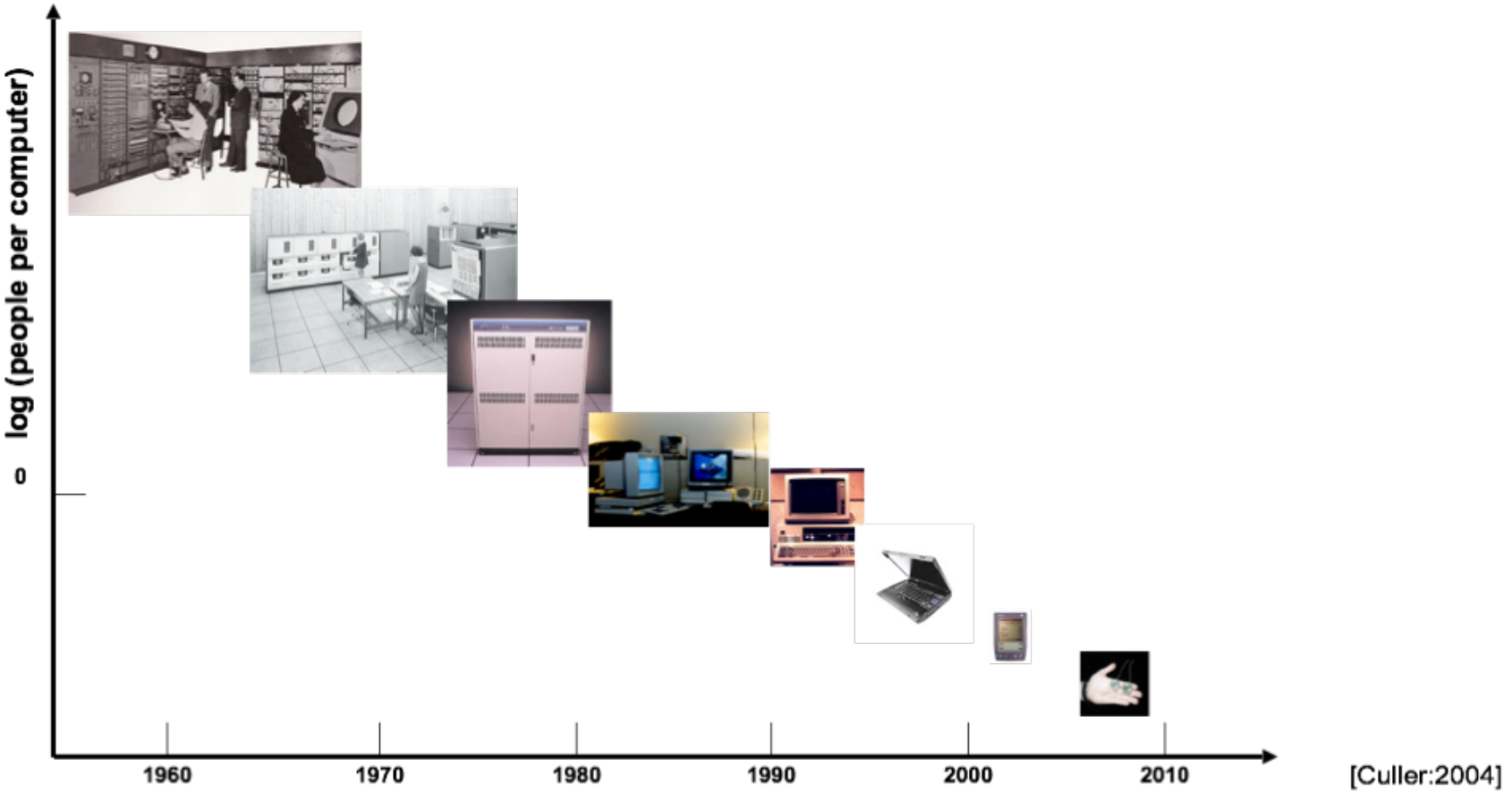
Introduction to the Internet of Things

Marco Zennaro, PhD
The Abdus Salam International Centre for Theoretical Physics

Vision



[Culler:2004]

History of IoT

- The first **telemetry** system was rolled out in Chicago way back in **1912**. It is said to have used telephone lines to monitor data from power plants.

Source: https://cdn2.hubspot.net/hub/246745/file-67175098-pdf/History_of_M2M_Infographic.pdf

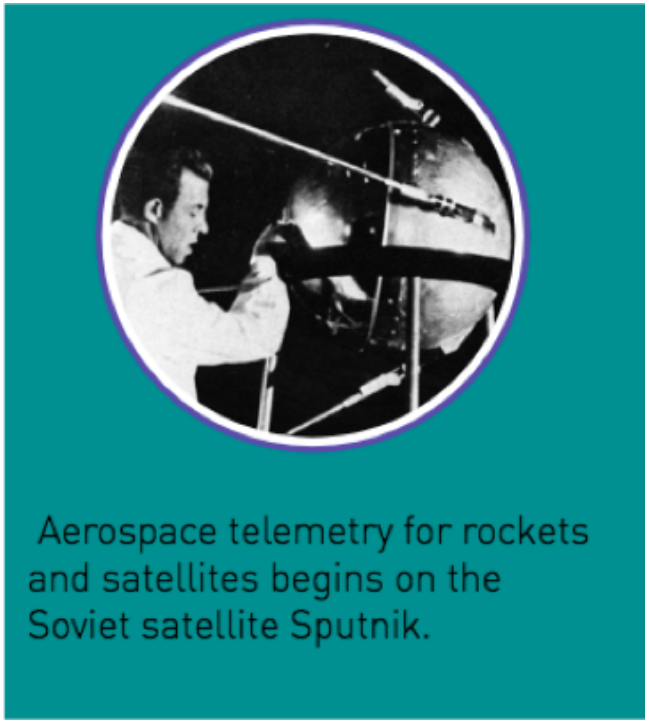
History of IoT

- Telemetry expanded to weather monitoring in the 1930s, when a device known as a **radiosonde** became widely used to monitor weather conditions from balloons.

Weather balloons transmit first meteorological data via telemetry.

History of IoT

- In 1957 the Soviet Union launched Sputnik, and with it the Space Race. This has been the entry of **aerospace telemetry** that created the basis of our global satellite communications today.



History of IoT

- Broad adoption of M2M technology began in the 1980s with wired connections for **SCADA** (supervisory control and data acquisition) on the factory floor and in home and business security systems.
- In the 1990s, **M2M** began moving toward wireless technologies. ADEMCO built their own private radio network to address intrusion and smoke detection because budding cellular connectivity was too expensive.
- In 1995, Siemens introduced the first cellular module built for M2M.

History of IoT

"Machine to Machine" (M2M)
(~1970s +)

Internet of Things Beginnings

Carnegie Mellon Internet
Coke Machine (1982, 1990)

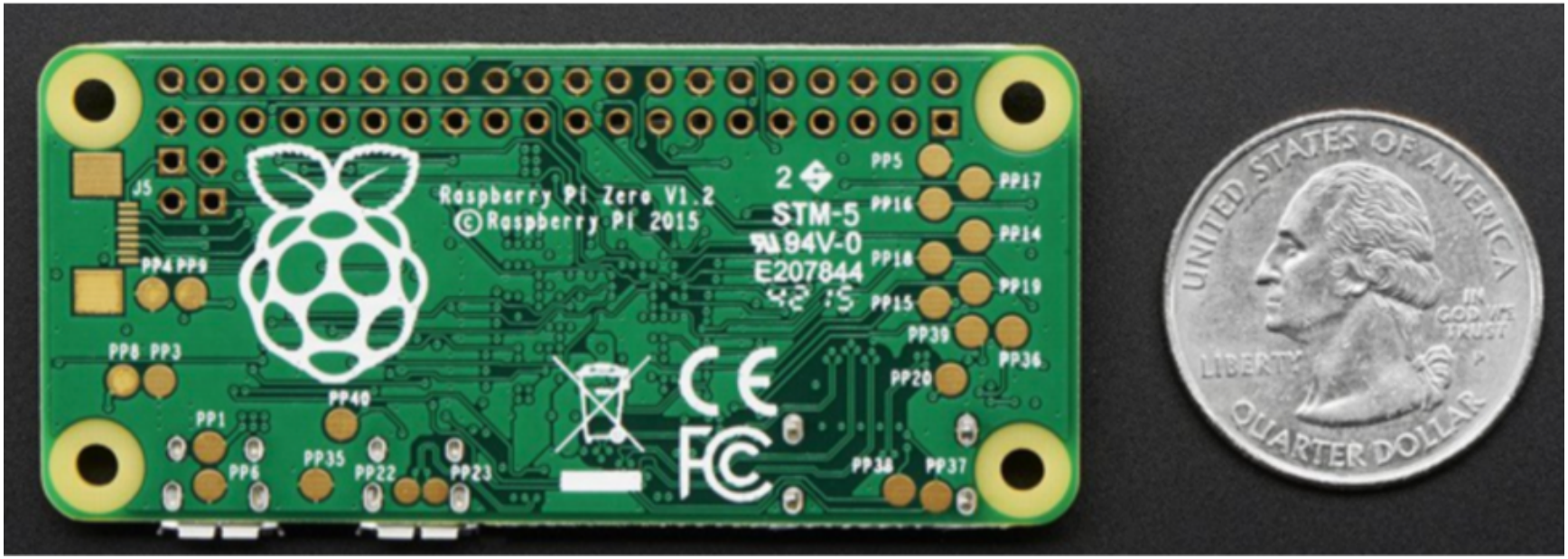
Internet Toaster
(1990)

Trojan Room Coffee
Pot
(first webcam)
(1991)

Why IoT now?

- *Ubiquitous Connectivity*
- *Widespread Adoption of IP*
- *Computing Economics*
- *Miniaturization*
- *Advances in Data Analytics*
- *Rise of Cloud Computing*

RPi Zero: $5


Raspberry Pi Zero V1.2
©Raspberry Pi 2015
STM-5
94V-0
E207844
UNITED STATES OF AMERICA
LIBERTY
QUARTER DOLLAR

IoT Definition

- **Wikipedia**: The Internet of Things (IoT) refers to uniquely identifiable objects and their virtual representations in an Internet-like structure.

  [http://en.wikipedia.org/wiki/Internet_of_things - 21-Jun-2014]

- **Cisco**: The Internet of Things (IoT) is the network of physical objects accessed through the Internet, as defined by technology analysts and visionaries. These objects contain embedded technology to interact with internal states or the external environment. In other words, when objects can sense and communicate, it changes how and where decisions are made, and who makes them.

  [http://www.cisco.com/web/solutions/trends/iot/overview.html - 21-Jun-2014]

ITU Definition

“The IoT can be viewed as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies (ICT).”

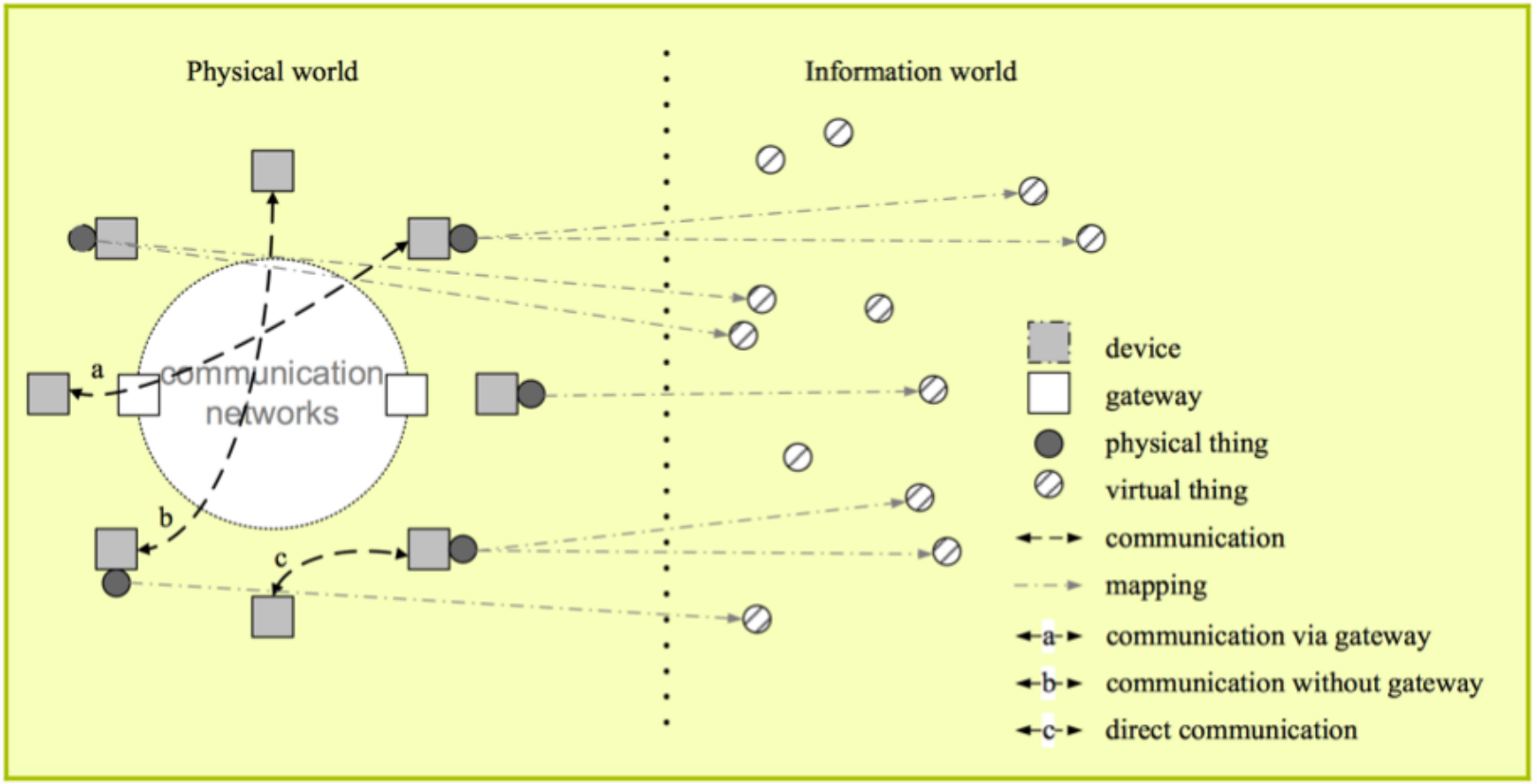
Source: Recommendation **ITU-T Y.2060**

Things

- **Physical things** exist in the physical world and are capable of being sensed, actuated and connected. Examples of physical things include the surrounding environment, industrial robots, goods and electrical equipment.
- **Virtual things** exist in the information world and are capable of being stored, processed and accessed. Examples of virtual things include multimedia content and application software.

Source: Recommendation **ITU-T Y.2060**

ITU Definition



Source: Recommendation **ITU-T Y.2060**

ITU Definition

A device is a piece of equipment with the **mandatory capabilities of communication** and **optional capabilities of sensing, actuation, data capture, data storage and data processing**. The devices collect various kinds of information and provide it to the information and communication networks for further processing.

Some devices also execute operations based on information received from the information and communication networks.

Source: Recommendation **ITU-T Y.2060**

Fundamental characteristics

- **Interconnectivity**: With regard to the IoT, anything can be interconnected with the global information and communication infrastructure.
- **Heterogeneity**: The devices in the IoT are heterogeneous as based on different hardware platforms and networks. They can interact with other devices or service platforms through different networks.
- **Dynamic changes**: The state of devices change dynamically, e.g., sleeping and waking up, connected and/or disconnected as well as the context of devices including location and speed. Moreover, the number of devices can change dynamically.

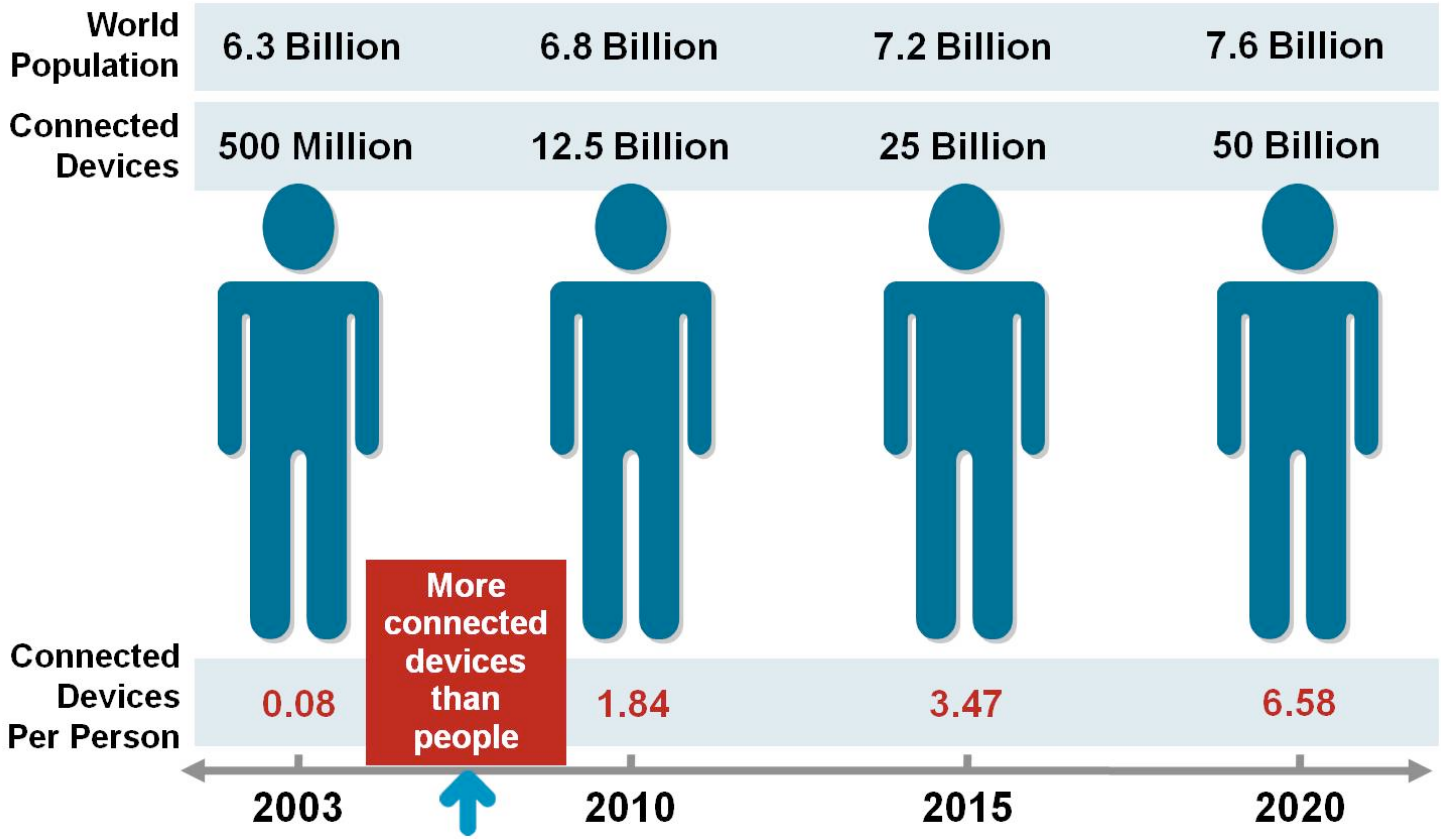
Source: Recommendation **ITU-T Y.2060**

Fundamental characteristics

- **Enormous scale**: The number of devices that need to be managed and that communicate with each other will be at least an order of magnitude larger than the devices connected to the current Internet. The ratio of communication triggered by devices as compared to communication triggered by humans will noticeably shift towards device-triggered communication.

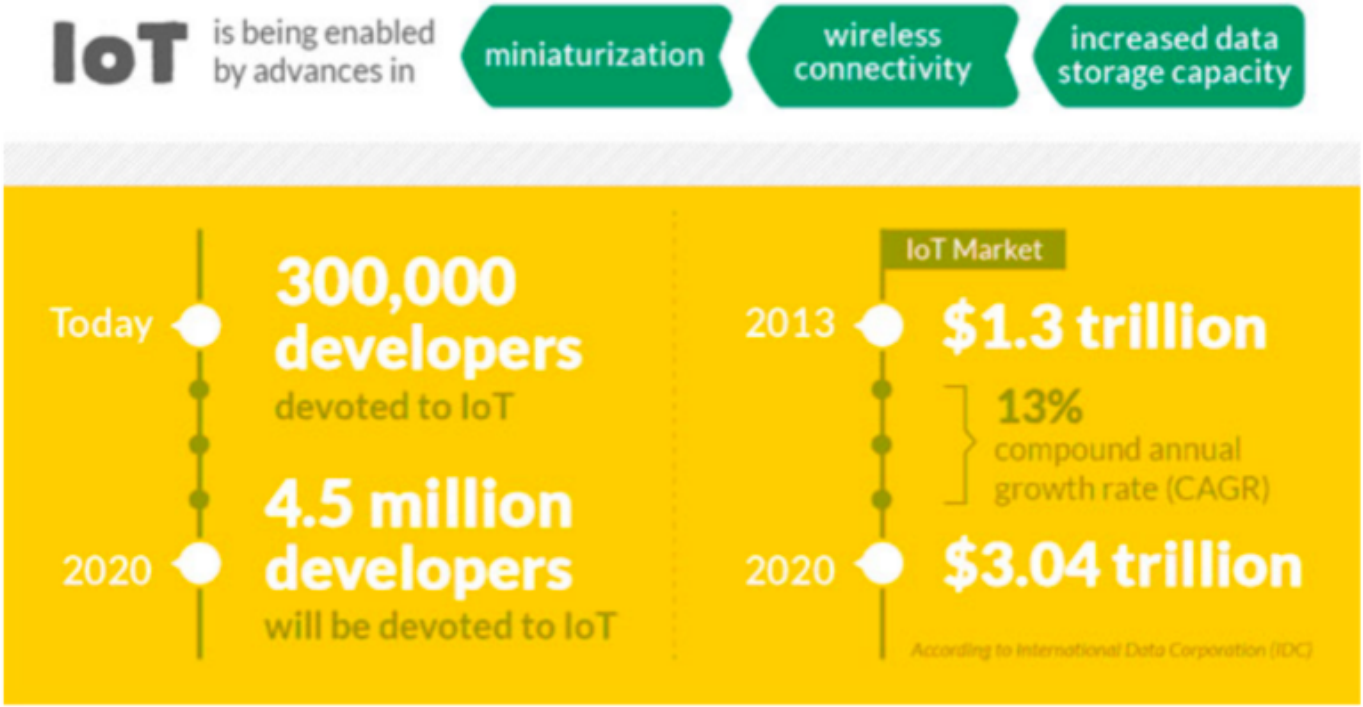
Source: Recommendation **ITU-T Y.2060**

Predictions



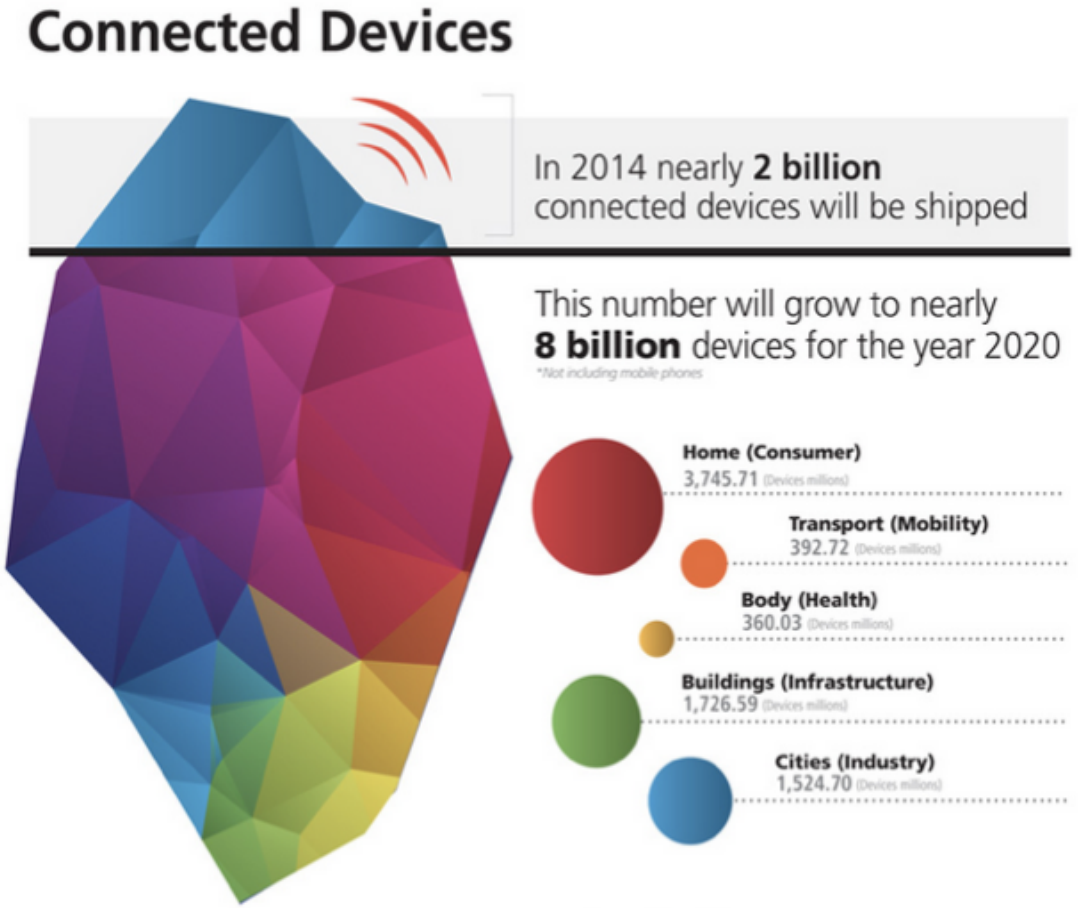
Source: Cisco IBSG, April 2011

Predictions



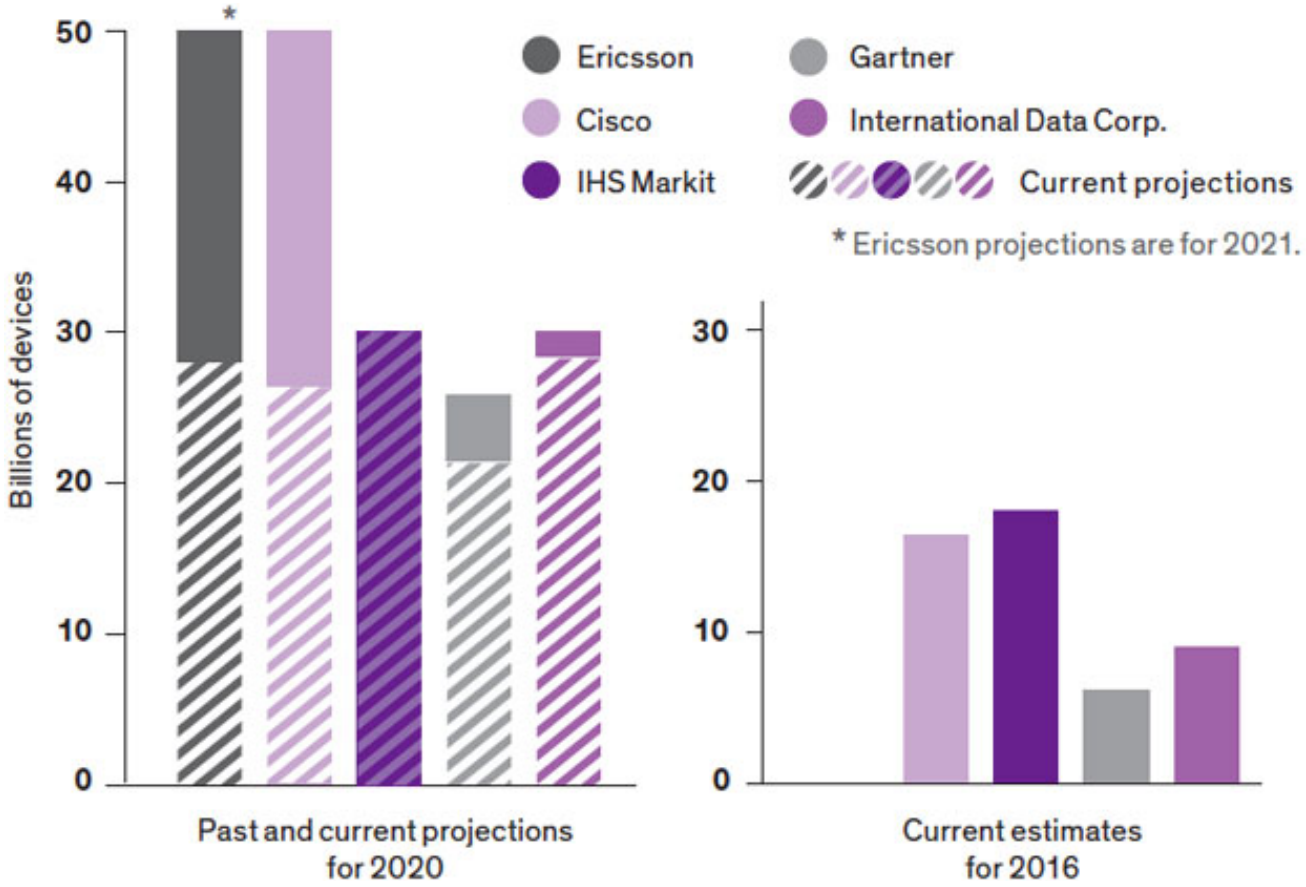
PwC's 6th Annual Digital IQ survey

Predictions



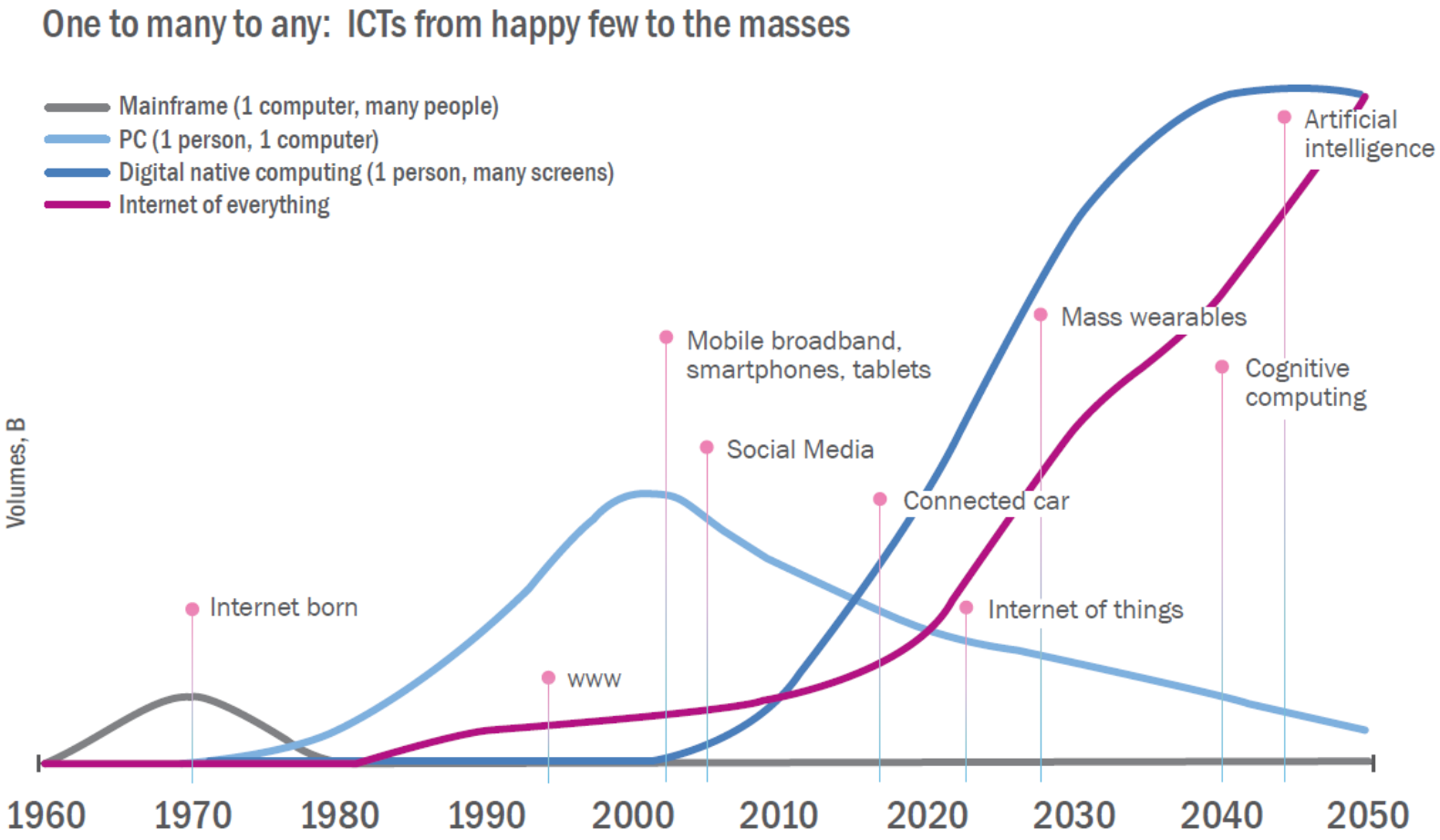
Source: http://www.postscapes.com/what-exactly-is-the-internet-of-things-infographic/

Internet of Fewer Things



http://spectrum.ieee.org/telecom/internet/the-internet-of-fewer-things

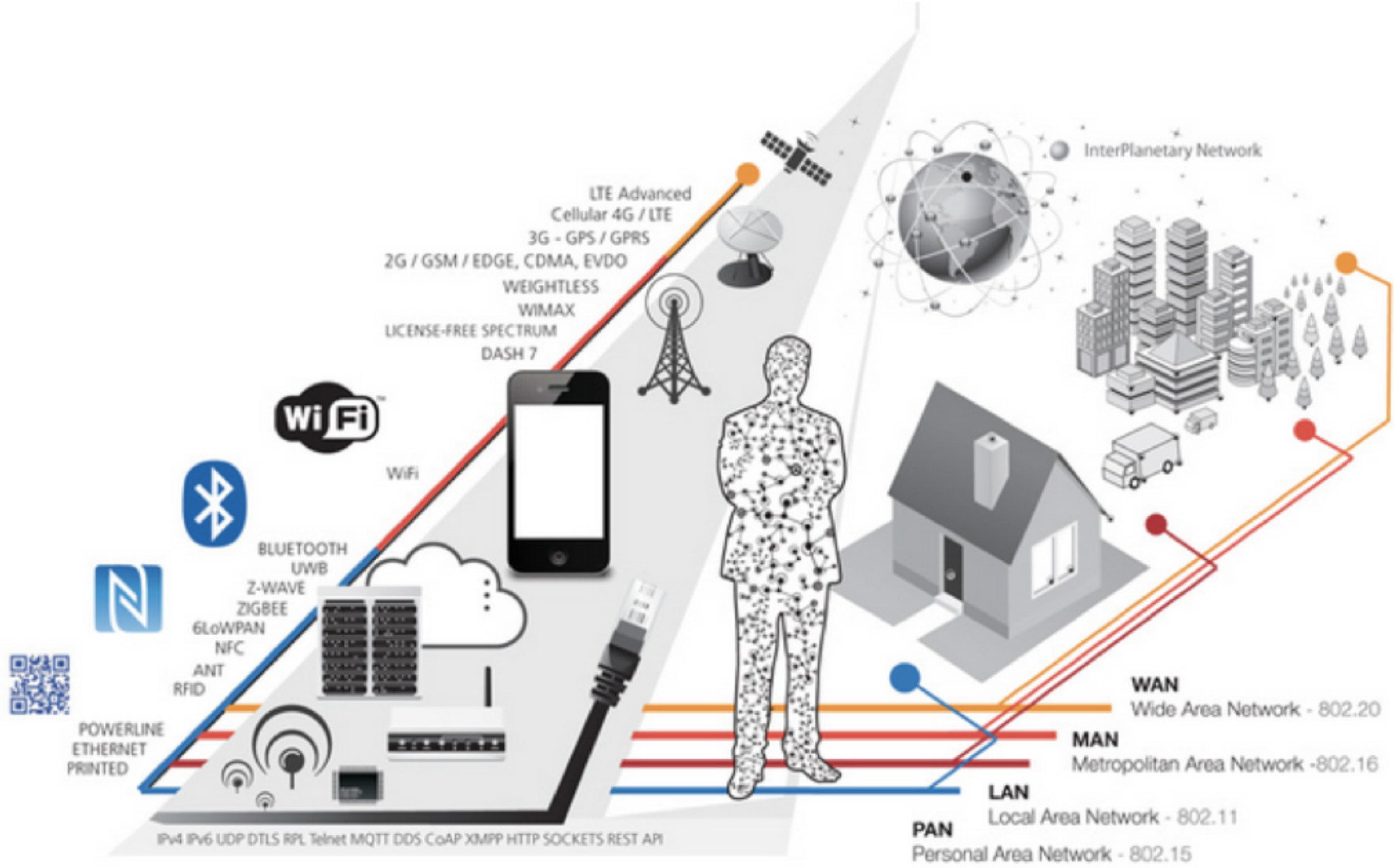
History of the future



Network Connectivity

Key aspects when considering network connectivity:

- **Range** - are you deploying to a single office floor or an entire city?
- **Data Rate** - how much bandwidth do you require? How often does your data change?
- **Power** - is your sensor running on mains or battery?
- **Frequency** - have you considered channel blocking and signal interference?
- **Security** - will your sensors be supporting mission critical applications?



Source: http://www.postscapes.com/what-exactly-is-the-internet-of-things-infographic/

Network Connectivity

3 Possible Device Network Topologies

Direct to Internet
(eg Connected Home)

Via Gateway
(eg Factory)

Via Multihop Network
(eg Remote Oil & Gas)

IPv6

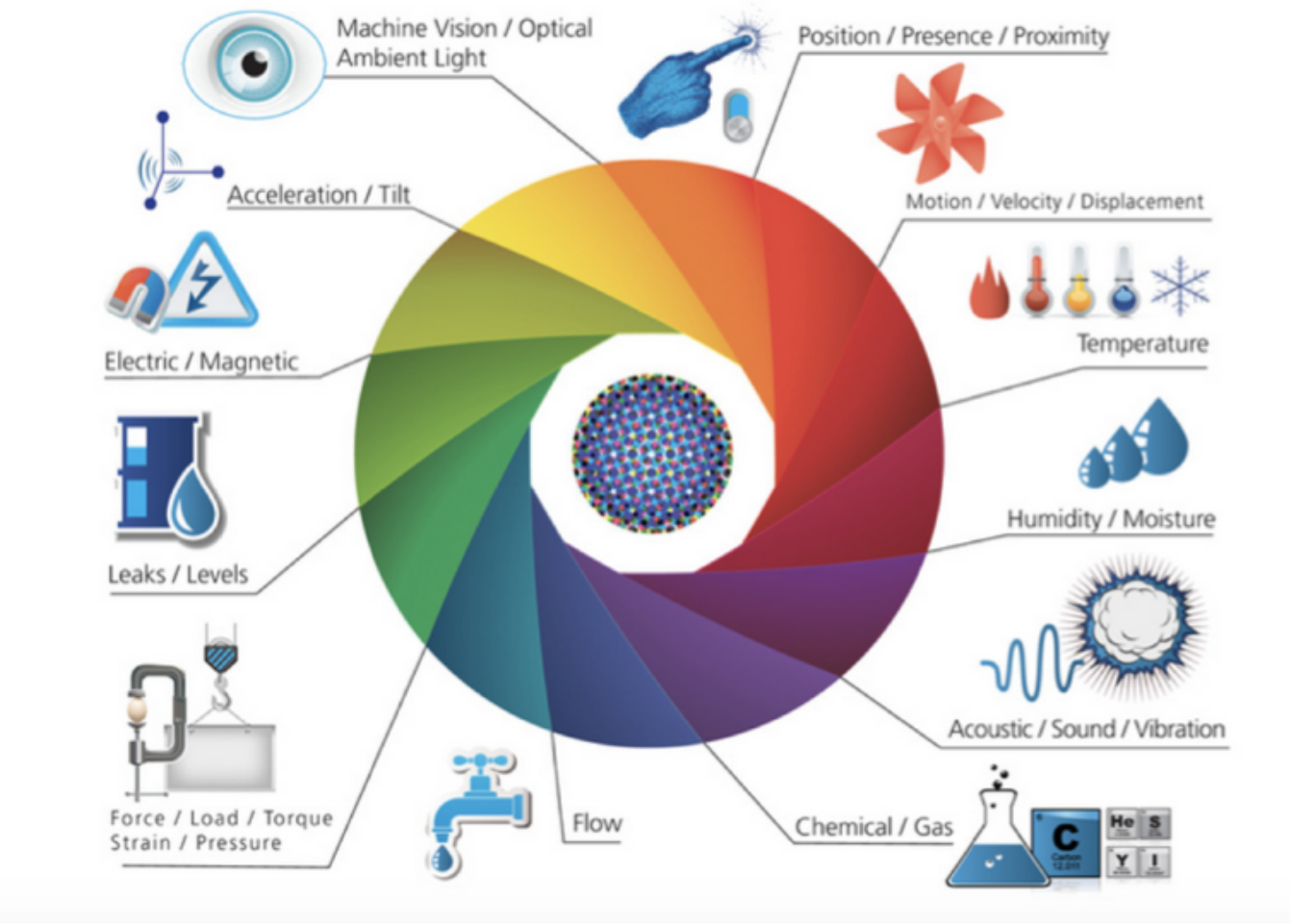
Smart Objects will add tens of billions of additional devices

There is no scope for IPv4 to support Smart Object Networks

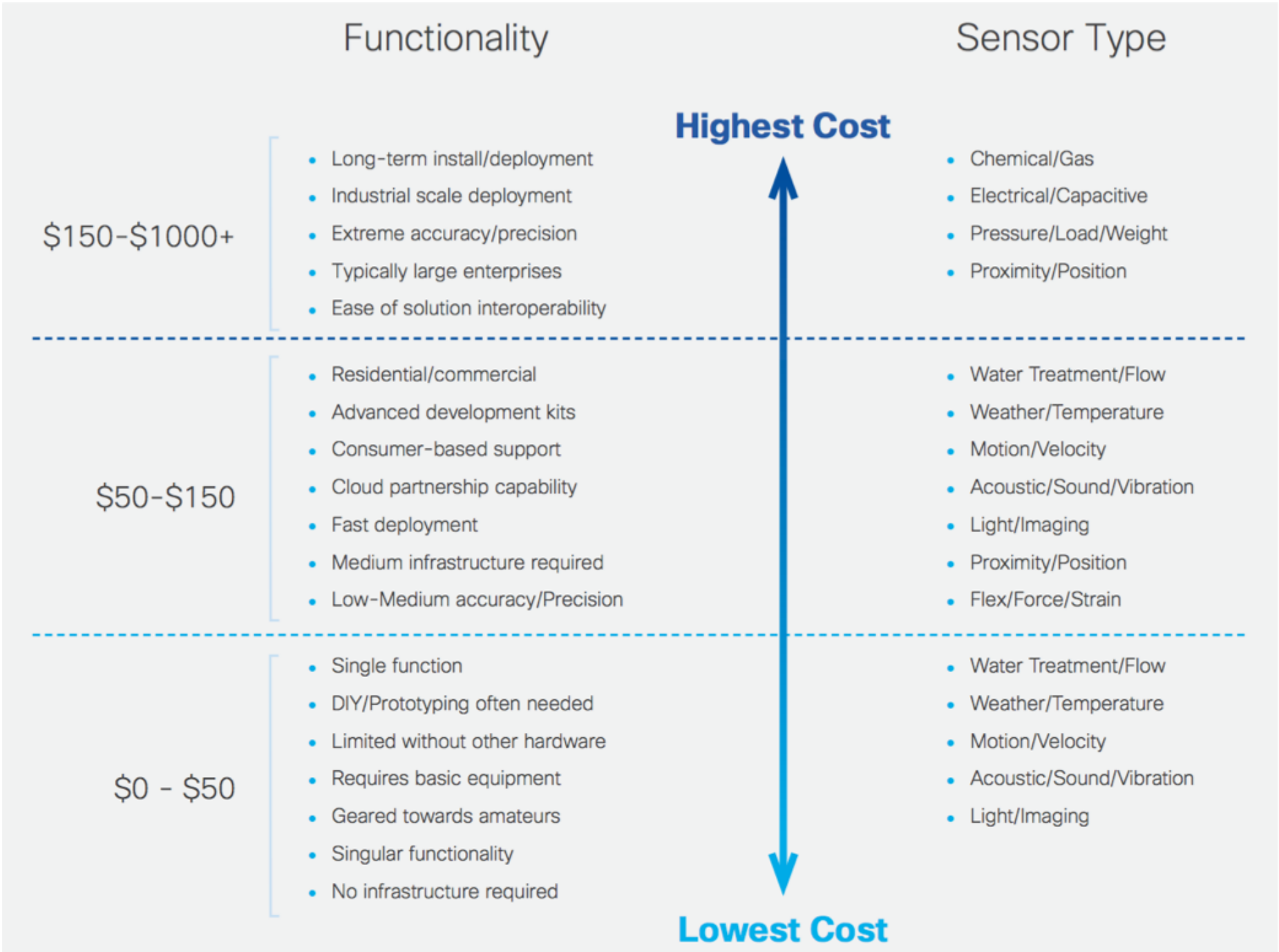
IPv6 is the only viable way forward

- Solution to address exhaustion
- Stateless Auto-configuration thanks to Neighbor Discovery Protocol
- Each embedded node can be individually addressed/accessed

Connectivity Landscape



Source: http://www.postscapes.com/what-exactly-is-the-internet-of-things-infographic/


Functionality
Sensor Type
Highest Cost
$150-$1000+
Long-term install/deployment
Industrial scale deployment
Extreme accuracy/precision
Typically large enterprises
Ease of solution interoperability
Chemical/Gas
Electrical/Capacitive
Pressure/Load/Weight
Proximity/Position
$50-$150
Residential/commercial
Advanced development kits
Consumer-based support
Cloud partnership capability
Fast deployment
Medium infrastructure required
Low-Medium accuracy/Precision
Water Treatment/Flow
Weather/Temperature
Motion/Velocity
Acoustic/Sound/Vibration
Light/Imaging
Proximity/Position
Flex/Force/Strain
$0 - $50
Single function
DIY/Prototyping often needed
Limited without other hardware
Requires basic equipment
Geared towards amateurs
Singular functionality
No infrastructure required
Water Treatment/Flow
Weather/Temperature
Motion/Velocity
Acoustic/Sound/Vibration
Light/Imaging
Lowest Cost

Applications

ambient™

Ambient Umbrella

Glowing intelligence
lets you know that there's
rain in today's forecast.


nest
75
IN 25 MIN
72
9:41 AM
nest
FORT WORTH, TX
88°
HOME
72
LIVING ROOM

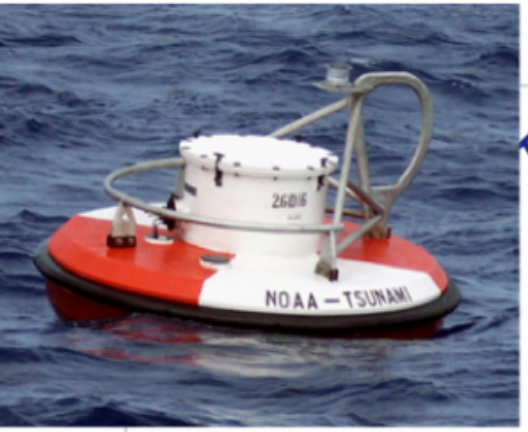
MyVessyl Cup

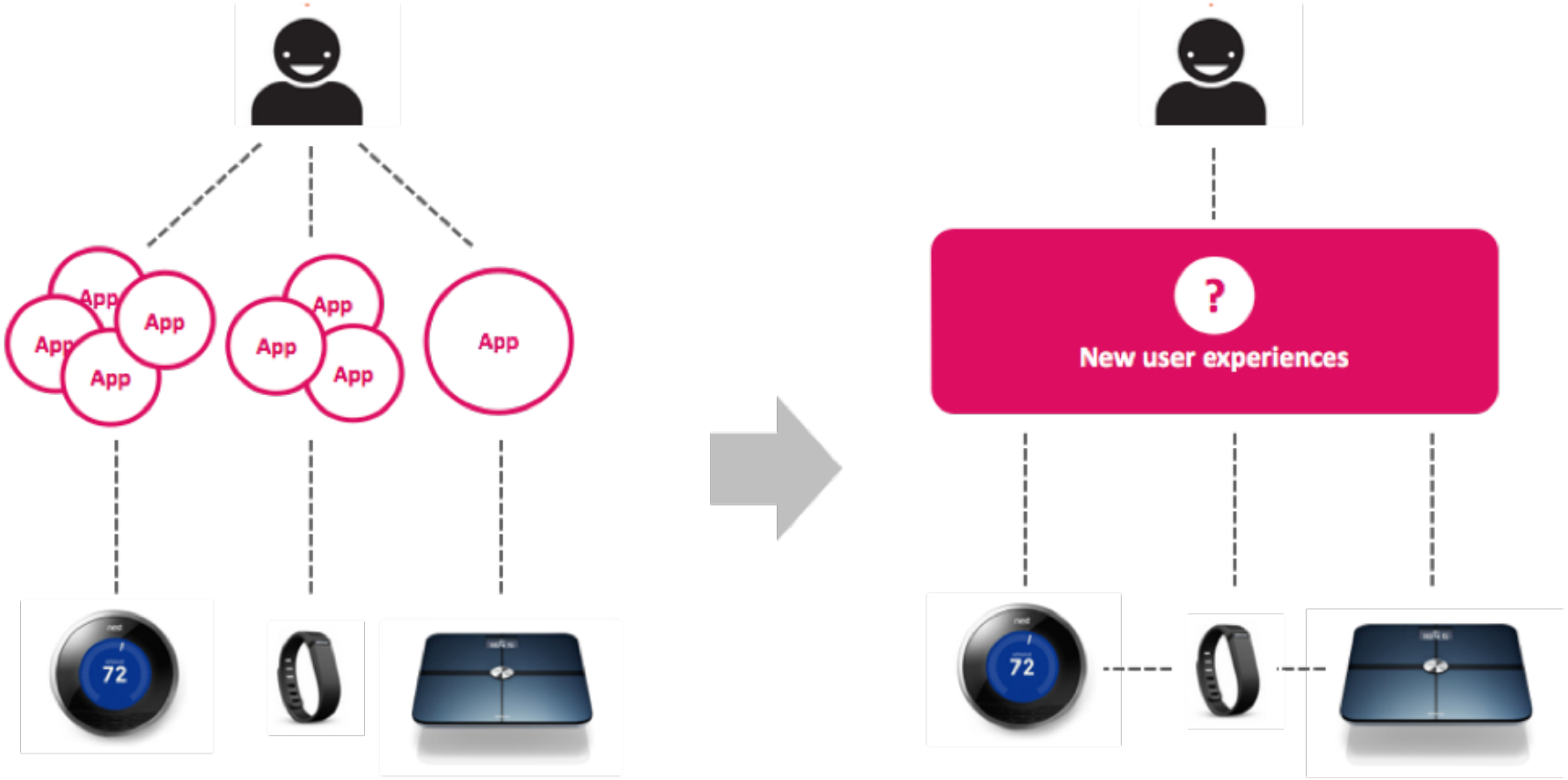
It can hold 13 ounces of liquid. The battery takes 60 minutes to fully charge and will last for 5-7 days. Also has wire-free charging.

https://www.myvessyl.com/


SMART CITIZEN
ARDUINO
ATHEART
SCK Urban Shield v1.1c
Designed in Barcelona
ICSP-A

Applications



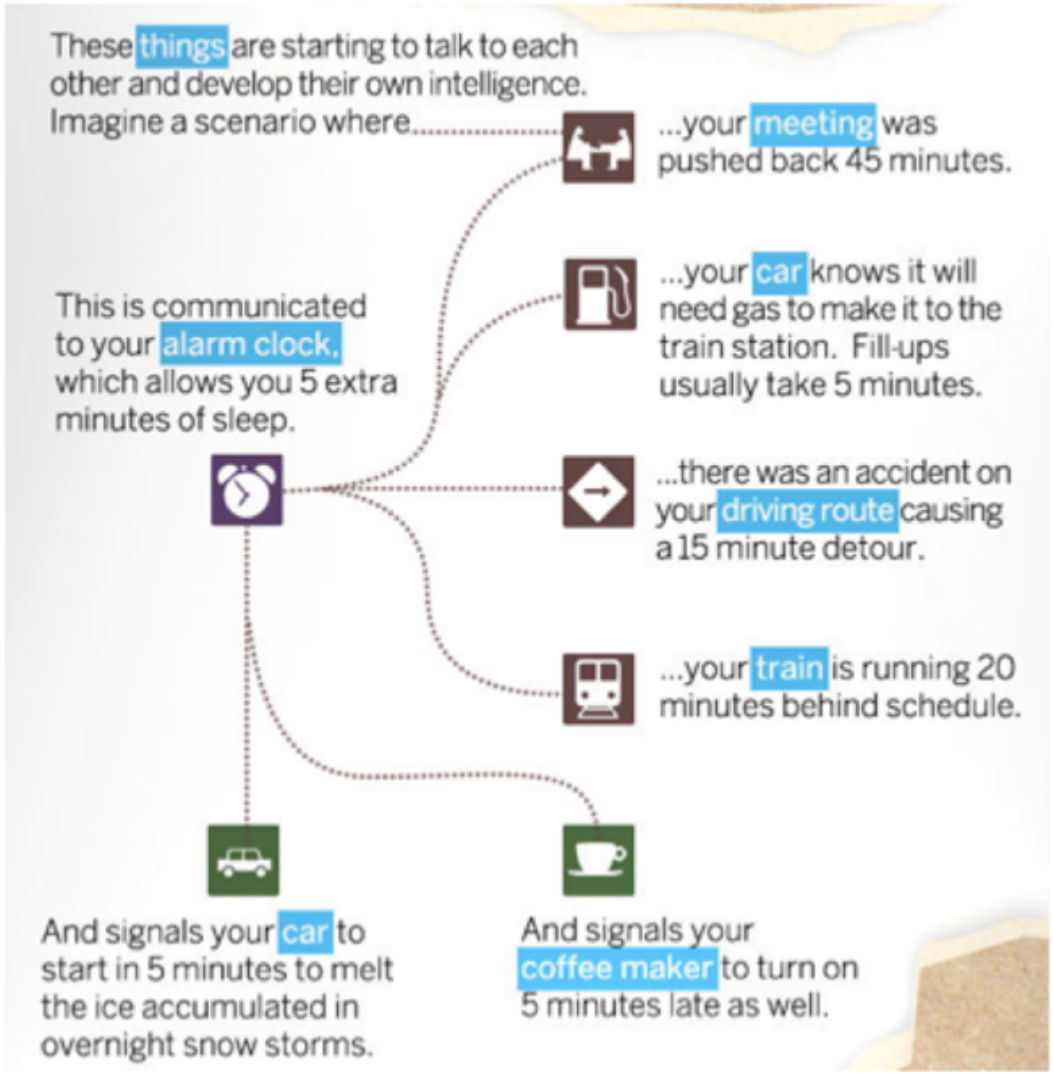


Today: **Intranets of Things**

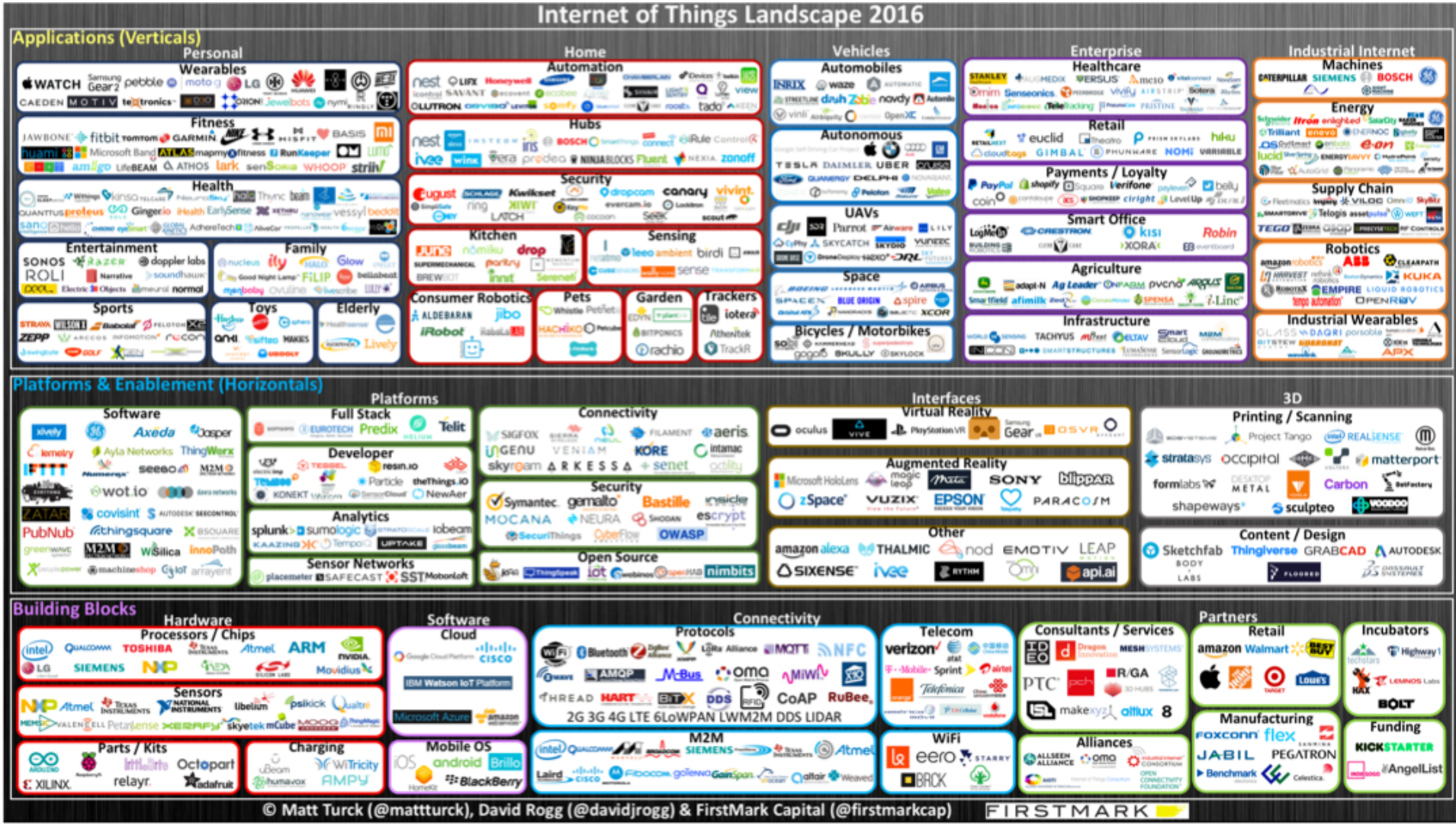
Connected devices

Tomorrow: **Internet of Things**

Interconnected devices


These things are starting to talk to each other and develop their own intelligence. Imagine a scenario where...
...your meeting was pushed back 45 minutes.
...your car knows it will need gas to make it to the train station. Fill-ups usually take 5 minutes.
This is communicated to your alarm clock, which allows you 5 extra minutes of sleep.
...there was an accident on your driving route causing a 15 minute detour.
...your train is running 20 minutes behind schedule.
And signals your car to start in 5 minutes to melt the ice accumulated in overnight snow storms.
And signals your coffee maker to turn on 5 minutes late as well.

IoT Landscape



Thank You