The Next Big Thing

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Contents

- What is the “Internet of Things” (IOT)?
- Why is IOT “The Next Big Thing”?
- The Idea
- The Vision
- Challenges
- Opportunities

What is the
nternet of Things (IOT

The Internet of Things (IOT)?

A network of Internet-connected objects able to

collect and exchange data

The Internet of Things (IOT)?

- A system of
  - Interrelated computing devices
  - Mechanical and digital machines
  - Objects
  - Animals or People
- provided with unique identifiers and
- the ability to transfer data over a network
- without requiring human-to-human or human-to-computer interaction

The Internet of Things (IOT)?

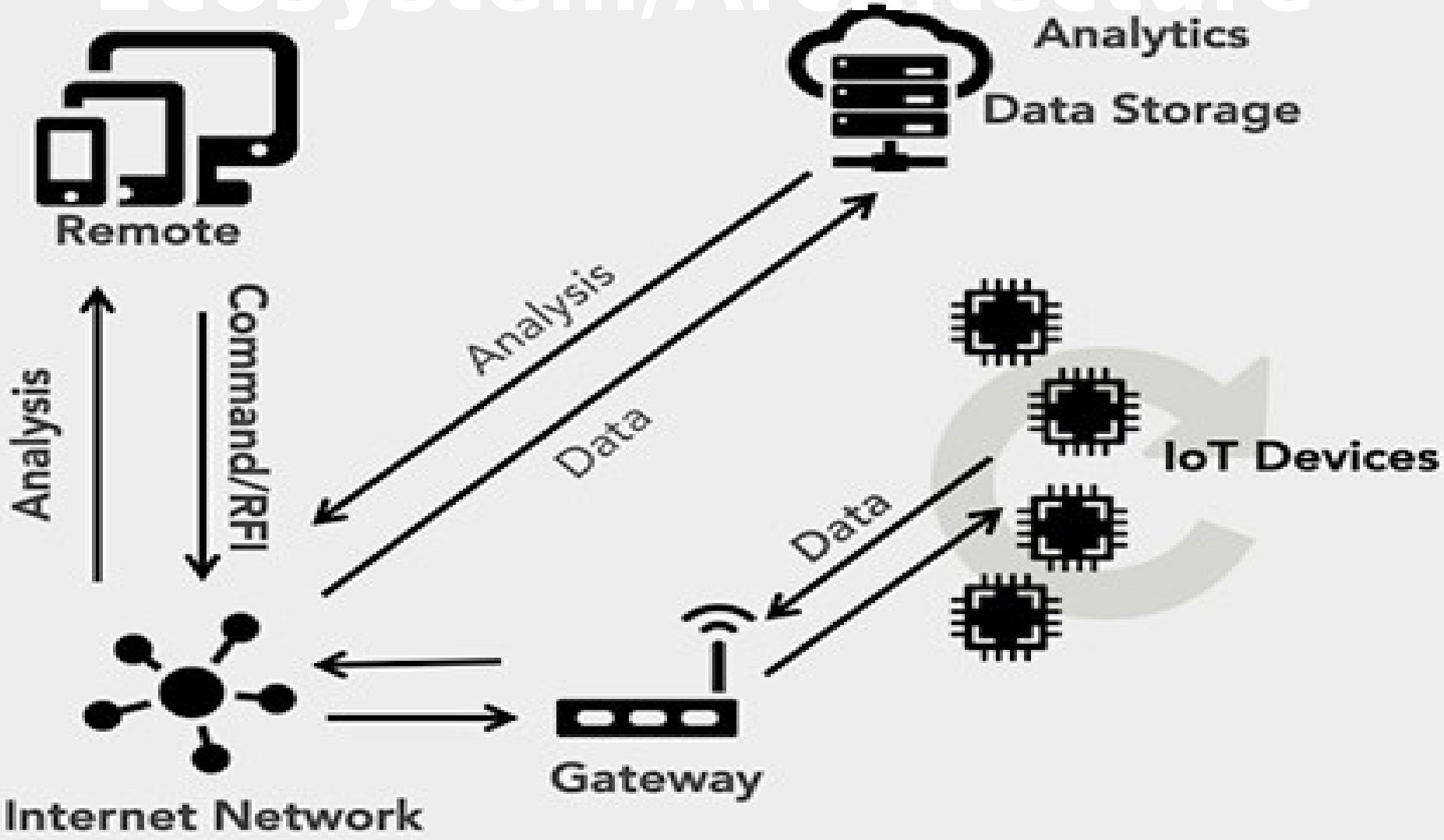
- From People Internet to Device Internet

People Interne  **Device Internet**

People Input Data
People Use Information

Devices generate Data
Devices Use Information
(Devices can take action/
Devices can be controlled

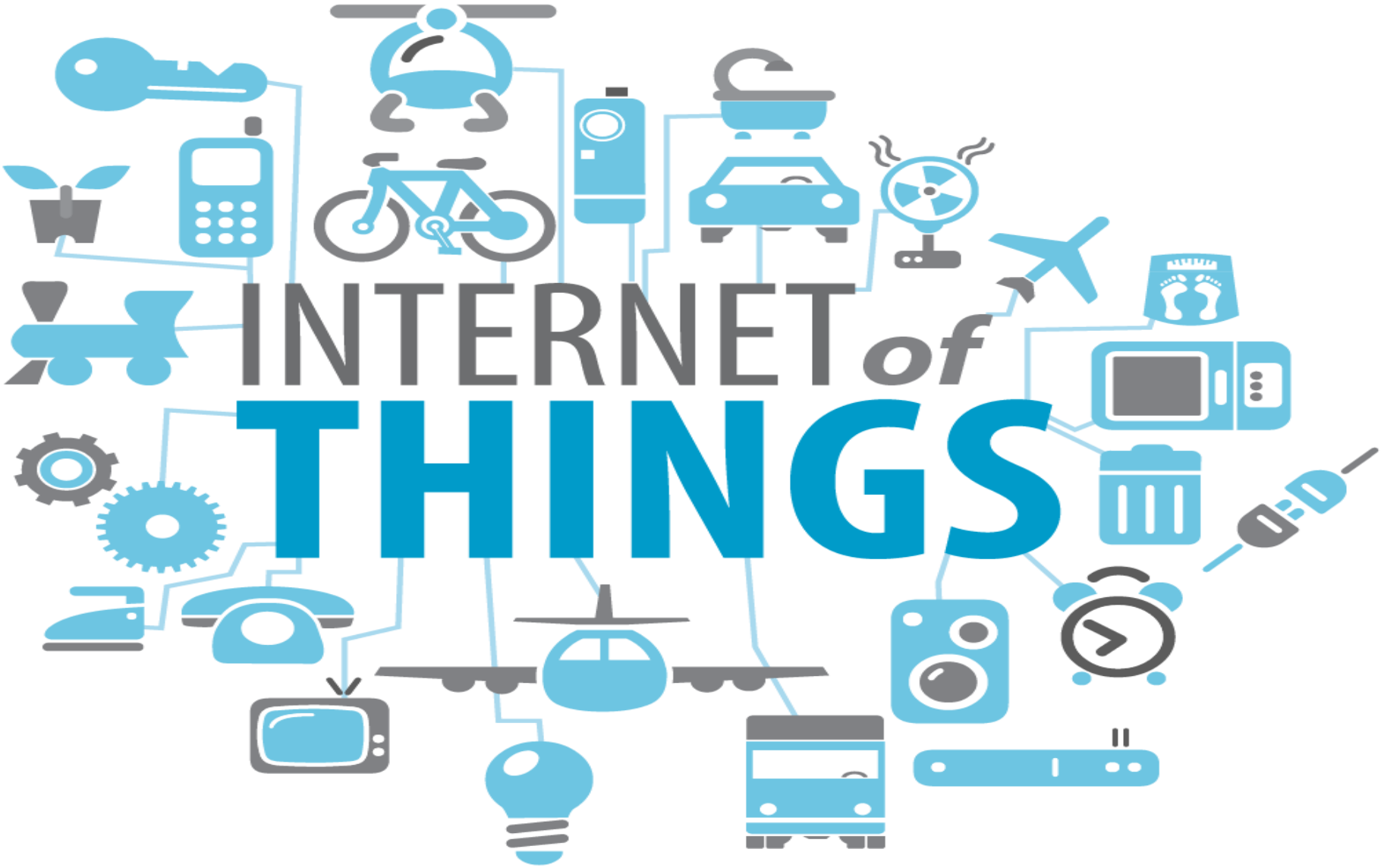
The IOT Ecosystem/Architecture



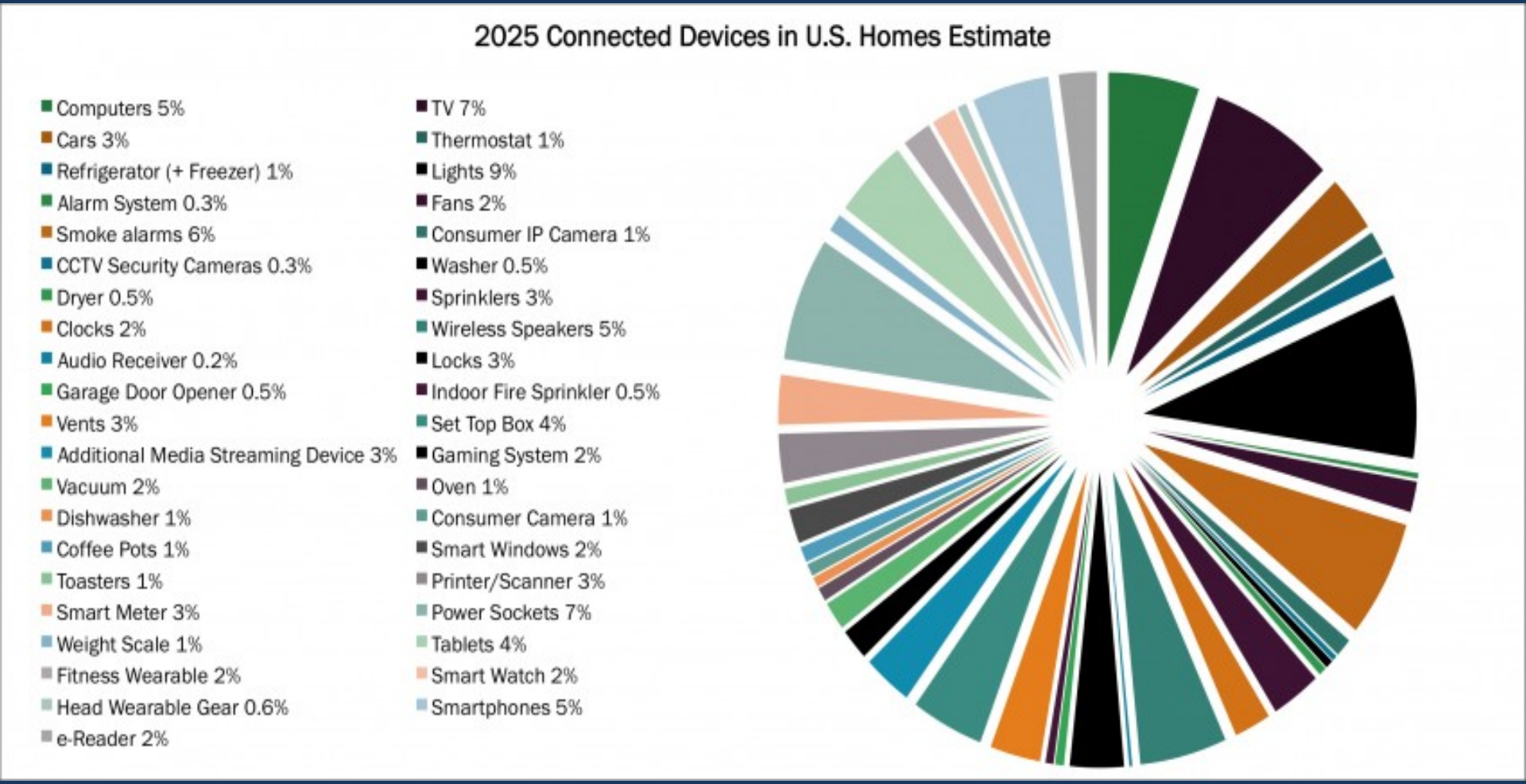
In IOT a “Thing” can be Anything

- A person with a heart monitor implant
- A farm animal with a biochip transponder
- An automobile that has built-in sensors to alert the driver when tire pressure is low
- An object in your home like a door or bicycle
- A component in Boeing 747 airplane
- Any other natural or man-made object
  - that can be assigned an IP address and
  - provided with the ability to transfer data over a network

“Things” in the IOT

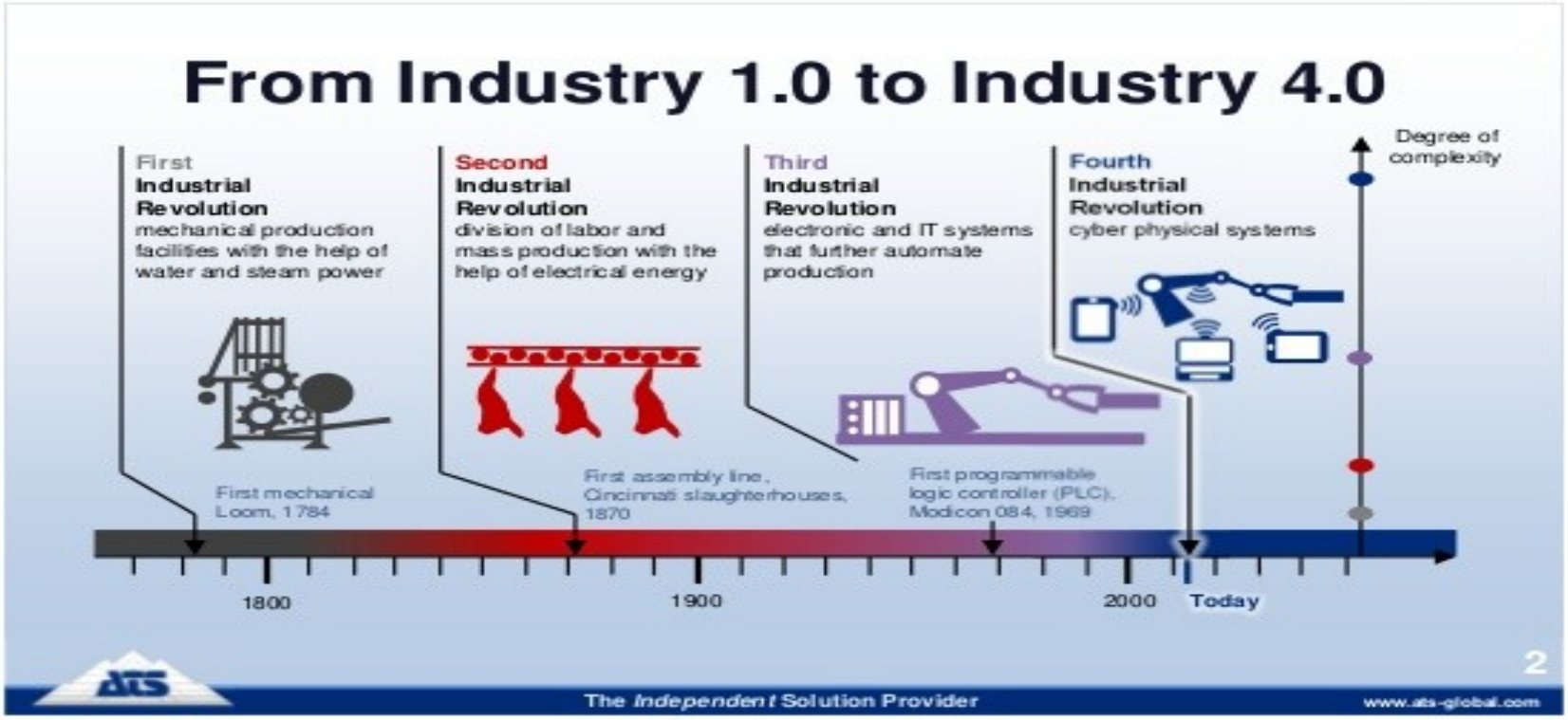


“Things” in US Homes by 2025

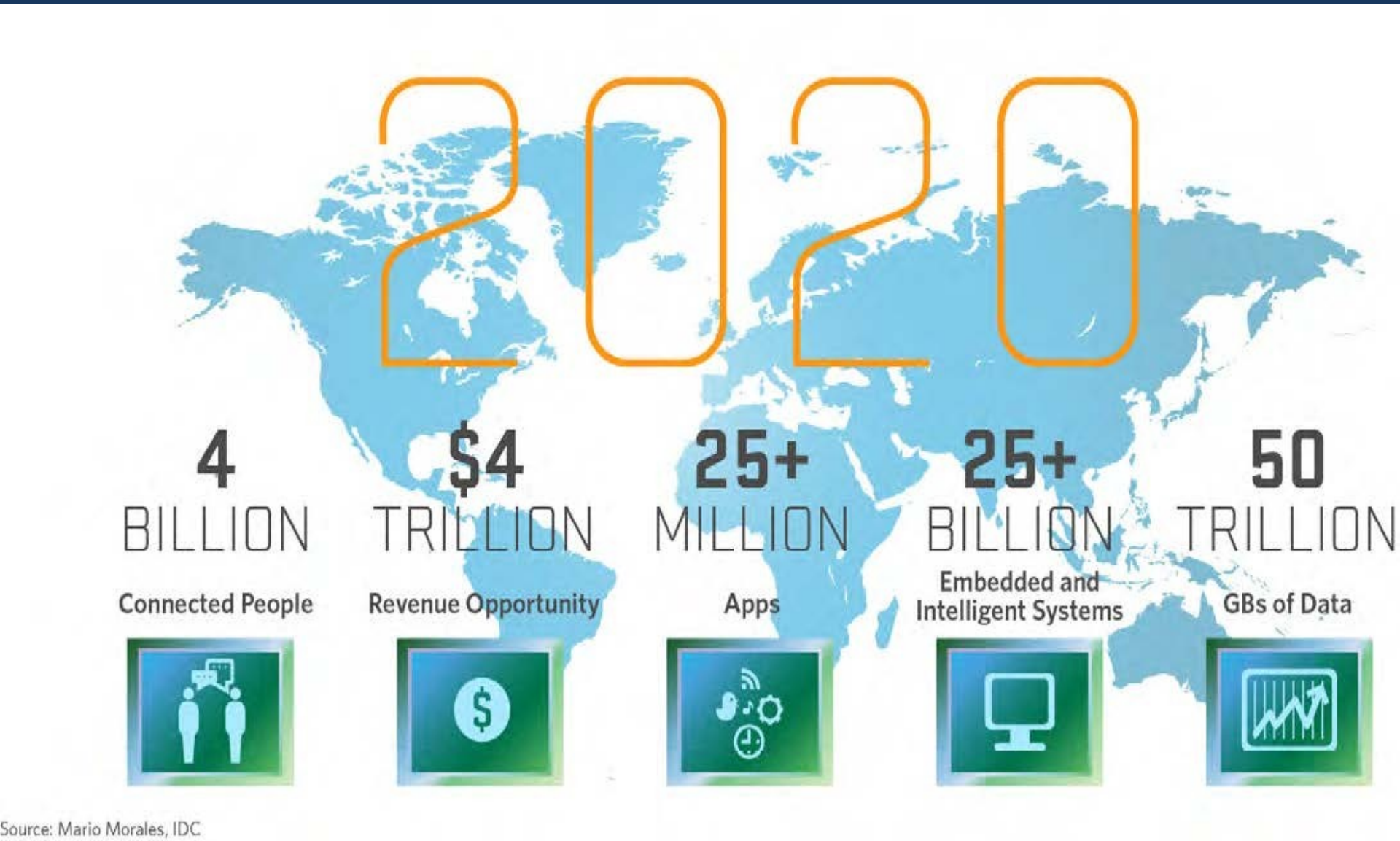


Why is IOT The Next Big Thing?

The Internet of Things will be as transformative to the world as was the Industrial Revolution

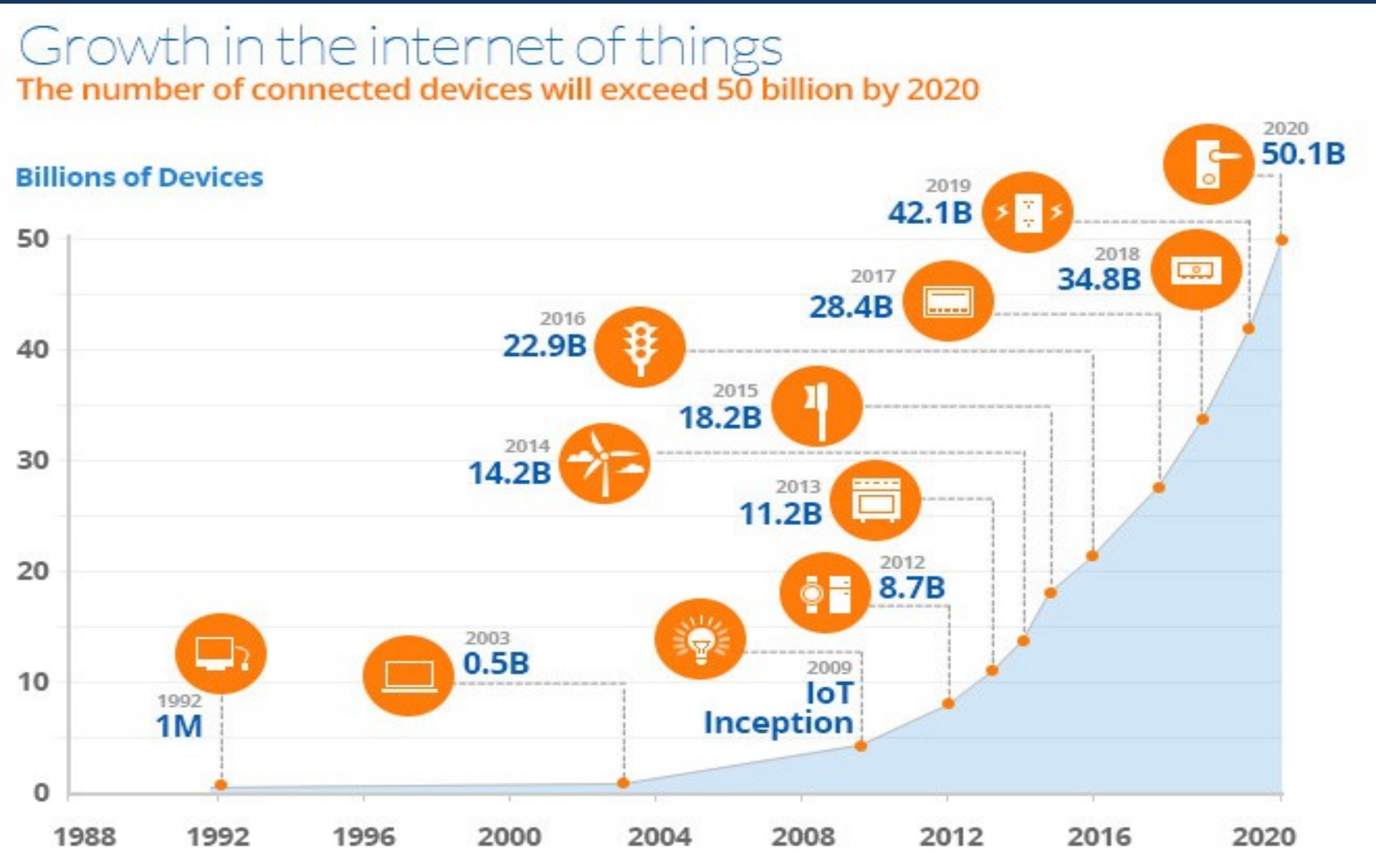


The Next Big Thing



Source: Mario Morales, IDC

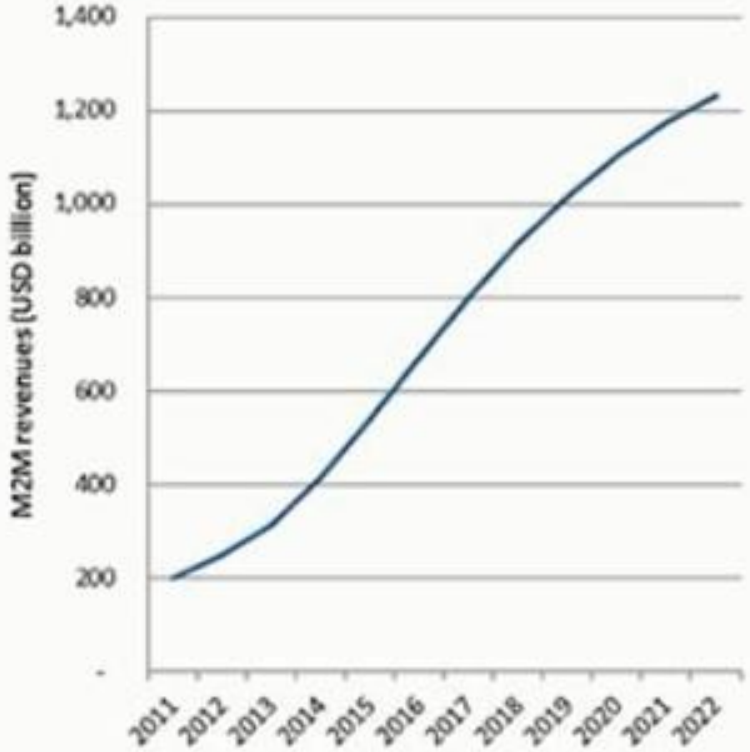
owth in Connected Devi



By 2022, M2M will be a USD 1.2 trillion opportunity

Total revenue from machine-to-machine, 2011-22

Source: Machina Research 2012



- **Total M2M revenue will grow from USD200 billion in 2011 to USD1.2 trillion in 2022, a CAGR of 18%**
- **Total revenue includes:**
  - device costs where connectivity is integral to the device
  - module costs where devices can optionally have connectivity enabled
  - monthly subscription, connectivity and traffic fees

Machina Research

IoT is top-of-mind with CEO's, CIO's, and VC's

WORLD ECONOMIC FORUM

2015 Tech Predictions

1. **Digital transformation**
2. **Internet of Things**
3. **Convergence of big data with consumer data**
4. Hybrid cloud
5. Collaboration
6. **Predictive analytics will lead big data**
7. **Mobile wearable technology**
8. A Platform and orchestration is needed
9. Networked Economy
10. The end of apps

Gartner SYMPOSIUM ITXPO 2014

Top 10 Strategic Technology Trends for 2015

1. Computing Everywhere
2. **Internet of Things**
3. 3-D Printing
4. **Advance, Pervasive Analytics**
5. Context-Rich Systems
6. **Smart Machines**
7. Cloud Computing
8. Software Defined Infrastructure
9. Web-scale IT
10. Risk-Based Security

TechCrunch

VCs Look To The Future As IoT Investments Soar

In 2014, investors contributed over $300 million in 97 venture rounds for IoT startups

The Idea

The concept was named in 1999

- By Kevin Ashton, cofounder and executive director of the Auto-ID Center at MIT
- “Today the internet is almost wholly dependent on human beings for information. Nearly all of the roughly 50 petabytes 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.”
- “Data gathering without human dependence would 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.”

IOT has evolved from the convergence of

- Wireless technologies
  - 6LoWPAN, ZigBee, Wi-Fi, Bluetooth, Cellular, etc.
- Micro-Electro-Mechanical systems (MEMS)
  - A technology that combines computers with tiny mechanical devices such as sensors, valves, gears, mirrors, and actuators embedded in semiconductor chips
- The Internet

Wireless technologies for IOT

- **6LoWPAN** (IPv6 based Low Power Personal Area Network)
  - Really the first wireless connectivity standard that was created for the IOT
  - 6LoWPAN devices can communicate with each other and with other IP-based servers or devices over the Internet
  - Require Ethernet or Wi-Fi gateway (with dual protocol stack) for Internet connectivity
  - No industry standard for the entire protocol stack

Wireless technologies for IOT

- **ZigBee**
  - At the forefront of IOT
  - Low-power
  - Mesh network
  - No device compatibility issues
  - Home-automation and smart energy products
  - Ship 400 million devices a year
  - But require gateway for connecting to Internet

Wireless technologies for IOT

- **Wi-Fi**
- Wi-Fi and TCP/IP software are fairly large and complex suitable for laptops and smart phones
- Recently silicon devices and modules embed the Wi-Fi software and the TCP/IP software inside the device
  - Enabling wireless Internet connectivity with the smallest microcontroller
  - Apply advanced sleep protocols and fast on/off times to reduce power consumption
  - Example: Wi-Fi based sports watch that uploads workout data to the Internet
  - **WiFi** HaLow (802.11ah) and HEW (802.11ax)

Wireless technologies for IOT

- **Bluetooth Low Energy (BLE) or Bluetooth Smart**
  - BLE suitable for IOT applications
  - Ultra low power
  - But require gateway such as smart phone, Wi-Fi bridge
  - Future BLE devices need IPv6
  - Efforts on-the-way

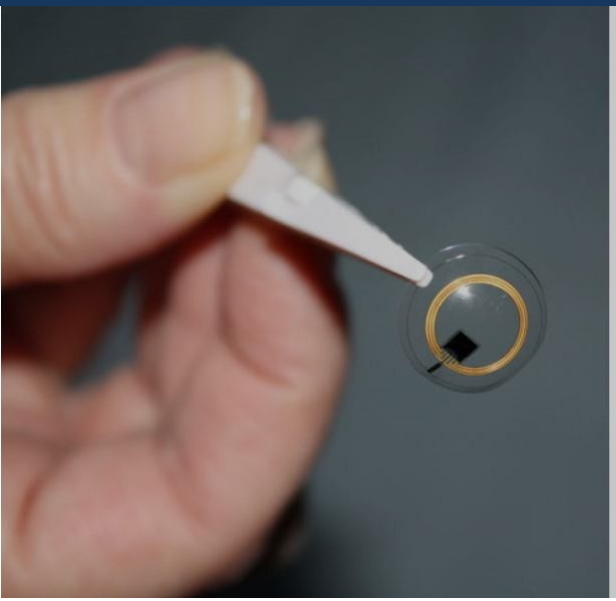
Wireless technologies for IOT

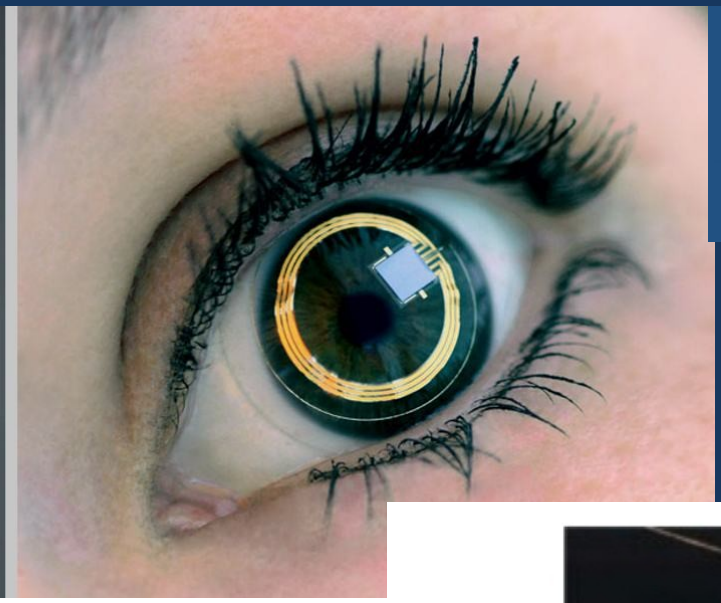
- **Cellular Networks**
  - Key to IOT for low power wide area applications
  - Massive IOT applications (Smart building, Smart agriculture, Smart metering)
  - Critical IOT applications (Remote healthcare, Traffic safety and control, Industrial application and control)
  - Global reach, QoS, scalability, security
  - EC-GSM (Extended Coverage GSM)
  - NB-IOT (Narrow Band IOT) and
  - LTE-M (Long Term Evolution-Machine to Machine)

Micro-Electro-Mechanical Systems MEMS or Micro-Machines

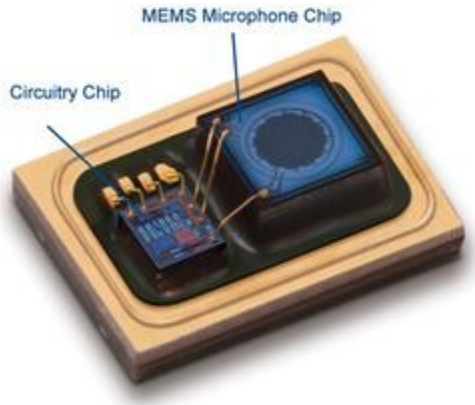
- MEMS devices contain micro-circuitry on a tiny silicon chip into which some mechanical device such as a mirror or a sensor has been manufactured
- MEMS are made up of components between 1 and 100 µm in size (i.e. 0.001 to 0.1 mm), and MEMS devices generally range in size from 20 µm s to a mm (i.e. 0.02 to 1.0 mm)
- MEMS usually consist of a central unit that processes data (the microprocessor) and several components that interact with the surroundings such as micro-sensors

Micro-Electro-Mechanical Systems
MEMS or Micro-Machines

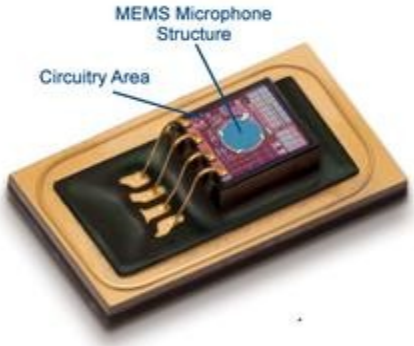


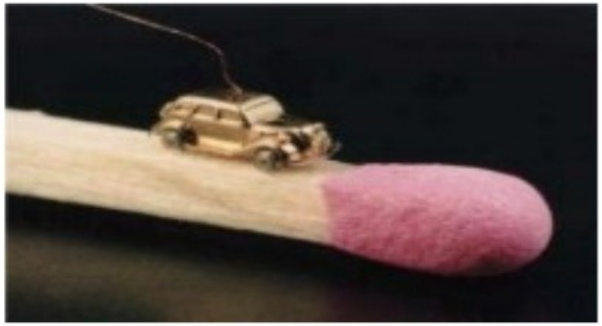


Akustica 2-chip MEMS Microphone



Akustica Monolithic MEMS Microphone





The DENSO Micro-Car is a miniature version of Toyota's first passenger car. Fabricated using MEMS, at 1/1000 th the size of the original.
It consists of a 0.67 mm magnetic-type working motor and when supplied with 3 V 20 mA of alternating current through a 18 µm copper wire,
The engine runs at 600 rpm equivalent to 5-6 mm/s

Internet

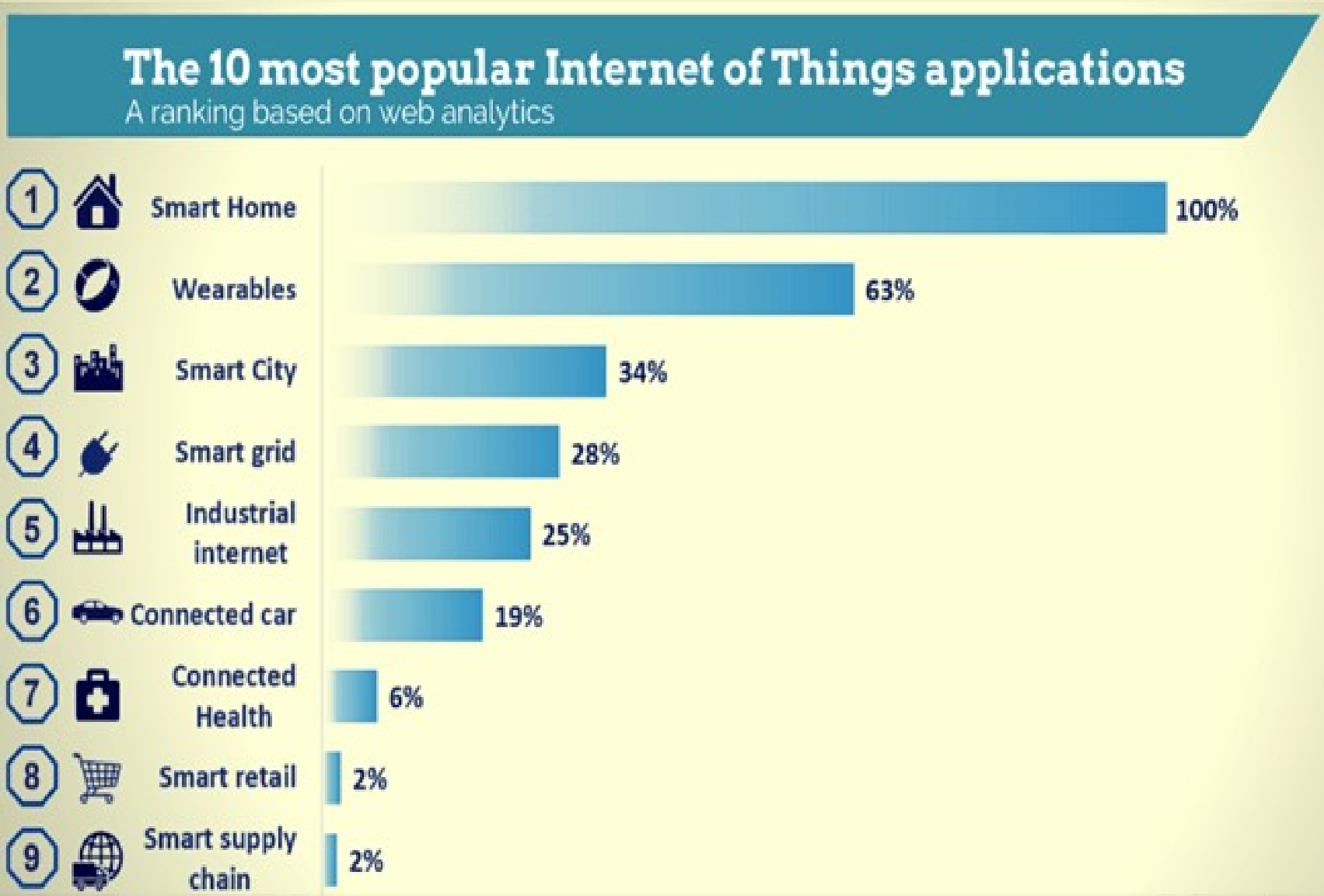
- 128-bit IP address instead of 32-bit
- Which means an IPv6 address to every atom on the surface of the earth and yet have addresses for another 100+ earths
- Hence IPv6 address can be assigned to every THING on earth
- And it can be “connected”

Vision

Define “Smart”

- Smart Grid, Smart Meters, Smart Cars, Smart Homes, Smart Cities, Smart Factories, Smart Smoke Detectors, Smart Refrigerators, Smart

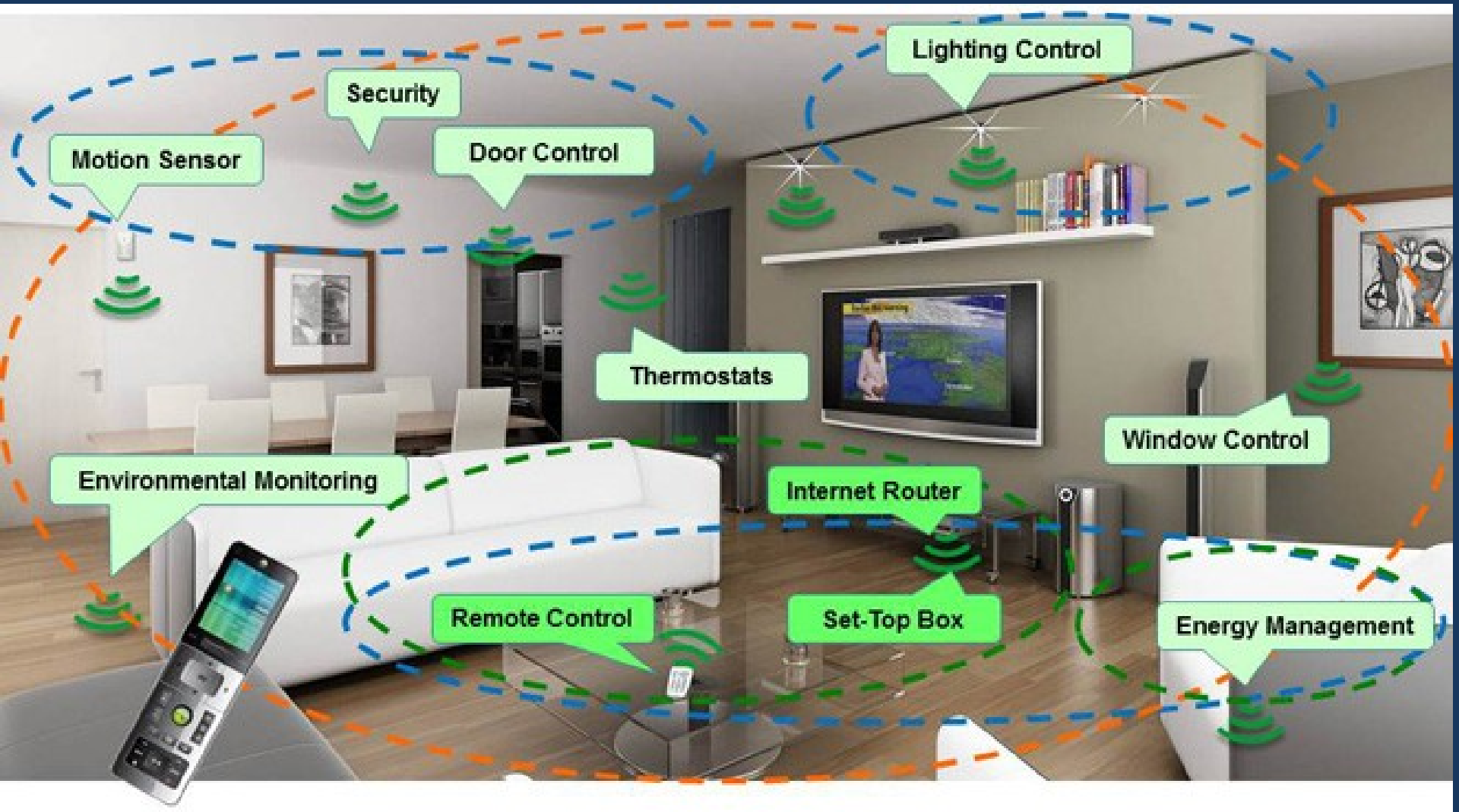
Popular Applications

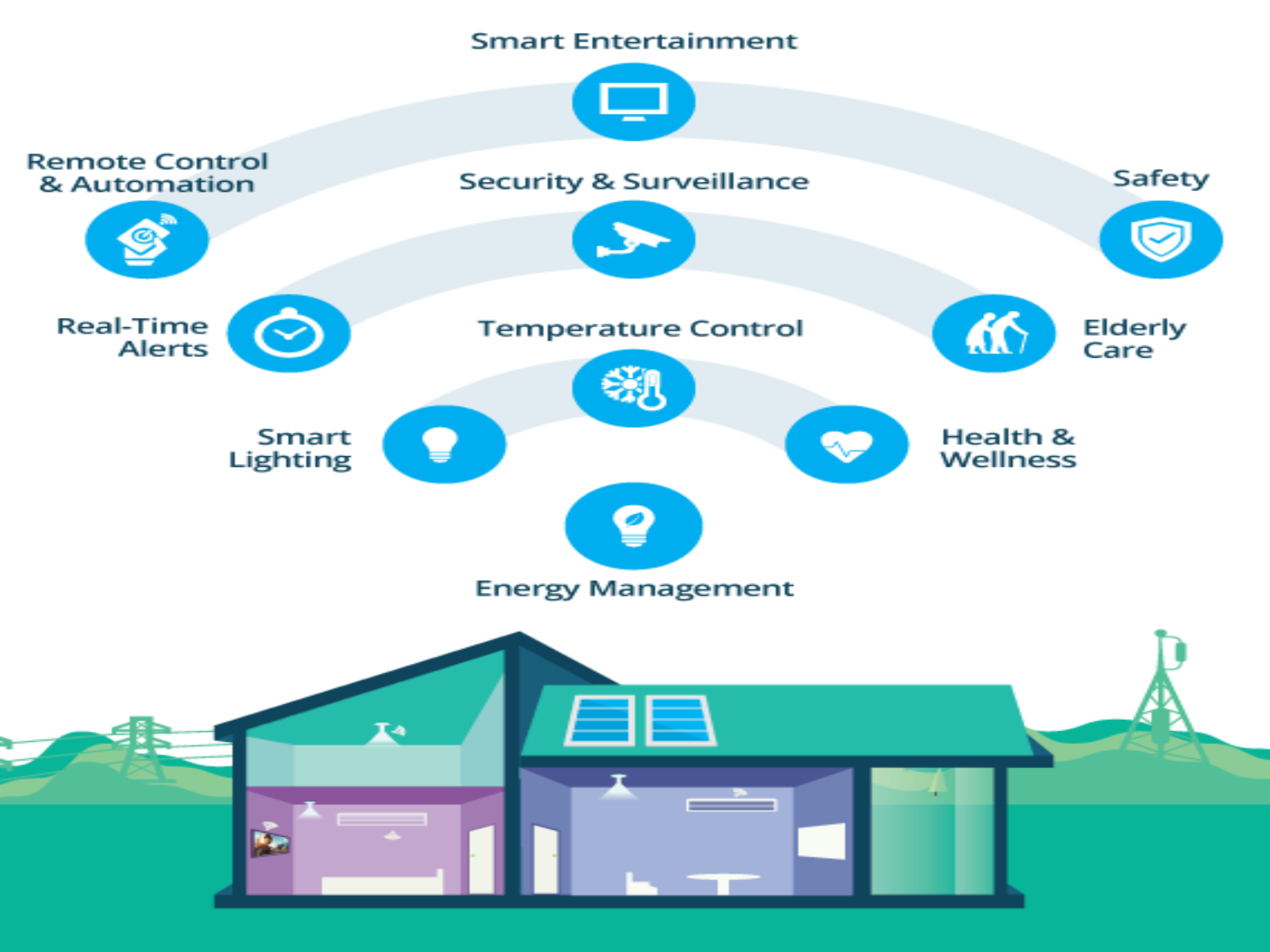


Smart Home

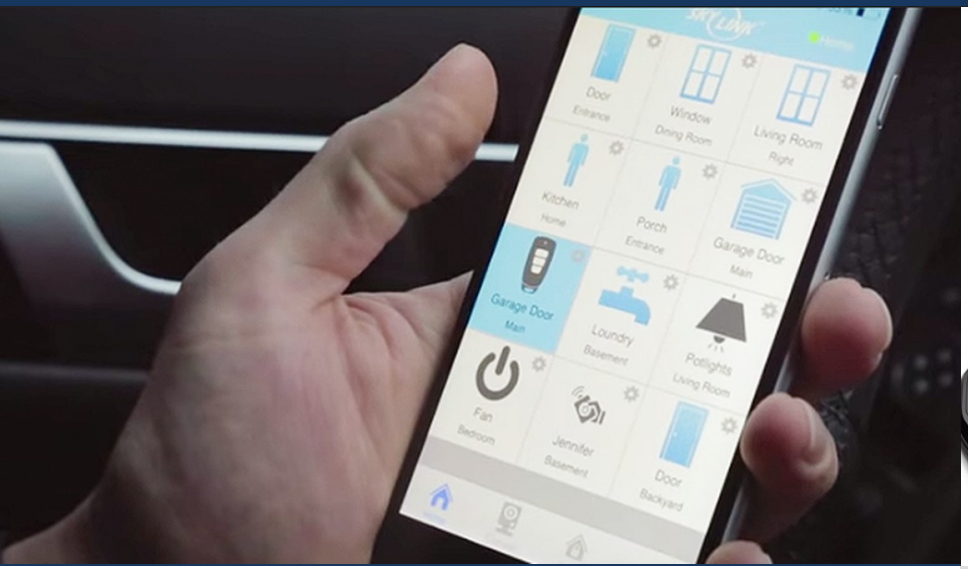
- Smart Home ranks highest among IOT applications
- More than 60,000 people currently search for the term “Smart Home” each month
- More companies are active in smart home than any other application in the field of IOT
- The total amount of funding for Smart Home startups currently exceeds $2.5bn
- Prominent startup names such as Nest or AlertMe as well as a number of multinational corporations like Philips, Haier, or Belkin
- Smart Home Products are being launched in the market

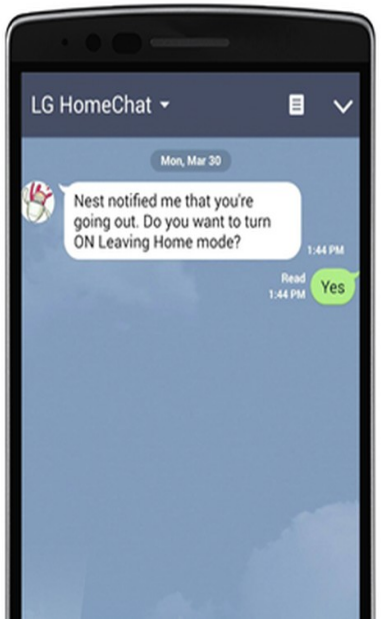
Smart Home


Lighting Control
Security
Motion Sensor
Door Control
Thermostats
Window Control
Environmental Monitoring
Internet Router
Remote Control
Set-Top Box
Energy Management


Smart Entertainment
Remote Control & Automation
Security & Surveillance
Safety
Real-Time Alerts
Temperature Control
Elderly Care
Smart Lighting
Health & Wellness
Energy Management

Smart Home Devices





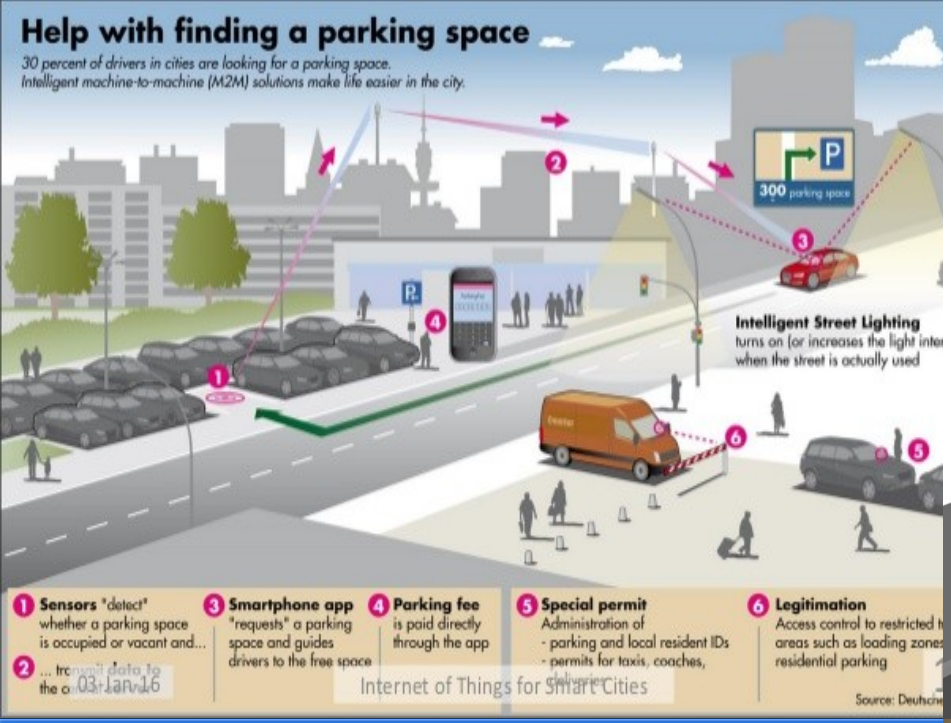
Smart Wearables

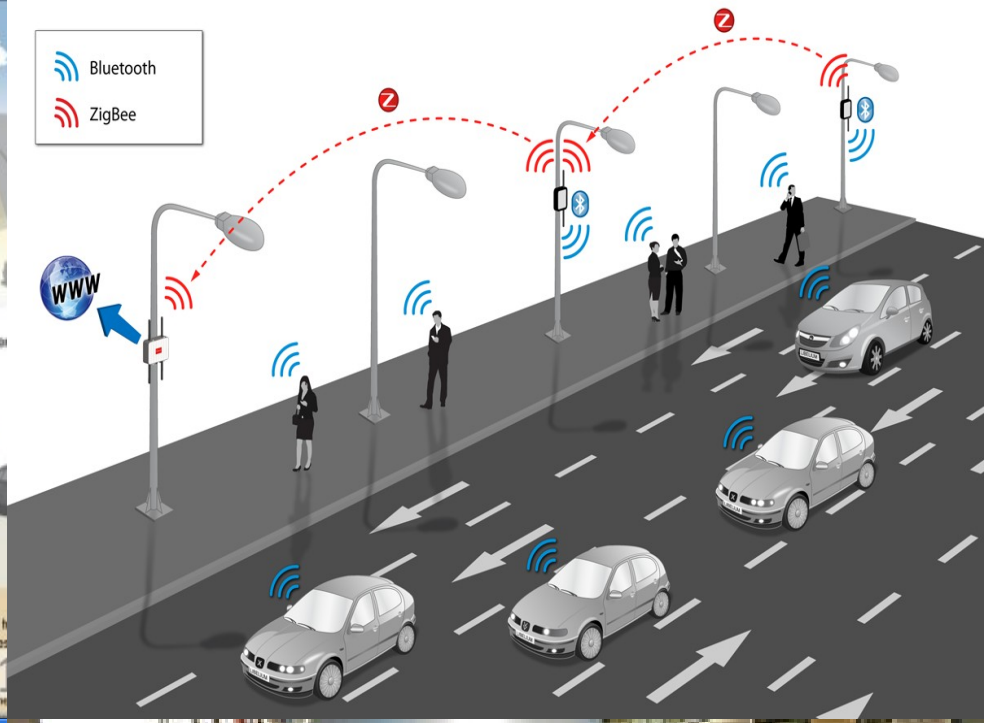
- Wearables remains a hot topic too.
- Apple’s new smart watch has been released in 2015
- Plenty of other wearable innovations like the Sony Smart B Trainer, the Myo gesture control, or LookSee bracelet
- Of all the IOT startups, wearables maker Jawbone is the one with the biggest funding to date. It stands at more than half a billion dollars!

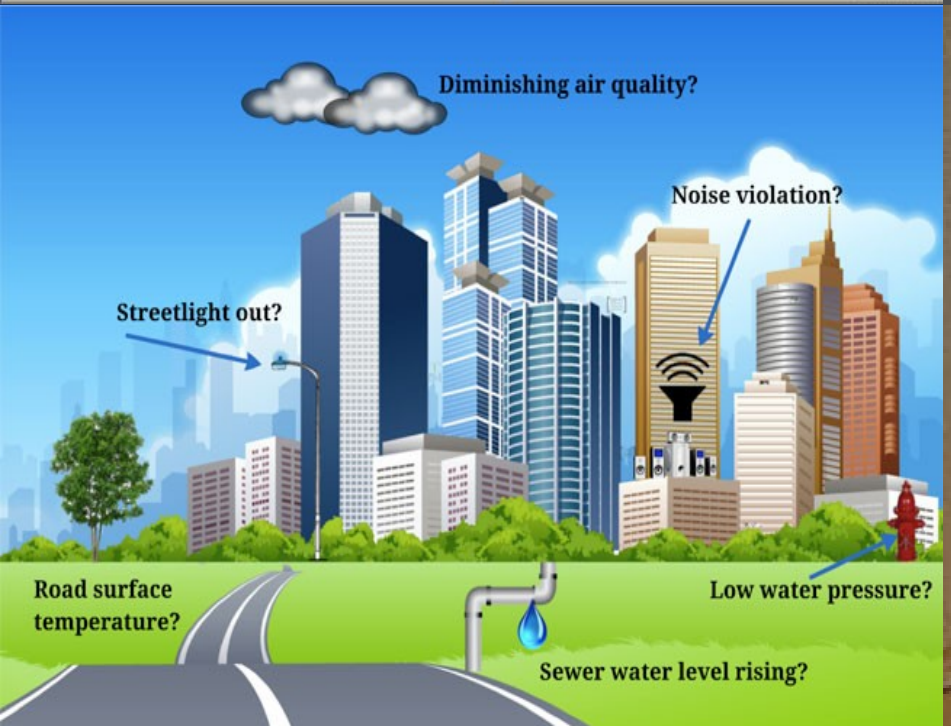
Smart Wearables

Smart City

- Smart city spans a wide variety of use cases
  - Traffic management
  - Water distribution
  - Waste management
  - Urban security and
  - Environmental monitoring
- Its popularity is fueled by the fact that many Smart City solutions promise to alleviate real pains of people living in cities these days. IOT solutions in the area of Smart City solve traffic congestion problems, reduce noise and pollution and help make cities safer


Help with finding a parking space
30 percent of drivers in cities are looking for a parking space.
Intelligent machine-to-machine (M2M) solutions make life easier in the city.
300 parking space
Intelligent Street Lighting
turns on (or increases the light inte
when the street is actually used
1 Sensors "detect" whether a parking space is occupied or vacant and...
2 ... tr... data to the c...
3 Smartphone app "requests" a parking space and guides drivers to the free space
4 Parking fee is paid directly through the app
5 Special permit Administration of
- parking and local resident IDs
- permits for taxis, coaches,
6 Legitimation Access control to restricted t... areas such as loading zones residential parking
Source: Deutsch...
03-Jan-16
Internet of Things for Smart Cities


Bluetooth
ZigBee
WWW

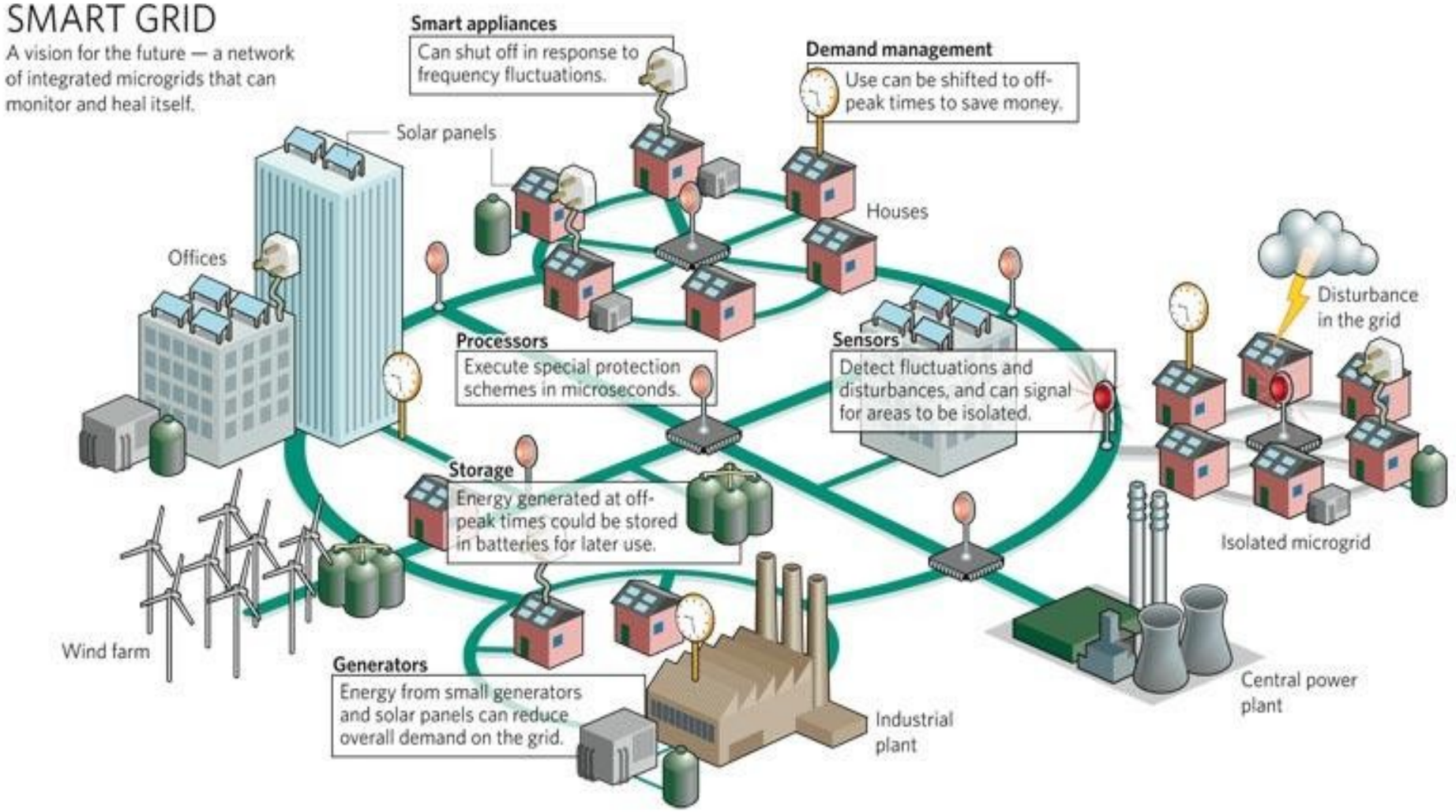

Diminishing air quality?
Noise violation?
Streetlight out?
Road surface temperature?
Low water pressure?
Sewer water level rising?


SIDEWALK CLOSED
USE OTHER SIDE

Smart Grid

- A future smart grid promises to use information about the behaviors of electricity suppliers and consumers in an automated fashion to improve the efficiency, reliability, and economics of electricity
- 41,000 monthly Google searches highlights the concept’s popularity

Smart Grid


SMART GRID
A vision for the future — a network of integrated microgrids that can monitor and heal itself.
Smart appliances
Can shut off in response to frequency fluctuations.
Demand management
Use can be shifted to off-peak times to save money.
Solar panels
Houses
Offices
Disturbance in the grid
Processors
Execute special protection schemes in microseconds.
Sensors
Detect fluctuations and disturbances, and can signal for areas to be isolated.
Storage
Energy generated at off-peak times could be stored in batteries for later use.
Isolated microgrid
Wind farm
Generators
Energy from small generators and solar panels can reduce overall demand on the grid.
Industrial plant
Central power plant

Challenges

S-E-N-S-E	What the Internet of Things does	How it differs from the Internet
Sensing	Leverages sensors attached to things (e.g. temperature, pressure, acceleration)	More data is generated by things with sensors than by people
Efficient	Adds intelligence to manual processes (e.g. reduce power usage on hot days)	Extends the Internet's productivity gains to things, not just people
Networked	Connects objects to the network (e.g. thermostats, cars, watches)	Some of the intelligence shifts from the cloud to the network's edge ("fog" computing)
Specialized	Customizes technology and process to specific verticals (e.g. healthcare, retail, oil)	Unlike the broad horizontal reach of PCs and smartphones, the IoT is very fragmented
Everywhere	Deployed pervasively (e.g. on the human body, in cars, homes, cities, factories)	Ubiquitous presence, resulting in an order of magnitude more devices and even greater security concerns

Major Research Challenges

- Security and Privacy
- Reliability and Dependability
- Usability, Management, Interoperability
- Software architecture
- Information-centric Networking
- Radio innovations
- Testing and evaluation
- Social, economic and policy issues
- education

Security and Privacy

- Identify security and privacy requirements (user, institution, or regulatory) for different IOT systems and applications
- Develop the science of data use and sharing to ensure secure, trustworthy data is delivered to the right users with low overhead in a way that guarantees privacy across time
- Design commissioning techniques, key management schemes, access policies, intrusion detection and response systems that are suitable for increasingly larger numbers of low power, unattended (and mobile) devices, with intermittent access to servers

Reliability and Dependability

- Develop simple and user-friendly tools for specification, coding, formal verification, testing to reduce bugs and vulnerabilities
- Develop design and analysis tools for IOT systems that describe what they can and cannot do, what guarantees they can provide at various layers, under time-varying operating conditions
- Inform programmers about inherent unreliability and uncertainty, including in sensing and actuation, through suitable abstractions

Usability, Management and Interoperability

- Make IOT systems easy to deploy, even in environments where they have to interoperate with legacy devices and networks
- Develop intuitive, effective, user-friendly interfaces and tools for human operators to gather information about network health, and to reconfigure the network as needed
- Ensure interoperability across multiple layers interoperability of communication (at PHY and MAC levels), applications, data between different IOT devices and networks

Software Architecture

- Create middleware/ tools for flexible implementation of processing at the edge and in the cloud
- Develop architecture and optimization frameworks that determine how best to split computation (and data) across edge devices and cloud servers in a distributed / hierarchical manner. to enable insights from the collected sensor data
- Develop architectures that allow IOT devices to network together seamlessly and enable computeintensive tasks and

Information-Centric Networking

- Information-centric networking (ICN) is an approach to evolve the Internet infrastructure away from a host-centric paradigm based on perpetual connectivity and the end-to-end principle, to a network architecture in which the focal point is “named information” (or content or data)
- The challenge is naming schemes for ICN, re-designing application protocols, congestion control, QoS, caching and routing schemes. Security, privacy and access control of objects

Radio Innovations

- Design new physical and link layers using techniques such as massive MIMO, network coding, successive interference cancellation, etc. that enhance spectrum efficiency, low-power operation, and reliability
- Develop and utilize low-cost, low-power, software defined radios to spur innovations at the lower layers
- Discover and develop new radio-based sensing capabilities

Social, Economic and Policy Issues

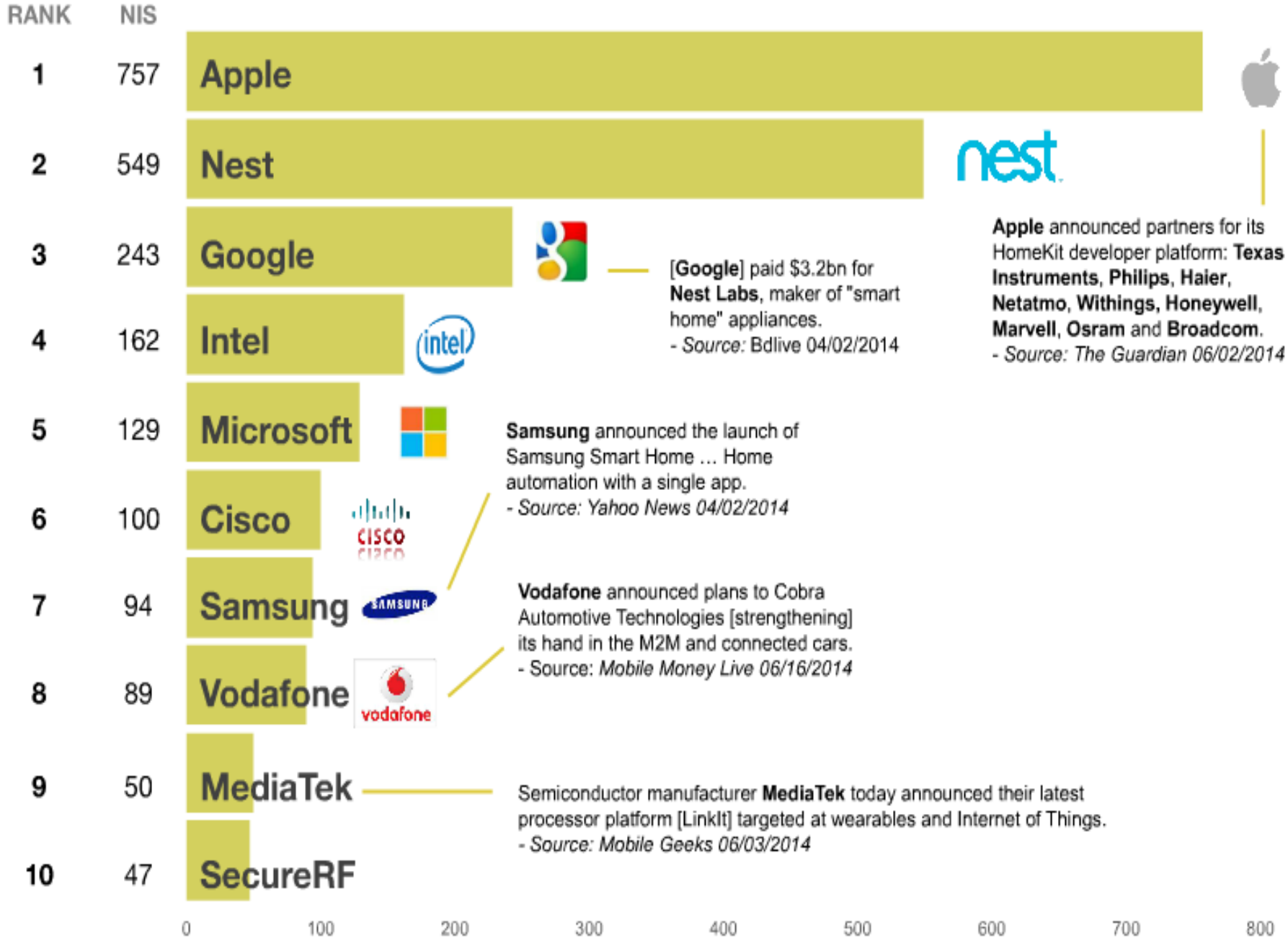
- Research social acceptance of new IOT technologies, their impact on the digital divide and sustainable living, new economic opportunities and disruptions
- Identify and study new regulatory policies and economic incentives for spectrum use, data sharing, and interoperability

Education

- Develop and disseminate interdisciplinary curricula and materials about new developments as well as relevant results and techniques from existing disciplines such as communications and networking, embedded systems, control theory, machine learning, software engineering
- Educate the next generation of developers to create software able to run with limited resources and exposed to faults
- Encourage test-bed operators to make test-beds more broadly accessible and available to students and researchers at universities

Opportunities

The 10 Most Influential Internet of Things Companies



Four critical indicators of market for IOT devices, products and services

- **Supplier Attention**
  - IOT developer tools and products are now available. Apple, for instance, has released HealthKit and HomeKit developer tools as part of its latest operating-system upgrade
  - Google acquired smart thermostat maker Nest (for $3.2 billion) to boost the development of an IOT platform and applications

Four critical indicators of market for IOT devices, products and services

- **Technological Advances**
  - MEMS at lower prices
  - Power and energy efficient processors, such as the ARM Cortex M
  - The initial smart watches (2012) had 400-MHz single processors and simple three-axis accelerometers. Now a typical smart watch includes 1-GHz dual-core processors and high-end, six-axis devices that combine gyroscopes and accelerometers
  - Prices of chip sets in these products declined by about 25 % per year over the past two years

Four critical indicators of market for IOT devices, products and services

- **Increasing Demand**
  - Demand for the first generation of IOT products (fitness bands, smart watches, and smart thermostats, for instance) increasing as component technologies are evolving and their costs are declining
  - A similar dynamic was observed in smart-phone usage. Consumer demand jumped from 170 million devices sold annually five years ago to one billion devices in 2014
  - This coincided with a steep decline in the price of critical smart-phone components

Four critical indicators of market for IOT devices, products and services

- Emerging Standards
  - Over the past two years, semiconductor players have joined forces with hardware, networking, and software companies, and with a number of industry associations and academic consortiums, to develop formal and informal standards for IOT applications
  - AT&T, Cisco, GE, IBM, and Intel cofounded the Industrial Internet Consortium, to establish interoperability standards across industrial environments so that data about fleets, machines, and facilities can be accessed and shared more reliably
  - Other groups focused on standardizing the APIs that enable basic commands and data transfer among IOT devices

Growth for Application Developers

- 2014 saw the inaugural “Internet of Things Developers Conference” make its debut, the Application Developers Alliance released its ”Internet of Things Developer’s Mandate” and a big push was seen from clients like Cisco, Samsung, Microsoft, Intel and others for recruitment of developers to their respective IOT programs and initiatives

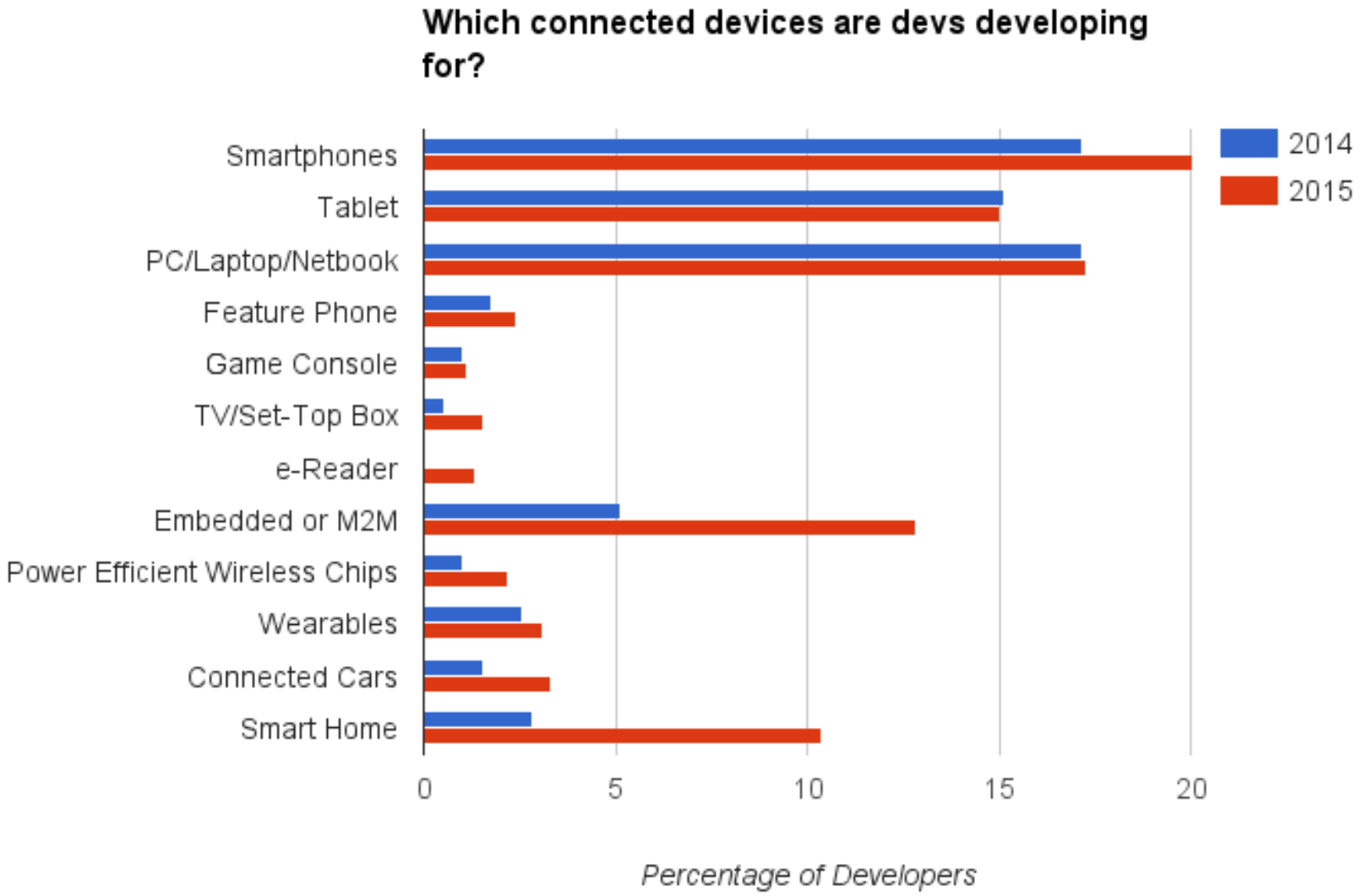
Growth for Application Developers

- A 34 % growth between 2014 and 2015 (in less than a year) in terms of the number of programmers developing software for connected devices!

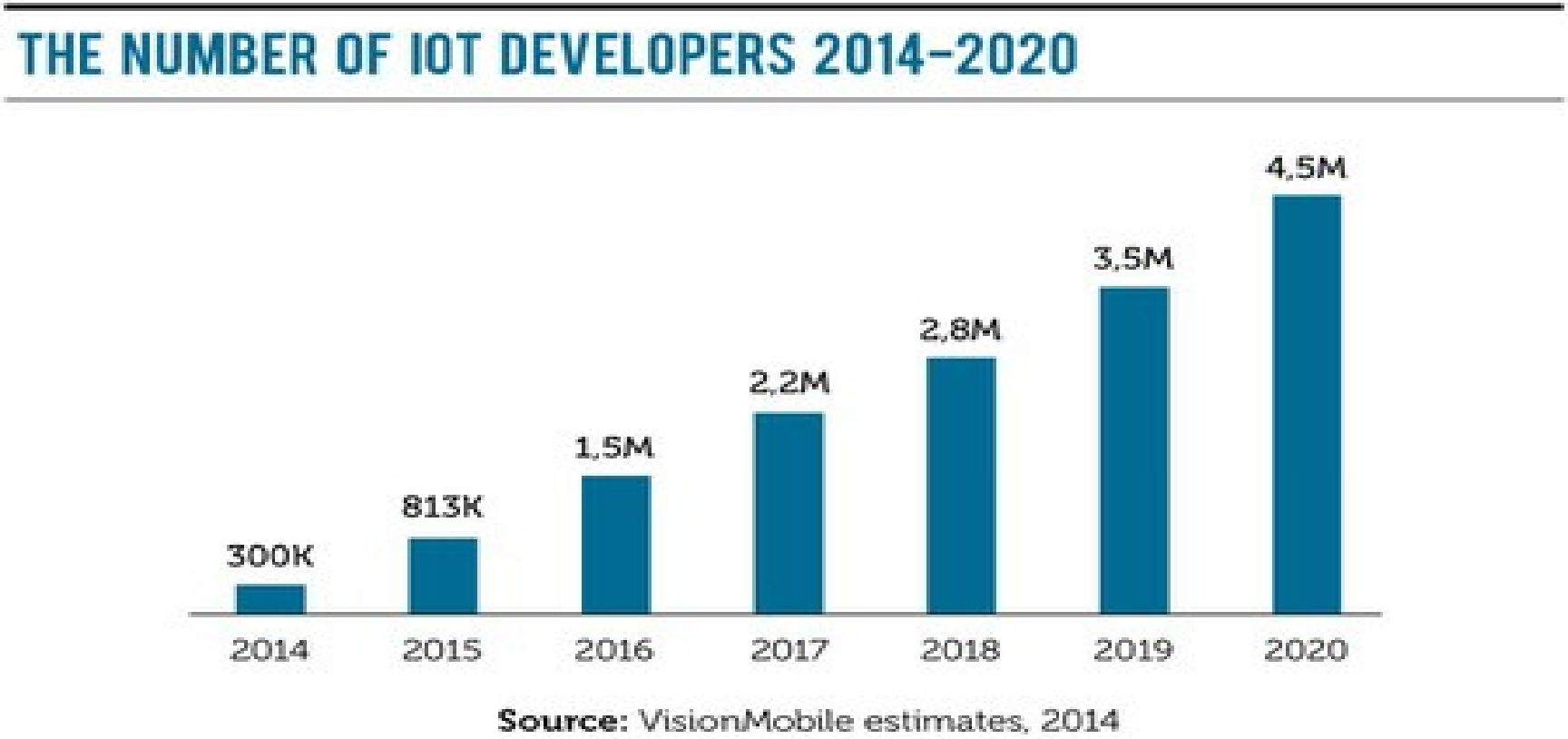
What will they build

- “Demand for IOT technology will not come from a single killer app, but from thousands of unexpected new use cases.”
- No single company will win in the IOT, nor will any one app.
- Such developer-driven demand “will create new IOT markets that are several times bigger than the ones we could ever predict with a spreadsheet that extrapolates today’s market.”
- The developers are fundamental to making IOT a big, profitable market, even if they don’t pay a single dime for a single sensor in that market

Which connected devices are developers developing for



How does the rapid growth of wearables and IOT devices impact developers?



Thank you