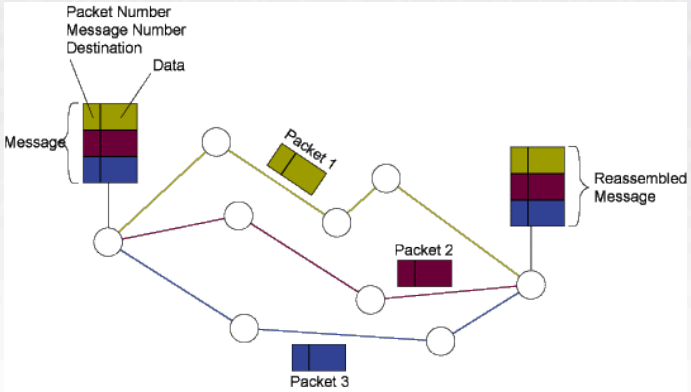
- Target: Improve Channel Utilization and Quality of Service
- Protocols (rules for using the channel): TCP/IP, UDP...
  - A set of rules and procedures to control the flow of data between points

Beyond the local network: Naming and addressing

- Most common: IP (Internet Protocol)
- IPv4 (current standard)
  - 4 byte address (ex: 130.91.161.162)
  - Mapped to a “domain name” or “host name” via the Domain Name System (DNS) (ex: rhsmith.umd.edu)
  - 4 billion possibilities, so why are we running out of addresses?
- IPv6 – 16 byte address
  - 1500 addresses per square foot on earth

On top of IP: TCP (Transmission Control Protocol)

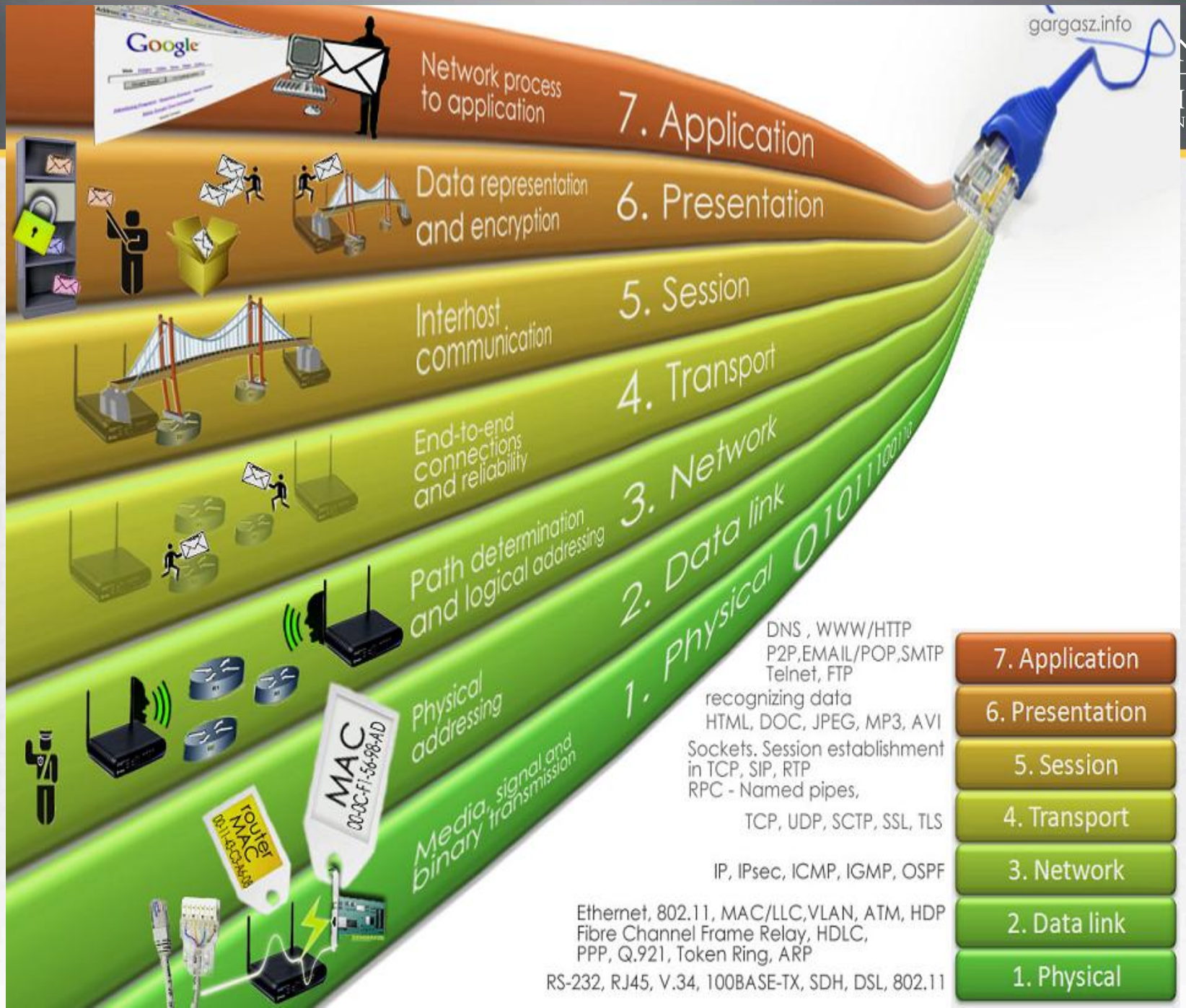
- Critical features
  - Defines two "ports" which represent services at the sending and receiving machine
  - Provides a "checksum" for the data to ensure integrity
  - Defines a sequence number for reassembling fragmented packets
  - Protocol can identify lost or damaged packets and request new ones



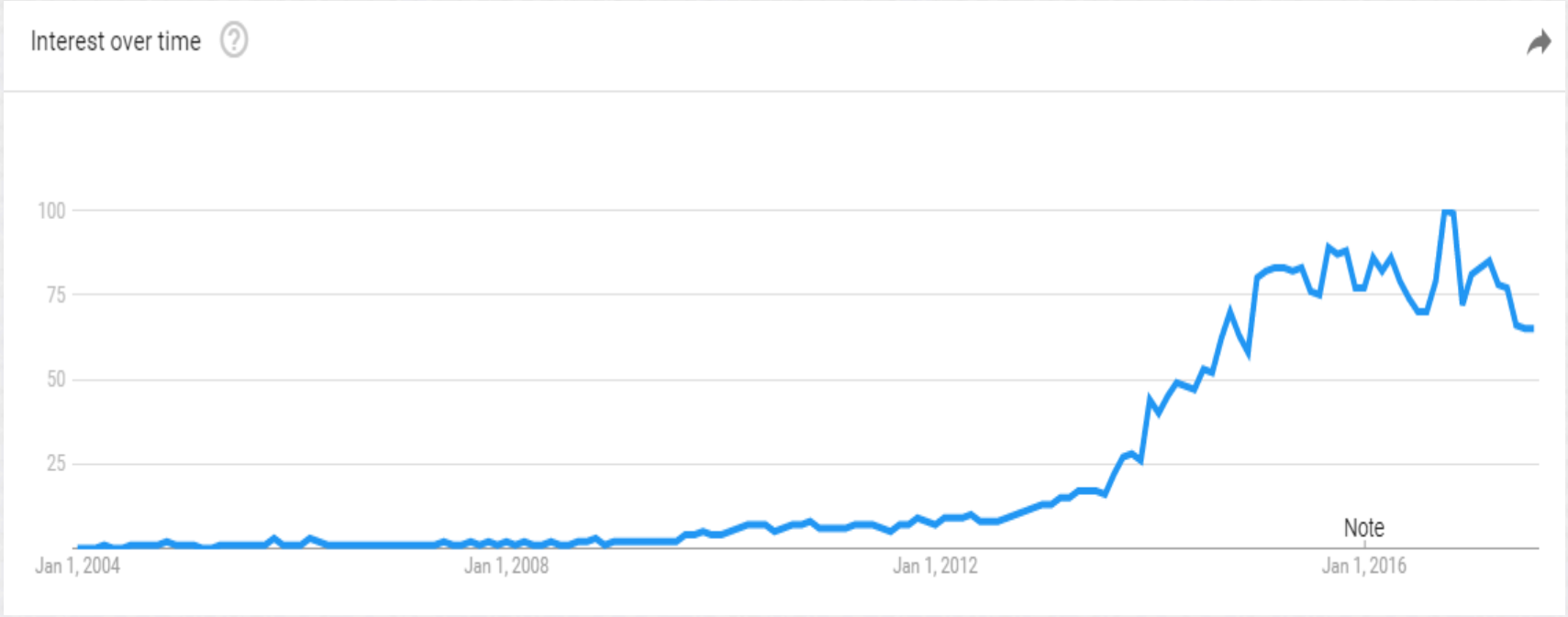
On top of TCP: Applications such as the Web, FTP, VOD

The Web is a system using HTTP (Hypertext Transfer Protocol) for storing, retrieving, formatting, and displaying information in a (client-server) networked environment.

- Basic unit: Web pages
- Locate the pages: URL (Universal Resource Locator)
- Linking the pages: Hyperlinks embedded in webpages
- Showing the pages:
  - HTML (Hypertext Markup Language)
  - Browser (like Firefox, Chrome)


gargasz.info
Google
Network process to application
7. Application
Data representation and encryption
6. Presentation
Interhost communication
5. Session
End-to-end connections and reliability
4. Transport
Path determination and logical addressing
3. Network
Physical addressing
2. Data link
Media, signal and binary transmission
1. Physical
MAC
router MAC
DNS , WWW/HTTP
P2P,EMAIL/POP,SMTP
Telnet, FTP
recognizing data
HTML, DOC, JPEG, MP3, AVI
Sockets. Session establishment
in TCP, SIP, RTP
RPC - Named pipes,
TCP, UDP, SCTP, SSL, TLS
IP, IPsec, ICMP, IGMP, OSPF
Ethernet, 802.11, MAC/LLC,VLAN, ATM, HDP
Fibre Channel Frame Relay, HDLC,
PPP, Q.921, Token Ring, ARP
RS-232, RJ45, V.34, 100BASE-TX, SDH, DSL, 802.11
7. Application
6. Presentation
5. Session
4. Transport
3. Network
2. Data link
1. Physical

The buzz of IoT



Source: Google Trends

"In God we Trust, all others bring data" -- W. Edwards Deming

IoT on the rise

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- To help put the amount of IoT devices into context, consider that Ericsson predicts that the amount of **IoT devices will surpass mobile devices** by next year.
- Research firm **Gartner** says that IoT devices have increased 31% from 2016 to 2017, hitting **8.4 billion** connected "things" this year, and that **the number will surge to 20.4 billion by 2020**.
- Spending on IoT devices and services will reach **nearly $2 trillion this year**. That spending will mostly be spread across North America, China, and Western Europe, where about 67% of IoT devices exist.

Table 1: IoT Units Installed Base by Category (Millions of Units)

Category	2016	2017	2018	2020
Consumer	3,963.0	5,244.3	7,036.3	12,863.0
Business: Cross-Industry	1,102.1	1,501.0	2,132.6	4,381.4
Business: Vertical-Specific	1,316.6	1,635.4	2,027.7	3,171.0
Grand Total	**6,381.8**	**8,380.6**	**11,196.6**	**20,415.4**

Table 2: IoT Endpoint Spending by Category (Millions of Dollars)

Category	2016	2017	2018	2020
Consumer	532,515	725,696	985,348	1,494,466
Business: Cross-Industry	212,069	280,059	372,989	567,659
Business: Vertical-Specific	634,921	683,817	736,543	863,662
Grand Total	**1,379,505**	**1,689,572**	**2,094,881**	**2,925,787**

Source: Gartner

Nest Learning Thermostat

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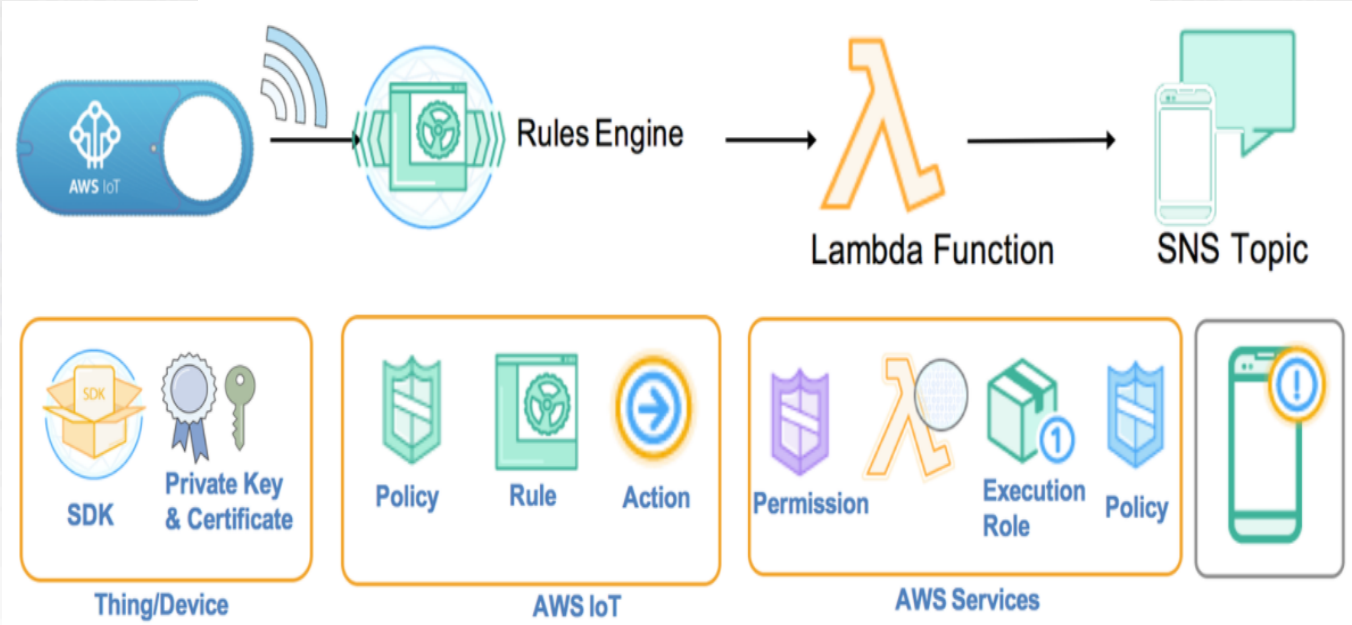
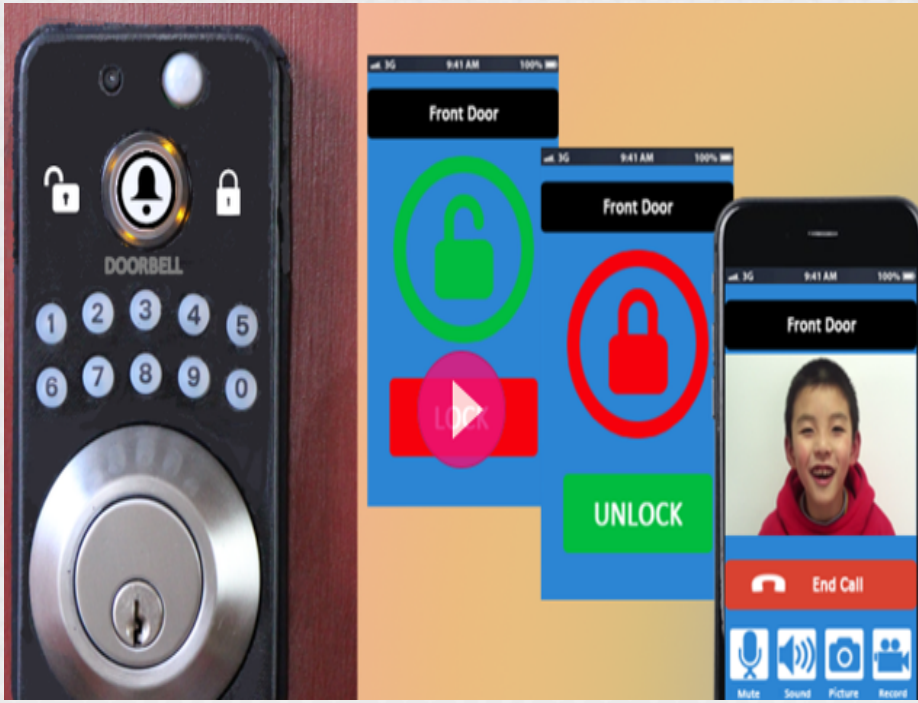
Philips Hue

16 million colors, 50,000 shades of white

AWS dash buttons



Door control



Mobile Personal Emergency Response System (PERS)

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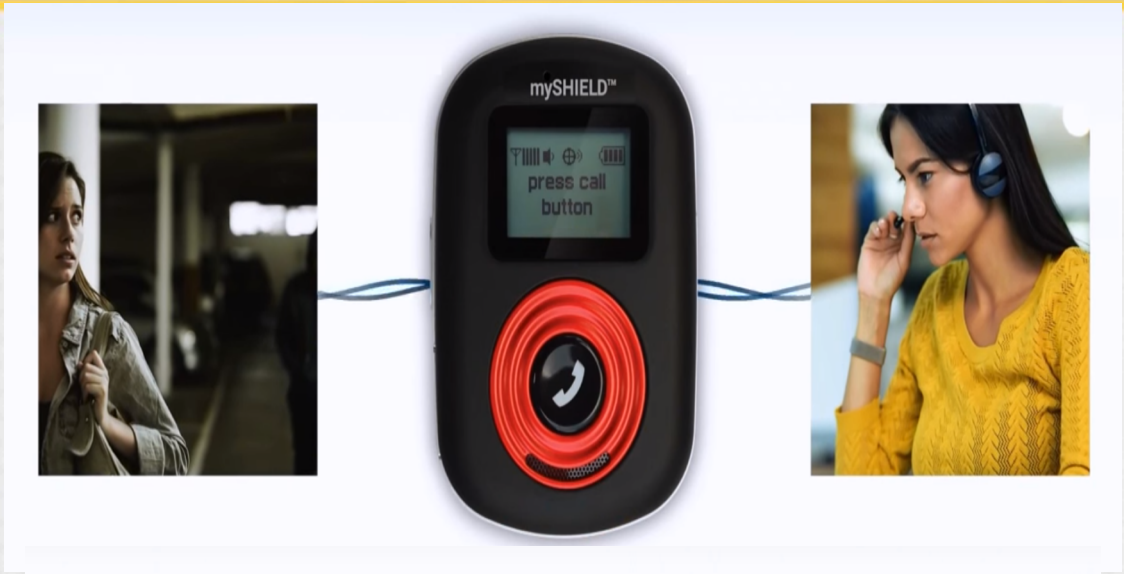

- LG Smart ThinQ: https://www.youtube.com/watch?v=SMeV9YFggfw

- Gartner recently reported a typical family home may contain more than 500 smart devices by 2022 (Gartner news, Sep 8, 2015).

Smart city

- 

https://www.youtube.com/watch?v=Br5aJa6MkBc

Intent of Things
IoT and business

Definition of IoT

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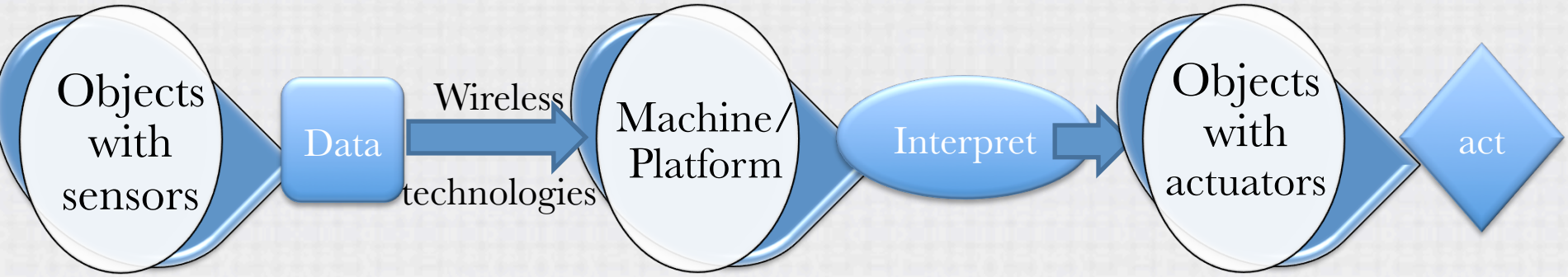
- The internet of things (IoT) is a computing concept that describes the idea of everyday physical objects being connected to the internet and being able to identify themselves to other devices. --techopedia.com
- The Internet of Things (IoT) is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment. -- gartner.com
- The Internet of Things (IoT) is the inter-networking of physical devices, vehicles (also referred to as "connected devices" and "smart devices"), buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data. – Wikipedia
- Internet of Things = "Sensors and actuators embedded in physical objects are linked through wired and wireless networks, often using the same Internet Protocol (IP) that connects the Internet." -- McKinsey
- Internet of Things is a vision where every object in the world has the potential to connect to the Internet and provide their data so as to derive actionable insights on its own or through other connected objects. – "Enterprise IoT" by Naveen Balani

My definition of IoT

- **IoT device:** any device, which represents an object, connected to the Internet is an IoT device.
- **IoT:** IoT devices organized in a certain structure to perform some function.



- Question: Is your smartphone an IoT device?

History of IoT

- 1982 Early use cases/models: Coca Cola vender machine in Carnegie-Mellon University Computer Science department
- 1990 the first IoT device: toaster by John Romkey

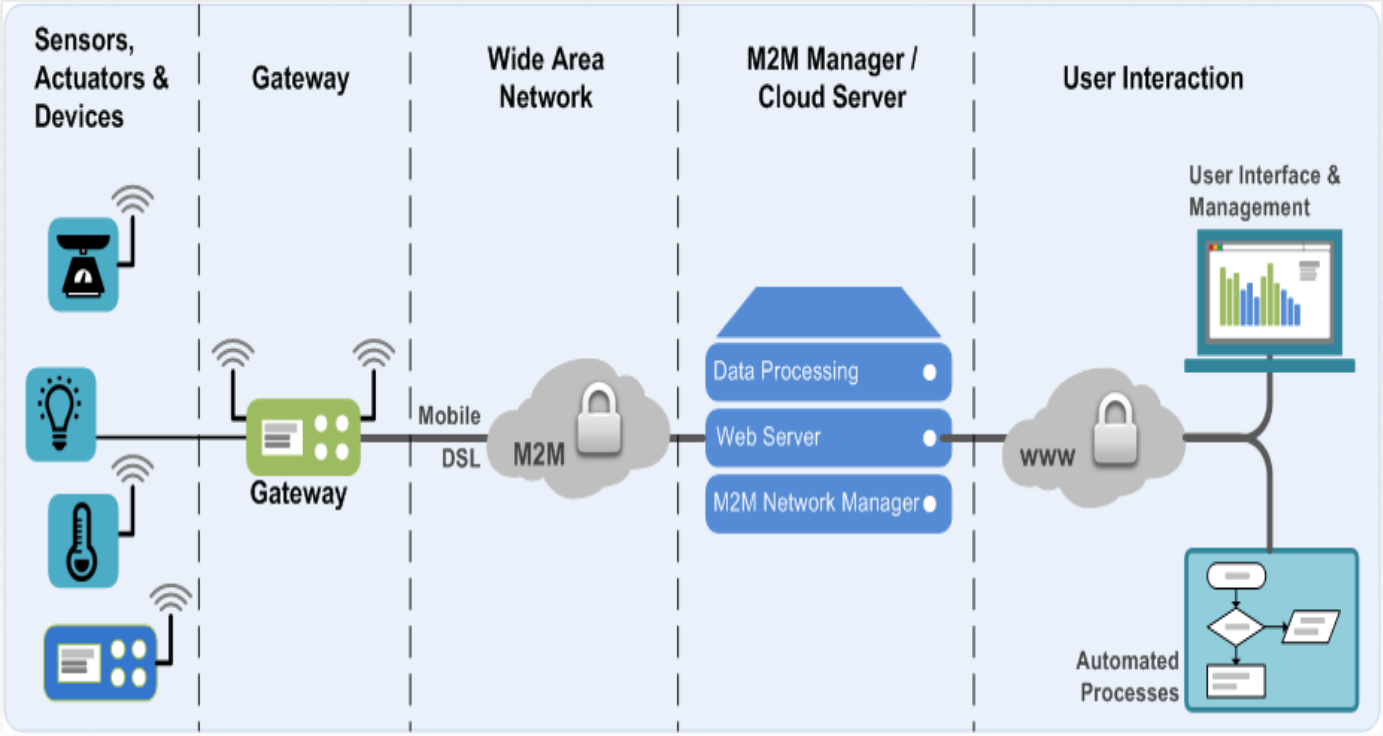
- 1993 the US government allowed civilians to use GPS
- 1999 The name of "Internet of Things" by Kevin Ashton
- 2008 According to Cisco Internet Business Solutions Group (IBSG), the Internet of Things was born in between 2008 and 2009 at simply the point in time when more "things or objects" were connected to the Internet than people: born of IoT
- 2010 two former Apple engineers started Nest Labs, the company that produces smart thermostats and smoke detectors. (acquired by Google in 2014 for $ 3.2 billion)
- 2010 Google launched their self-driving car concept, taking a huge leap forward in the development of connected and autonomous cars.
- 2014 the number of mobile devices and machines exceeds the world population

Important driving forces of IoT

- IPV6
  - 2011 IPV6 - IPV4: 4,294,967,296 addresses, IPV6: 340,282,366,920,938,463,463,374,607,431,768,211,456. 340 undecillion, which is the equivalent of 3,4 with 38 zeros.
  - There are about 7.2 * 10^24 addresses per square feet, all over surface area of the earth.
- Big data technologies

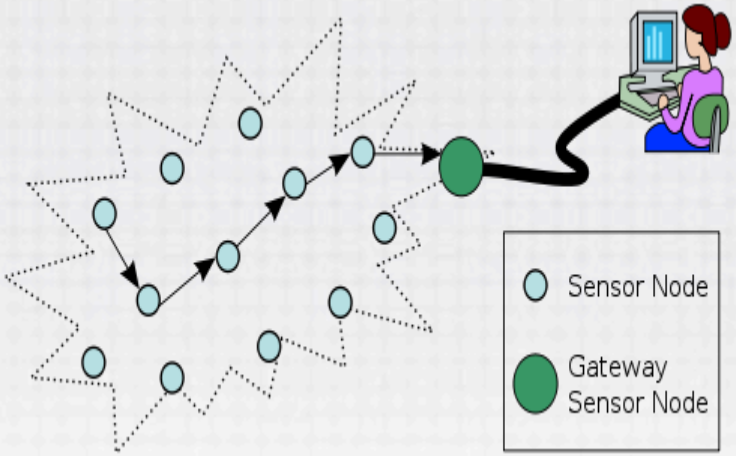
IoT technology ecosystem

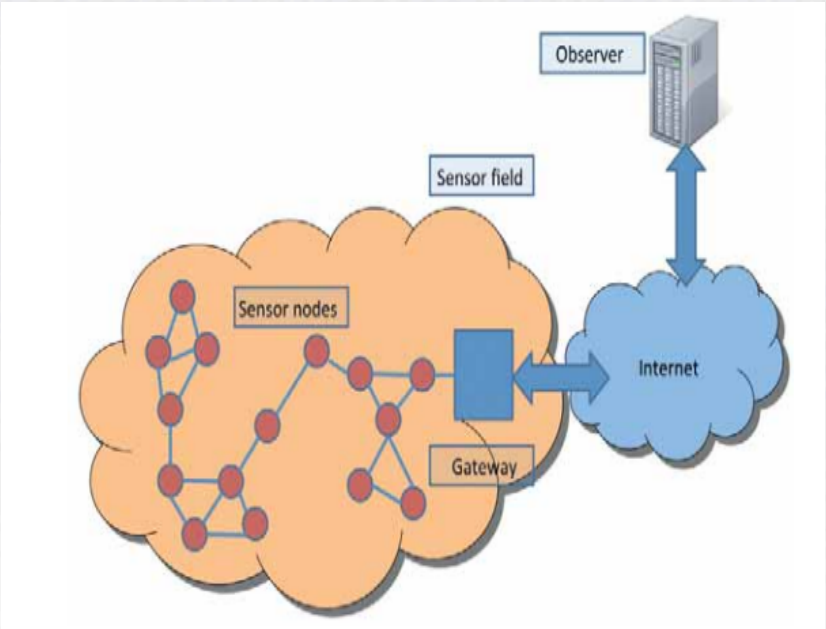
- data acquisition, data transport, and data analysis



Wireless sensor networks (WSN), or wireless sensor and actuator networks (WSAN)

- Between data acquisition and data transport there is a Connected Device Platform (CDP). The CDP, sometimes referred to as middleware, ensures that the devices and sensors can be easily connected





Source: http://www.ni.com/white-paper/7142/en/ Source: International Electrotechnical Commission http://www.iec.ch/whitepaper/pdf/iecWP-internetofthings-LR-

Data transport: Wireless technologies

- RFID
- Bluetooth and BLE
- Near-Field Communication (NFC)
- Infrared radiation
- ZigBee

- Wifi
- WiMax

- Cellular
- Satellite signals
- …

NFC vs. RFID vs. Infrared vs. Bluetooth

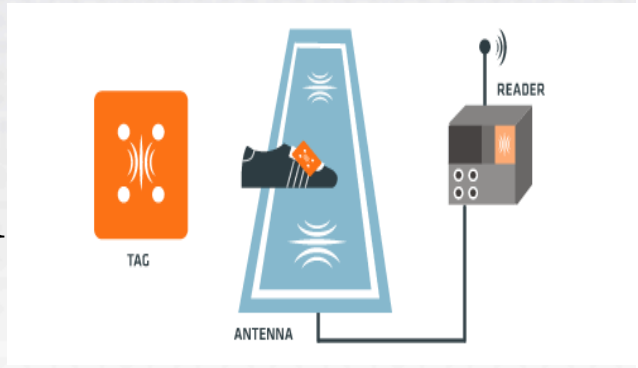
	NFC	RFID	IrDa	Bluetooth
Set –up time	<0.1ms	<0.1ms	~0.5s	~6 sec
Range	Up to 10cm	Up to 3m	Up to 5m	Up to 30m
Usability	Human centric Easy, intuitive, fast	Item centric Easy	Data centric Easy	Data centric Medium
Selectivity	High, given, security	Partly given	Line of sight	Who are you?
Use cases	Pay, get access, share, initiate service, easy set up	Item tracking	Control & exchange data	Network for data exchange, headset
Consumer experience	Touch, wave, simply connect	Get information	Easy	Configuration needed

WiFi vs. WiMAX

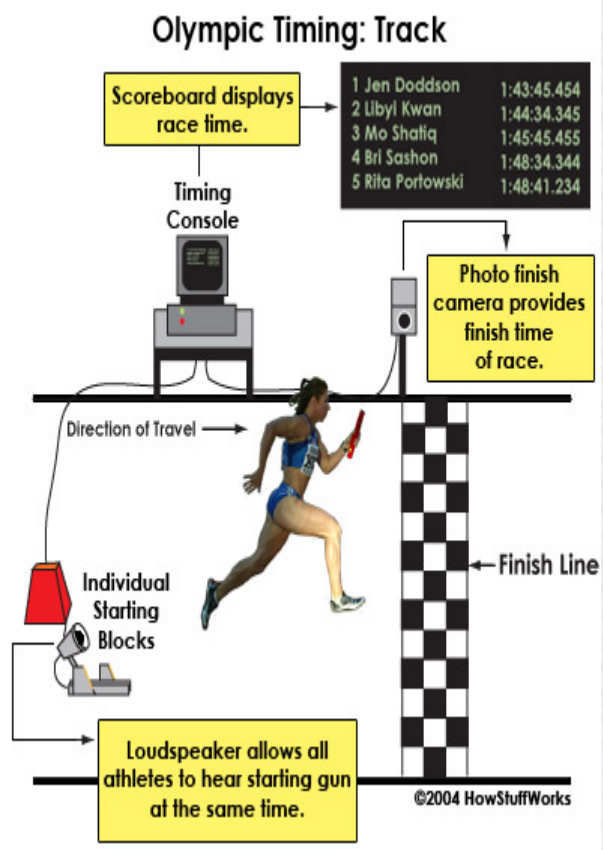
	IEEE 802.11	IEEE 802.16a
Max Speed	54Mbps (a&g)	10-100Mbps
Range	100m	40 km
QoS	none	yes
Coverage	Indoor	Outdoor
Users	Hundred	Thousand
Service Level	None	Yes

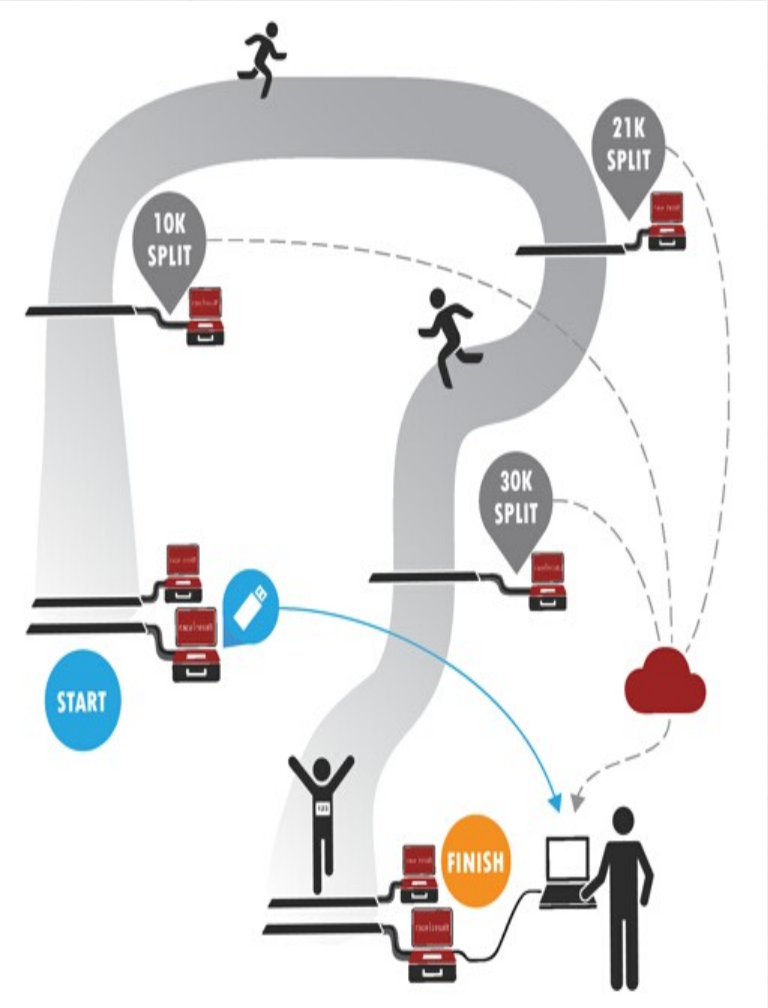
Radio-frequency identification (RFID)

- RFID in real world
  - Logistics & Supply Chain Visibility
  - Item level inventory tracking
  - Race timing
  - Attendee Tracking
  - Access Control
  - Asset Tracking
  - Library Systems
- RFID VS. Barcod



Two race timing technologies



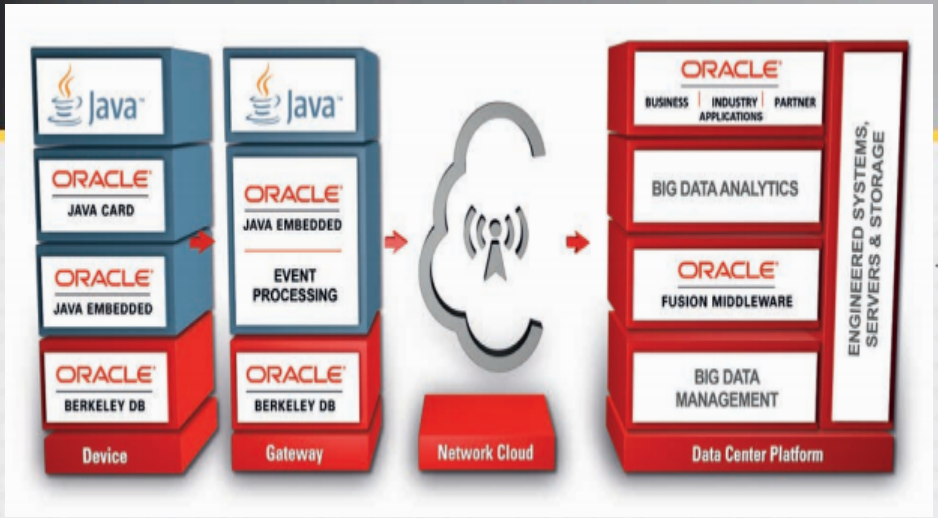


Application Enablement Platform (AEP)

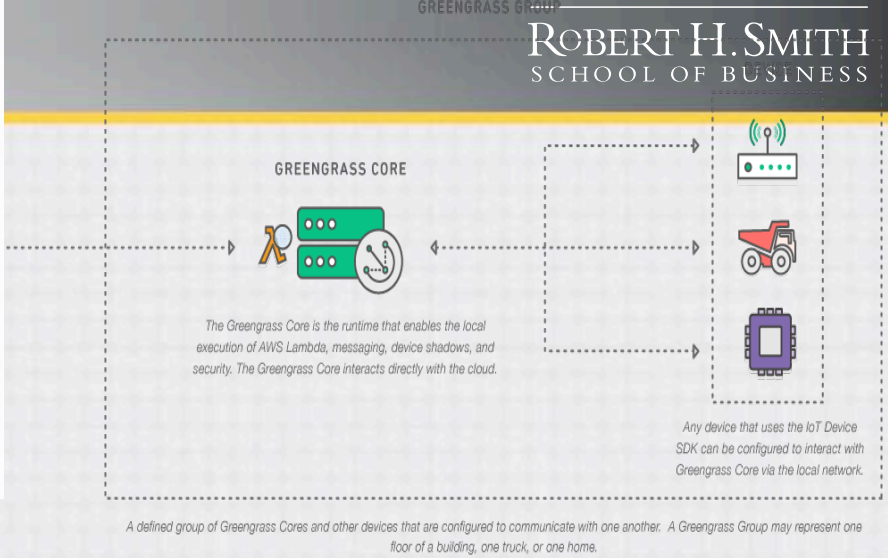
- Between data transport and data analysis there is an Application Enablement Platform (AEP). The AEP allows developers to produce applications that run using the data from connected devices. For example, an AEP will have well-defined APIs (Application Programming Interfaces) to the devices in the field.

- More than 300 IoT platforms in market

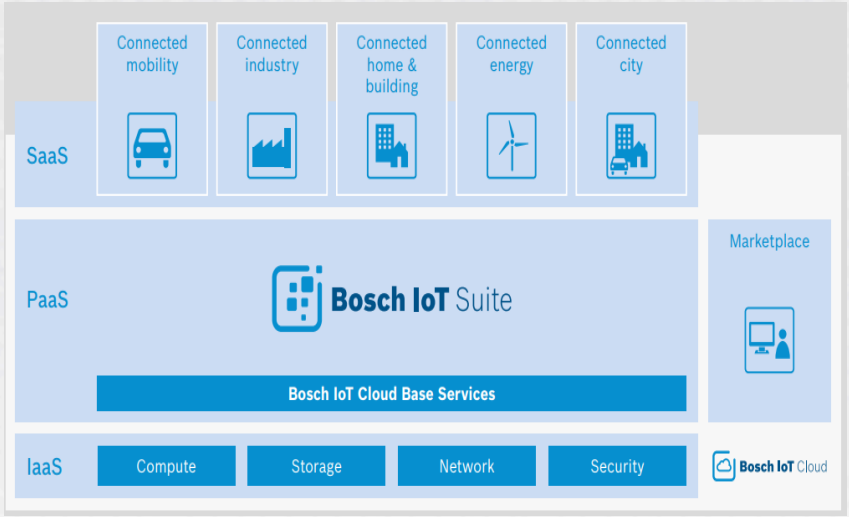
- Amazon: AWS Greengrass and AWS IoT
- Microsoft: Azure IoT Suite (video: https://youtu.be/L8xjSjxaaVA)
- Google: Google Cloud IoT (video: https://youtu.be/51bq_Yhuof4)
- IBM: Watson IoT
- Apple: HomeKit
- Cisco: Jasper
- Salesforce: IoT Cloud
- Bosch: Bosch IoT Suite
- SAP: SAP Cloud Platform
- Zebra: Zebra EAI Platform
- General Electrics: Predix—The Premier Industrial Internet Platform
- Comcast/Xfinity: icontrol networks (acquired)



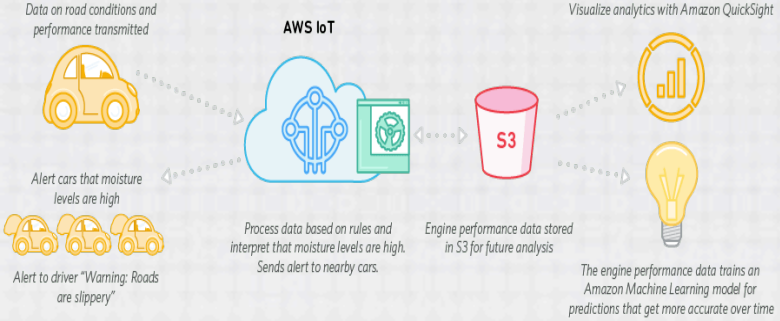
Oracle IoT



AWS Greengrass

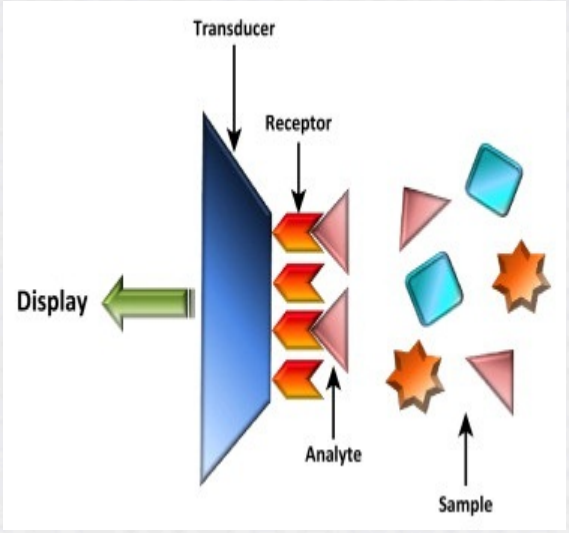


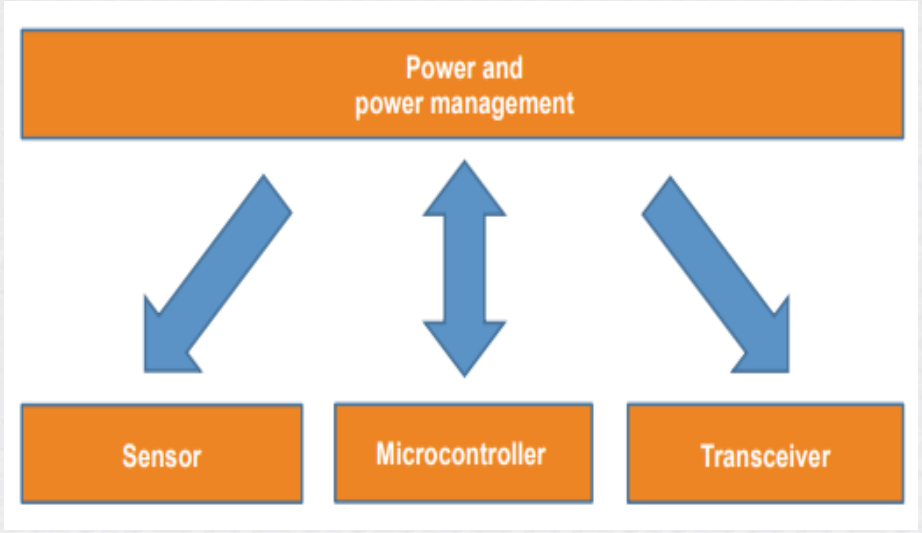
Bosch IoT Suite



AWS IoT

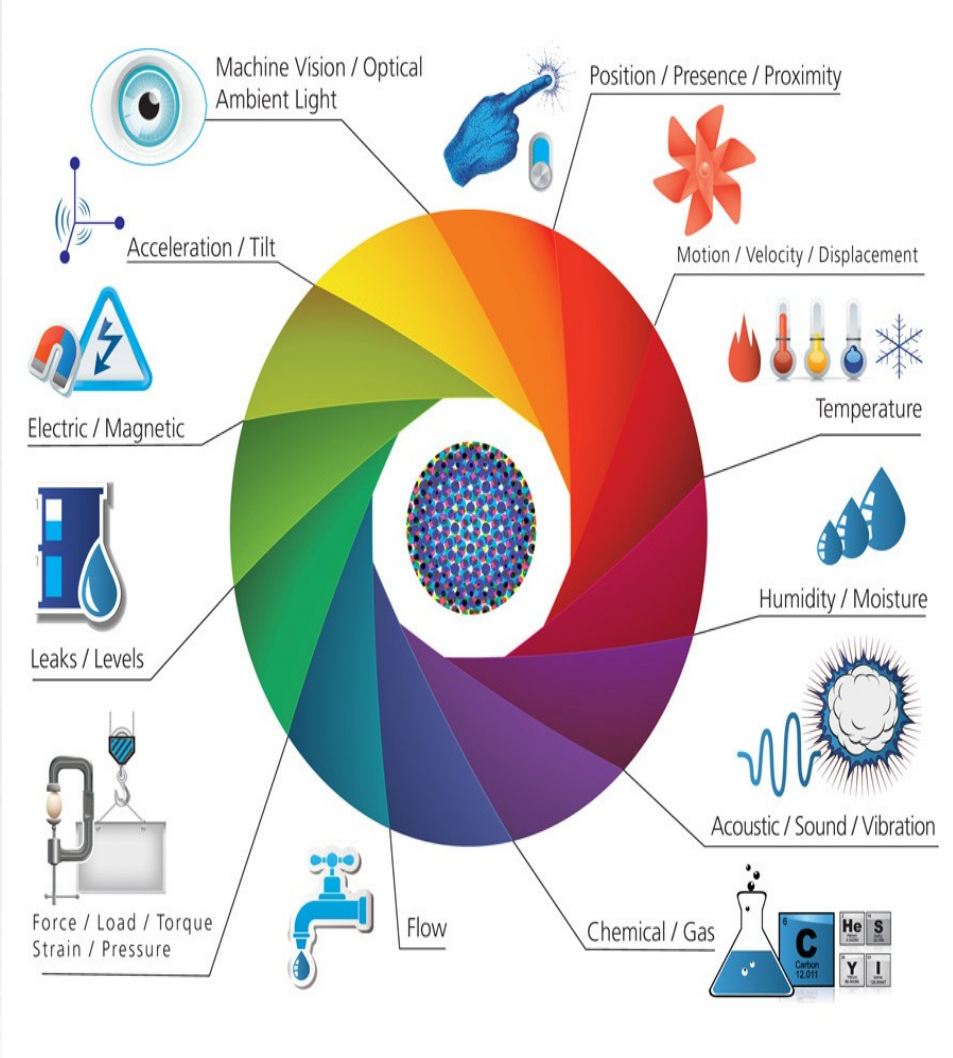
Sensor


Transducer
Receptor
Display
Analyte
Sample

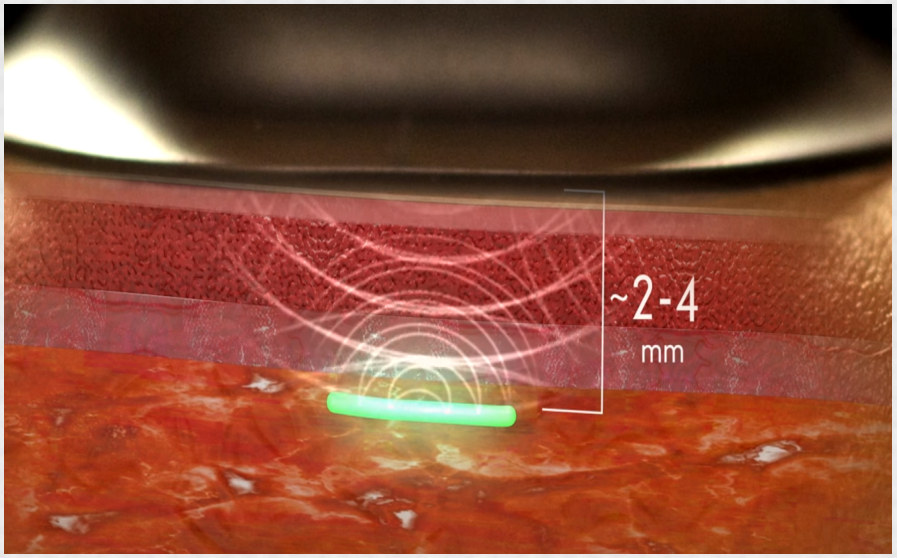

Power and
power management
Sensor
Microcontroller
Transceiver

What can be sensed by an IoT sensor?

- Electromagnetic
- Electrochemical
- Electromechanical
- Electroacoustic
- Electrooptical
- Electrostatic
- Thermoelectric
- Radioacoustic

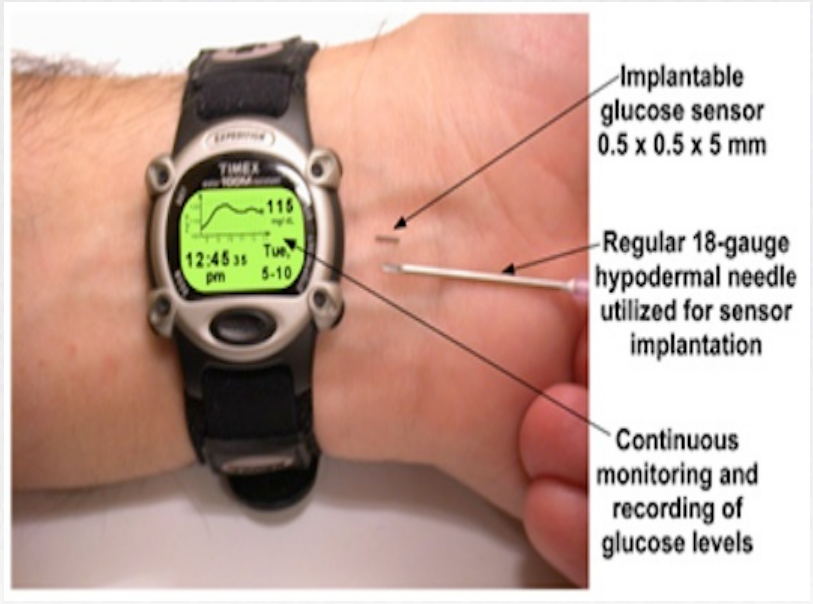


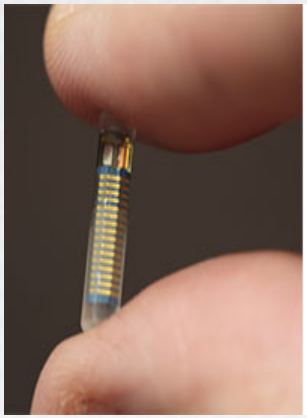
Measuring oxygen concentration



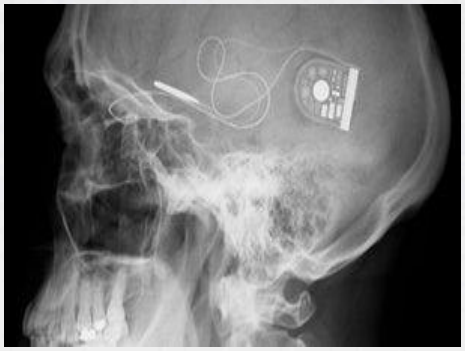
European CE Mark approved in Oct. 2016

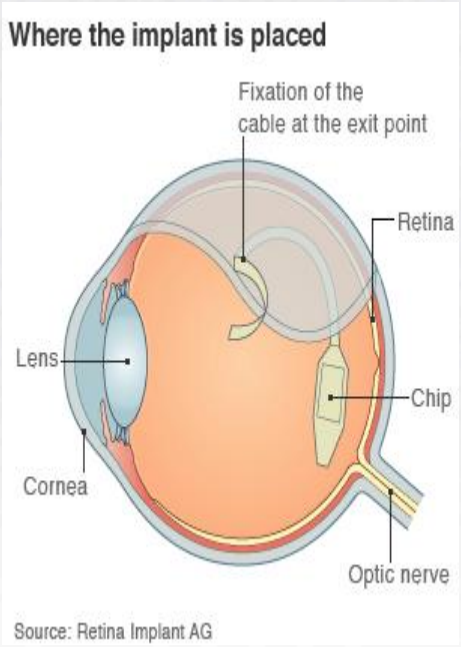
Blood glucose





- Two British men who have been totally blind for many years have had part of their vision restored after surgery to fit pioneering eye implants.





Challenges: Powering sensors

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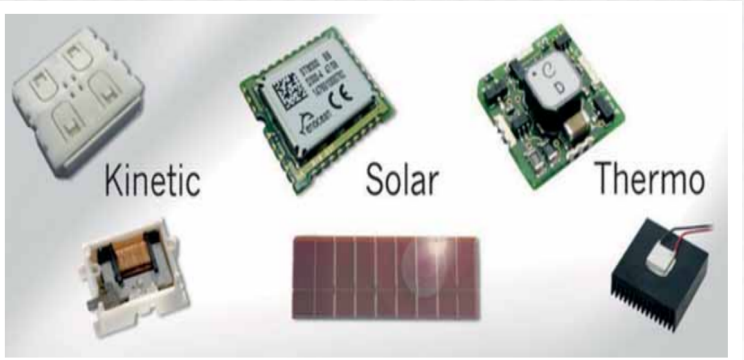
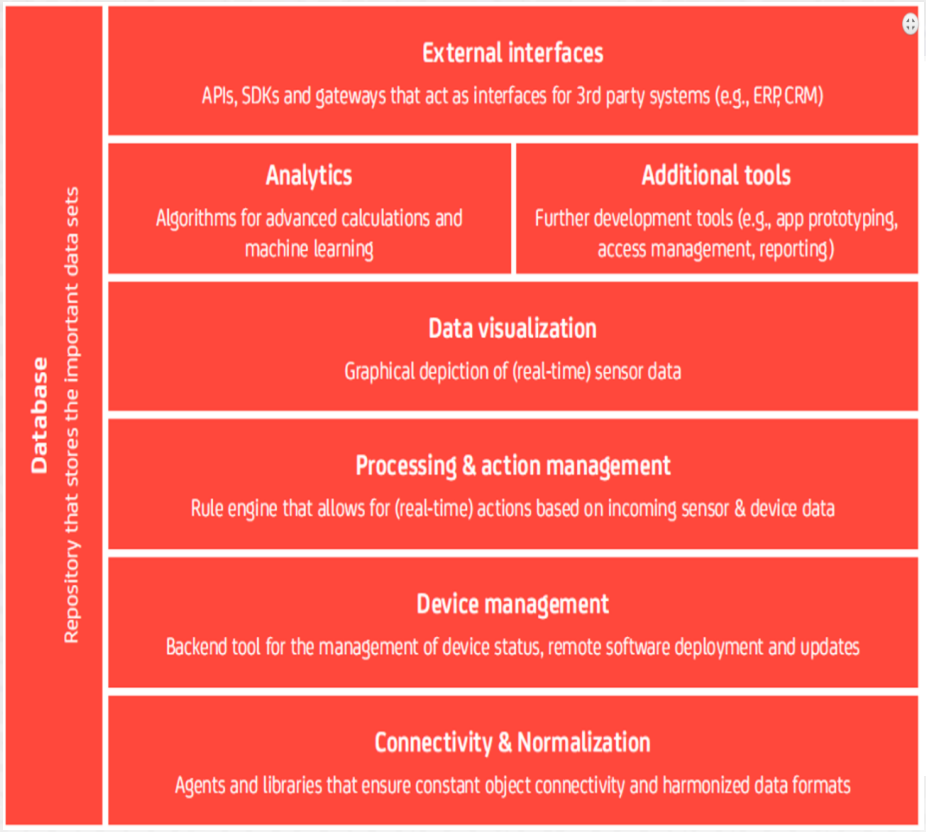
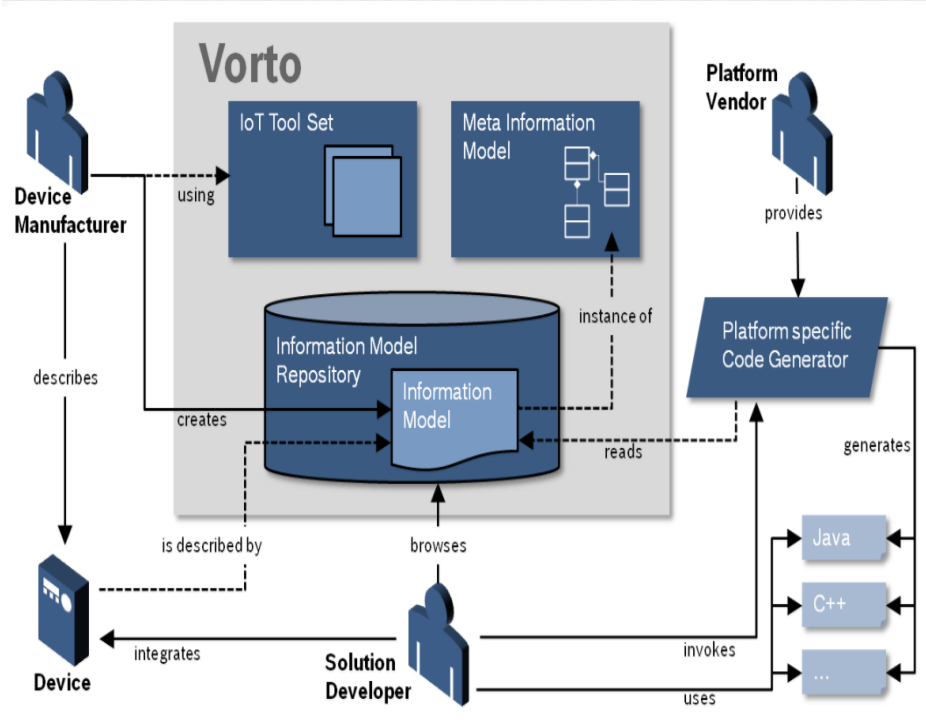
- Chemical batteries:
  - Lithium, Alkaline, Lead acid, Nickel
- Ambient energy harvesting technology:
  - Many ideas
  - Reducing the size of the device and, boosting its energy conversion ratio
- Wireless charging



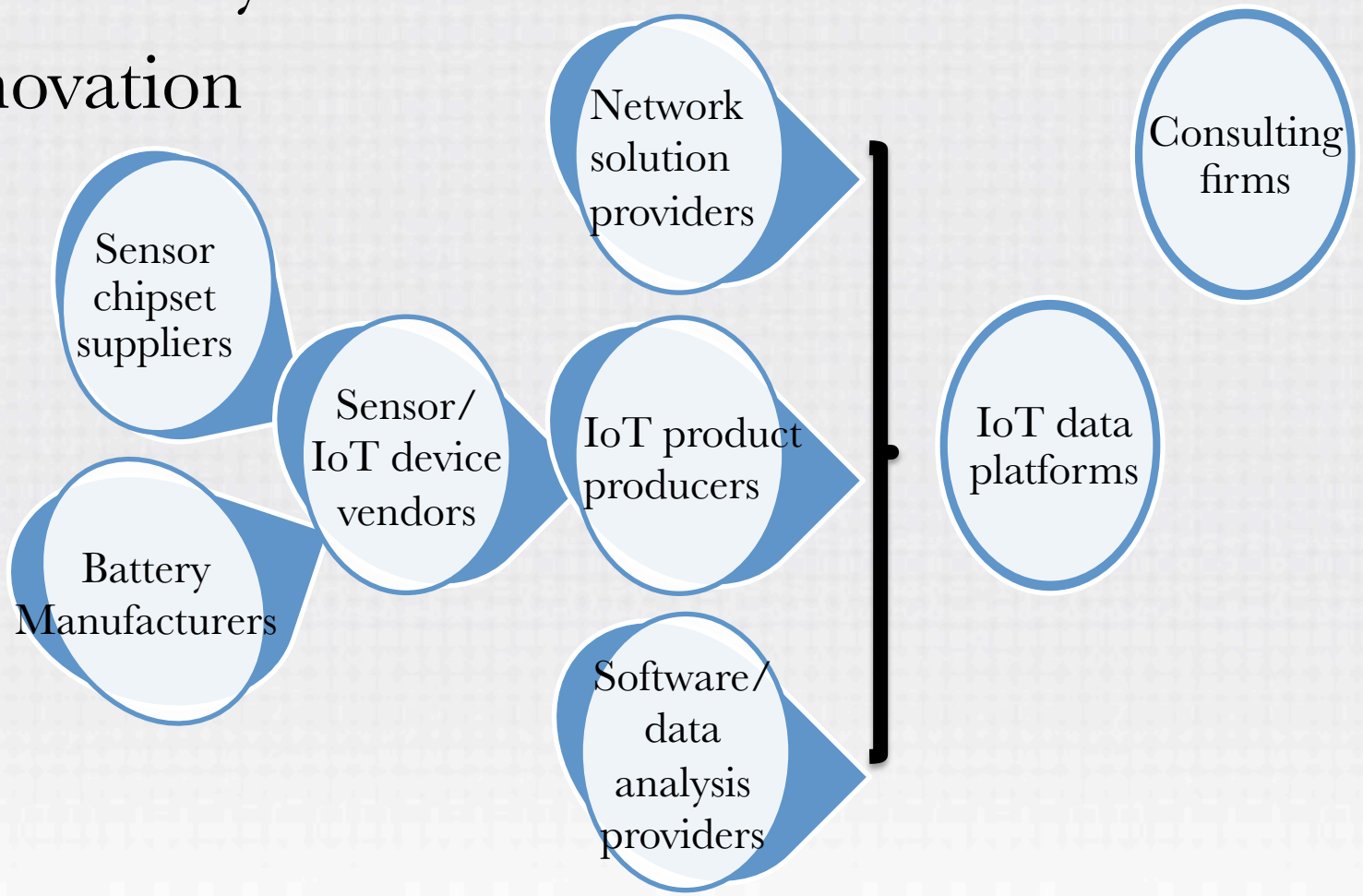
Challenges: IoT interoperability



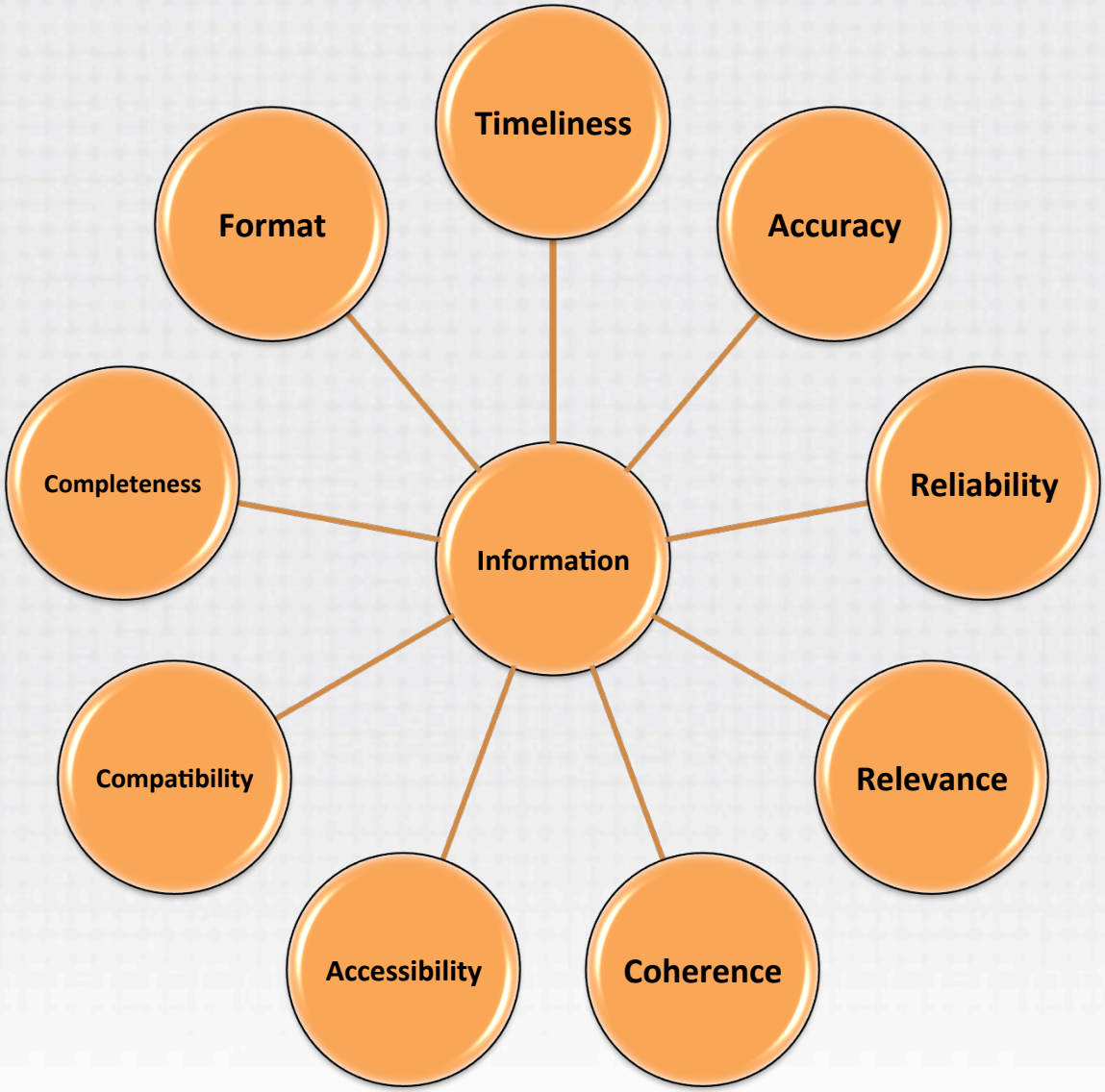


Business opportunities

- Profitability
- Innovation

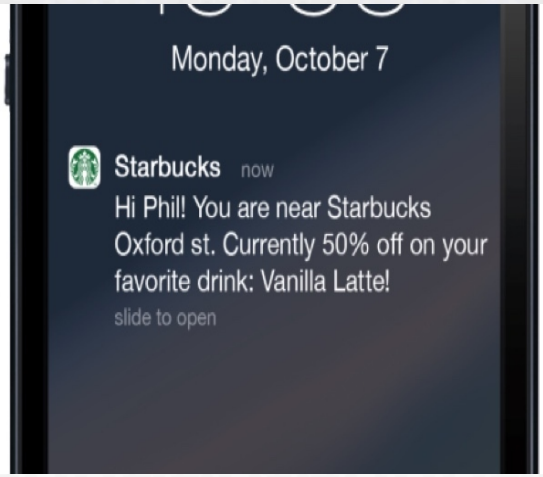


Business reshaped by IoT: a perspective



Use case of IoT

- Current use case
- Smarter operations
  - E.g. Amazon Go https://www.youtube.com/watch?v=NrmMk1Myrxc
- Smarter decisions
  - E.g. Location-based advertising: personalized, timely, targeted
- New business models (e.g. SaaS, PaaS)

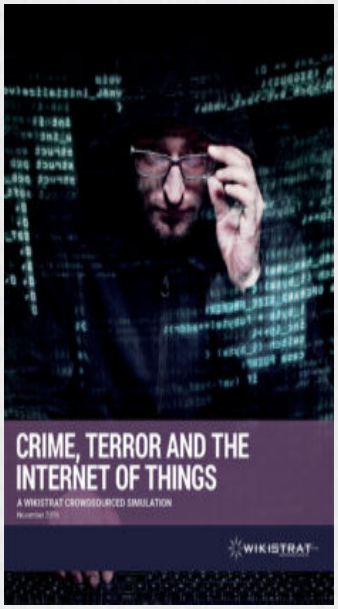


Location-Based Advertising (LBA)

Network Attached Storage (NAS)

Crimes and cyber security

New York Police Begin Using ShotSpotter System to Detect Gunshots



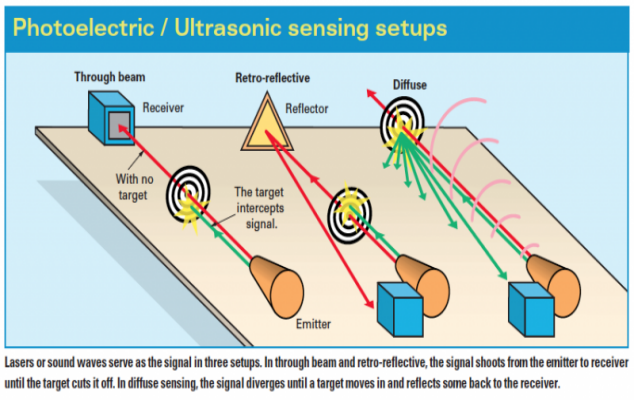
Marc Goodman has said, “When everything is connected, everyone is vulnerable.”

10 sensors in iPhone - optional

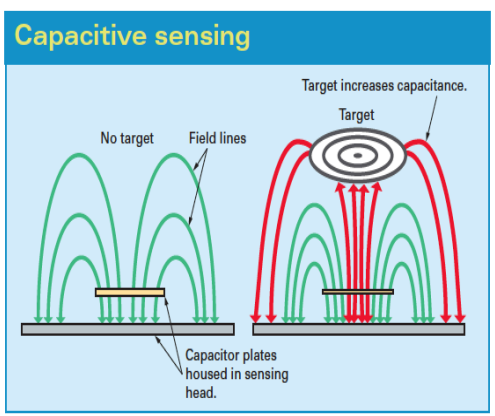
- Proximity sensor
- Ambient light sensor
- 12MP Camera
- Accelerometer
- Gyroscope
- Compass
- Barometer
- NFC chip for Apple Pay
- Touch ID fingerprint scanner
- Pressure sensitive display

Proximity sensor

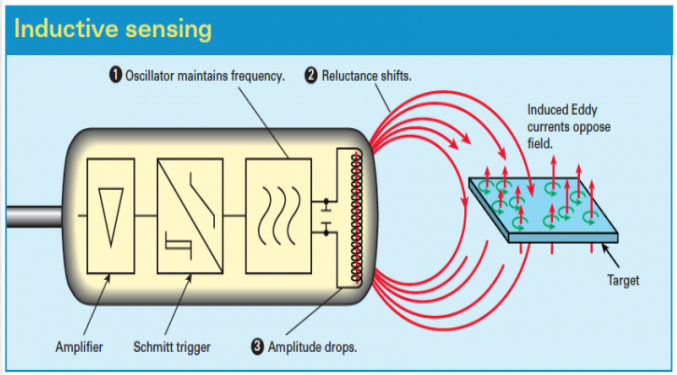
- For example, a capacitive or photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target.



Lasers or sound waves serve as the signal in three setups. In through beam and retro-reflective, the signal shoots from the emitter to receiver until the target cuts it off. In diffuse sensing, the signal diverges until a target moves in and reflects some back to the receiver.

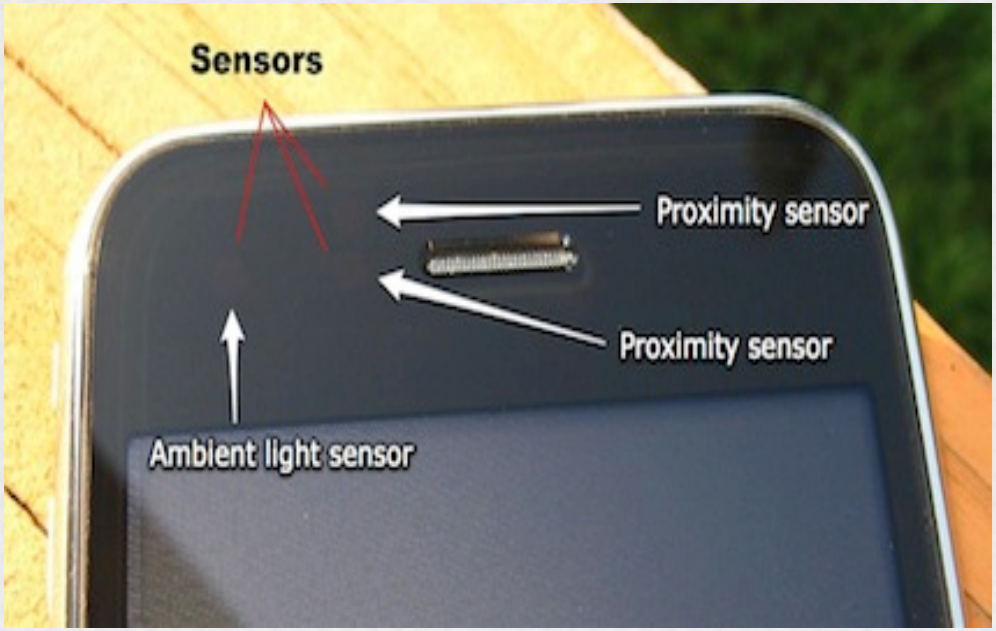


As a ferrous or nonferrous target enters the sensing zone, capacitance increases; circuit natural frequency shifts towards the oscillation frequency, causing amplitude gain.



Ferrous targets change the reluctance of the magnetic circuit; system oscillation frequency, which gets left behind when the natural frequency shifts, then loses amplitude.

Ambient light sensor



Accelerometer and Gyroscope

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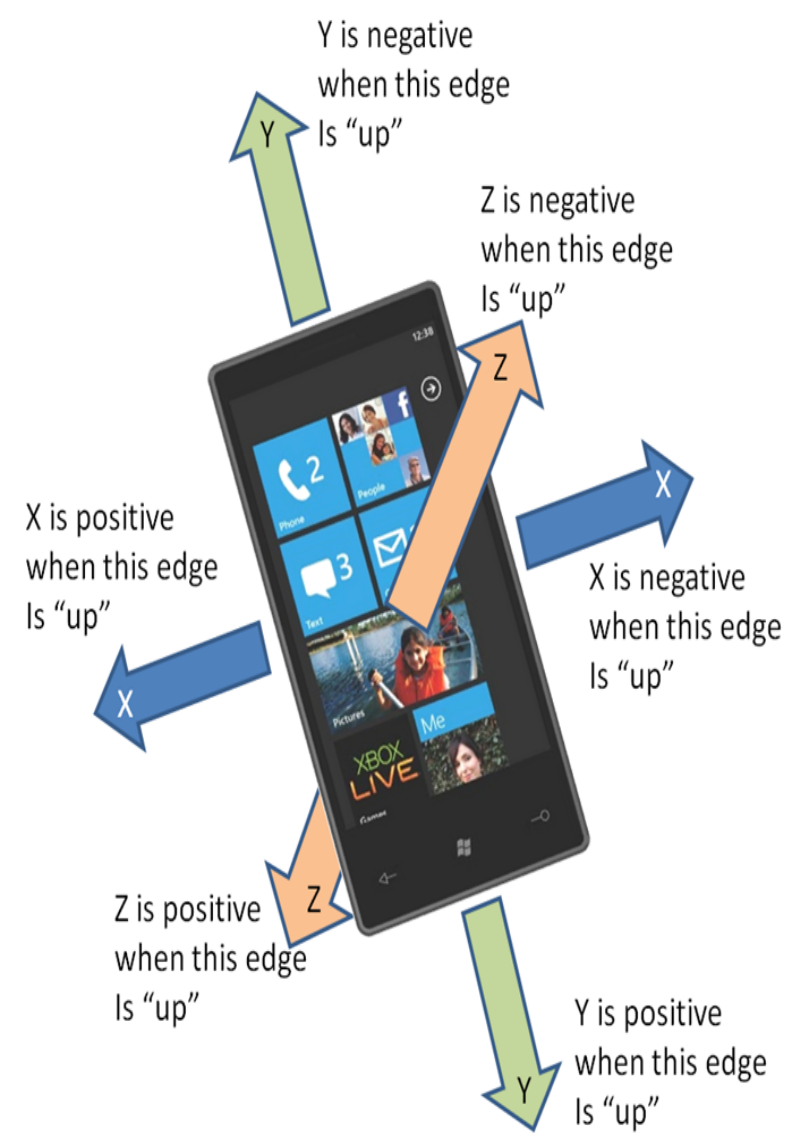
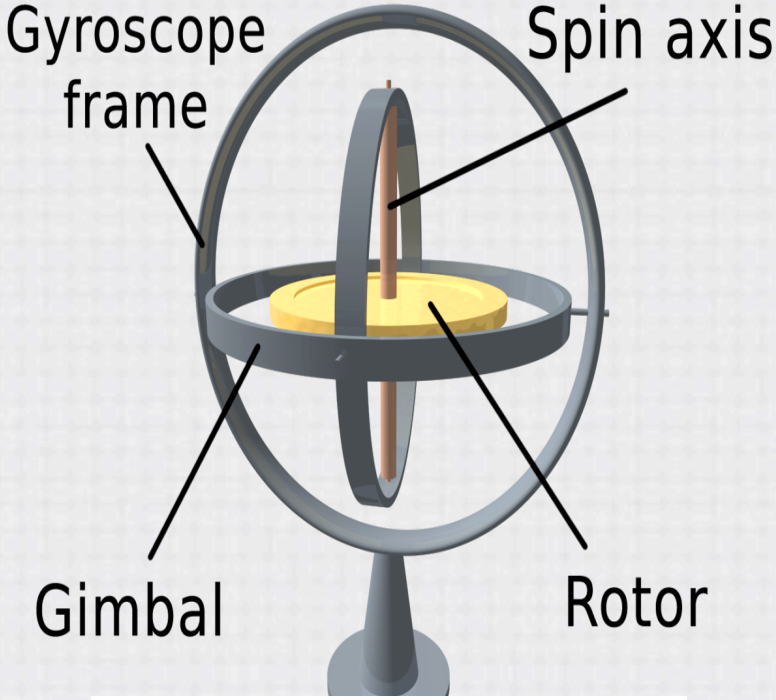
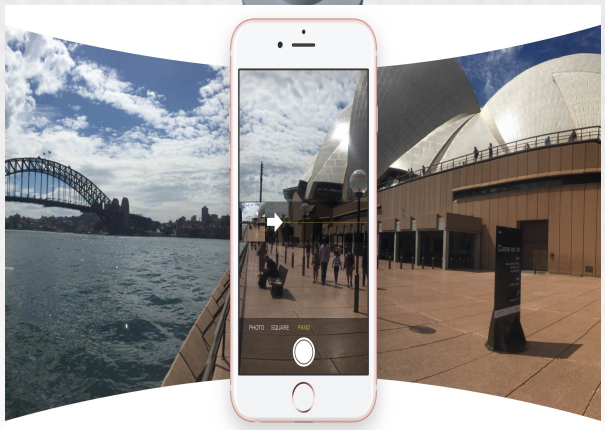
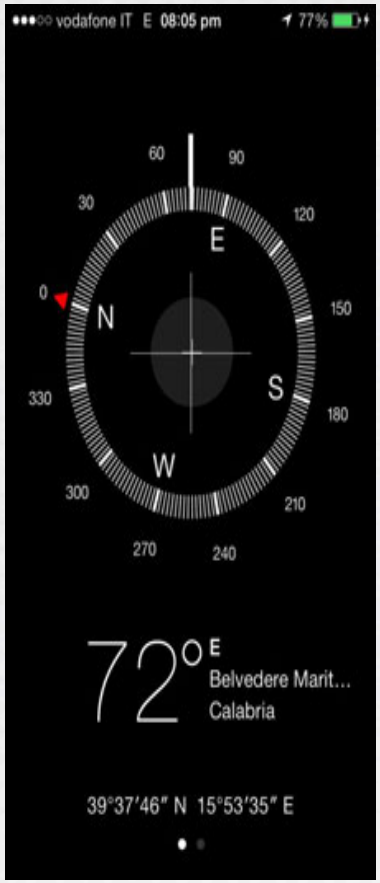
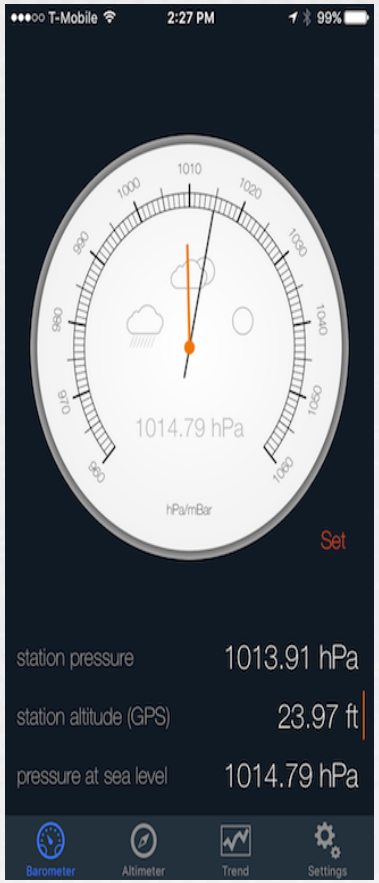






Compass and Barometer





NFC and Touch ID fingerprint scanners

Apple Pay

Google Wallet

There are more…

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- Pressure sensitive display
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- Magnetometer sensor
- Voice assistant
- Facial recognition technology
- …