

Internet of Things

Introduction and Basic Concepts

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Contents

- Basic Concepts
- Ecosystem
 - Things
 - Platform
 - Networks
 - Applications and Verticals
- Architecture
- Challenges
- Business and Market Opportunities
- Trends

Mostly adopted from **IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Thing**, Cisco press, 2017

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What is IoT?

- "IoT" term was first introduced by Kevin Ashton in 1999.
- **Kevin Ashton:**
 - If we had computers that knew everything there was to know about things—using data they gathered without any help from us—we would be able to track and count everything, and 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. We need to empower computers with their own means of gathering information, so they can see, hear and smell the world for themselves.

What is IoT?

- **ITU-T, 2012**
 - Internet of things (IoT): 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**.

What is IoT?

- IERC, 2014
 - A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual ‘things’ have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network.



* Internet of Things Challenges, Advances, and Applications, CRC Press, 2018

* http://www.internet-of-things-research.eu/about_iot.htm

What is IoT?

- ISO/IEC, 2015
 - An infrastructure of interconnected objects, people, systems, and information resources together with intelligent services to allow them to process information of the physical and the virtual world and react.

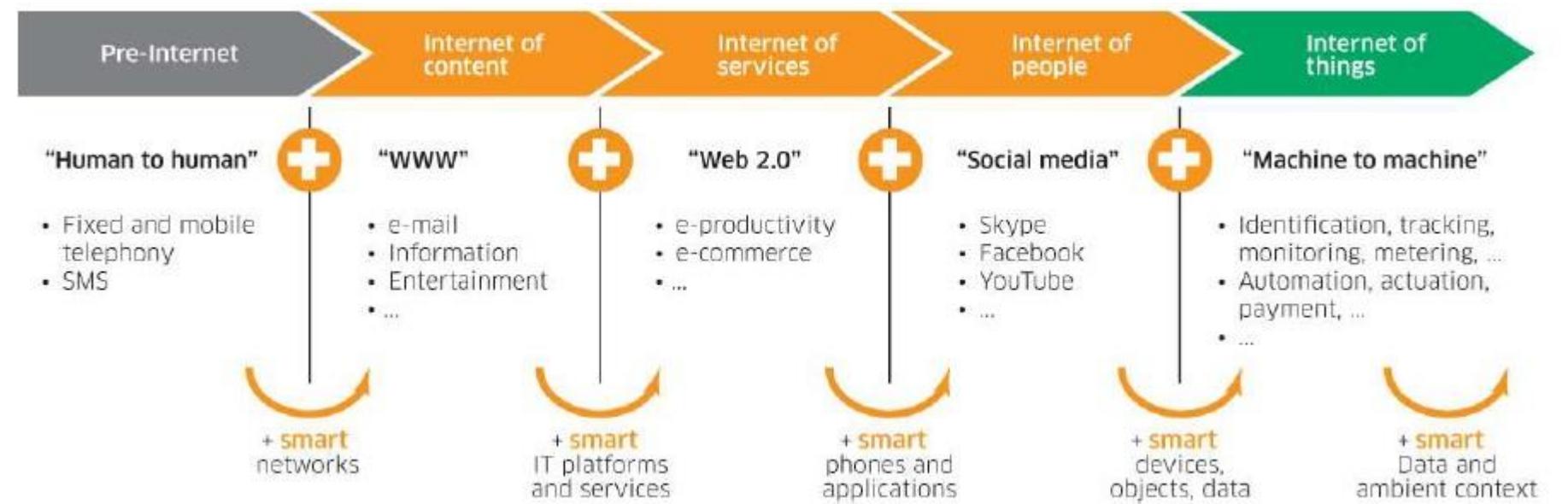
What is IoT?

- **IEEE IoT, 2015**
 - An IoT is a network that **connects uniquely identifiable ‘Things’** to the Internet. Through the exploitation of unique identification and sensing, information about the ‘Thing’ can be collected and the state of the ‘Thing’ can be changed from anywhere, anytime, by anything.”

What is IoT?

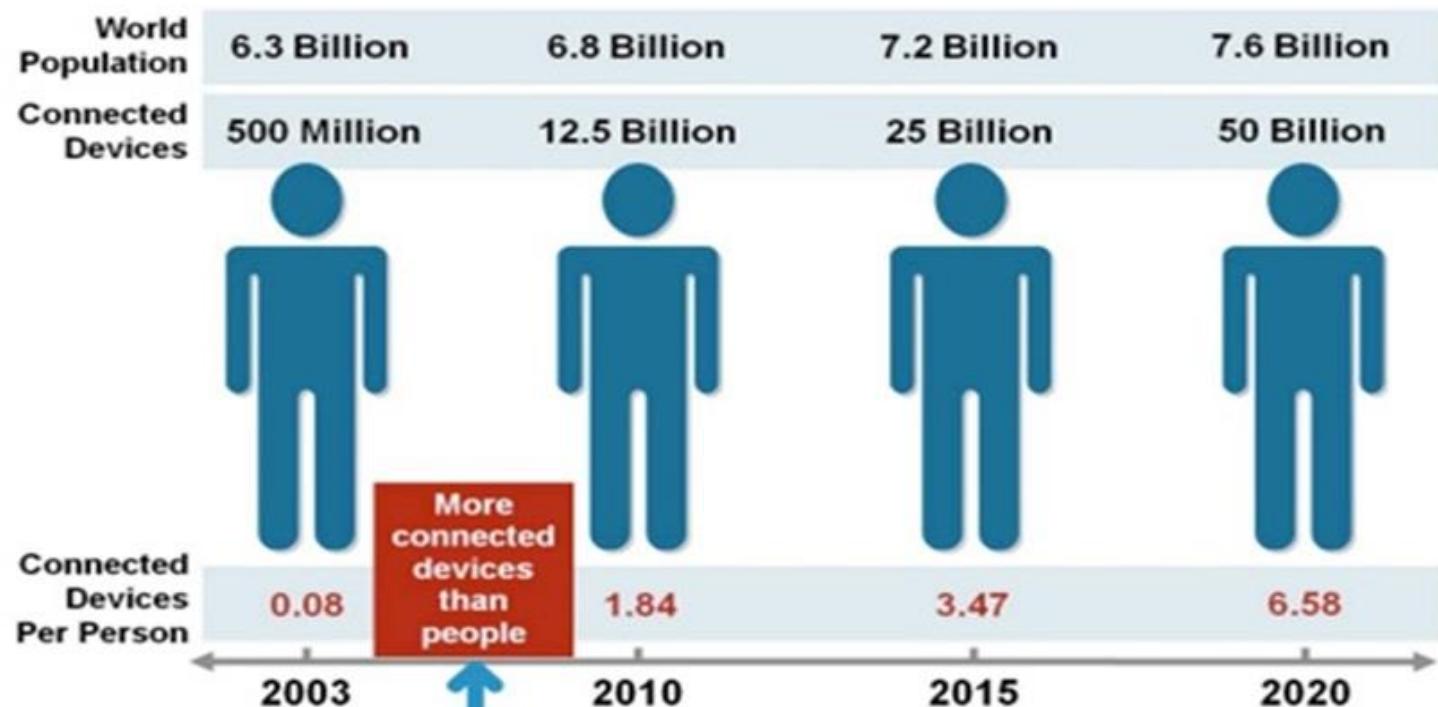
- IoT is a world of **interconnected things** which are capable of **sensing**, **actuating**, and **communicating** among themselves and with the environment (i.e.,smart things or smart objects) while providing the ability to **share information** and act in parts autonomously to real/physical world events and by triggering processes and creating services with or without direct human intervention.

History of IoT



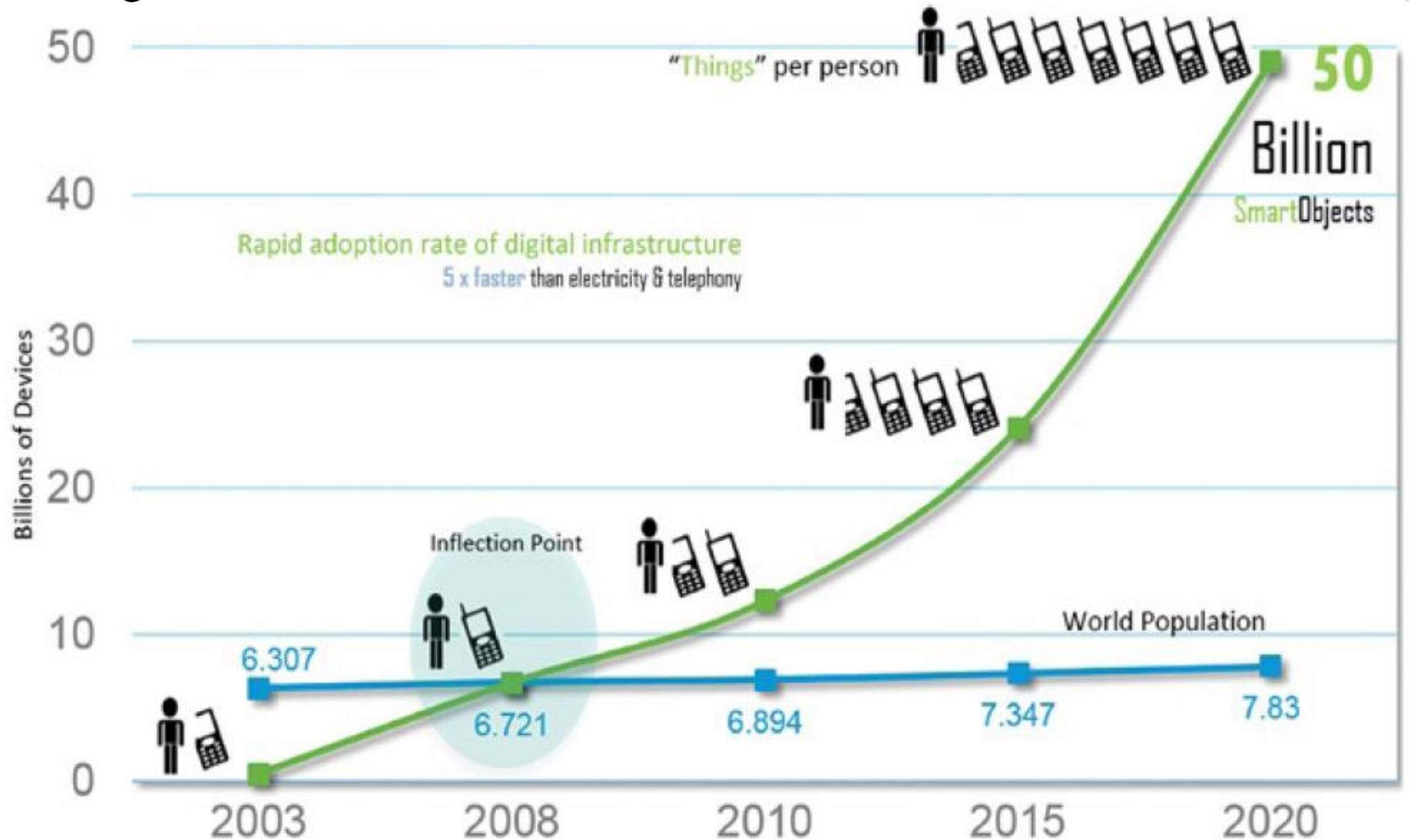
The number of connected devices:

- Devices connected to the internet exceed the number of people



IoT Impact

- Growing the number of connected devices to 50 billion in 2020.



History of IoT



1982 Carnegie-Mellon researchers connect a **vending machine** to the Internet so they can remotely check for cold sodas.

1995 The **GPS** satellite network (version 1) is completed.

1999 The term "**Internet of Things**" is first used by Kevin Ashton of MIT.

The Internet of Things (IoT) has come a long way, going from one or two machines in the 1980s to billions in 2019.

1969 ARPANET, the precursor to the Internet, is developed.

1990 John Romkey demonstrates the first **toaster** controlled via the Internet.

1998 IPv6 adds 2^{128} new IP addresses, which even IoT devices will have trouble eating up.

2000 LG announces the first **smart fridge**. It's cool (literally) but also too expensive to sell well.

2007 The first **iPhone** is released.

2009 Google starts testing **self-driving cars**.

2014 Amazon releases the **Echo**, which sets off a scramble to enter the smart home hub market.

2017-2019 IoT continues to grow as Internet penetration, **AI**, **blockchain**, **edge computing**, and cheap devices and sensors proliferate.

2008 The first international **IoT conference** is held. Also, there are now more online devices than there are humans on earth.

2013 Google Glass is released. Too soon, apparently. VR and AR are still in early stages.

2016 GM, Lyft, Uber, and Tesla are all testing **self-driving cars** now. Mirai, the first large-scale IoT attack, also takes place.

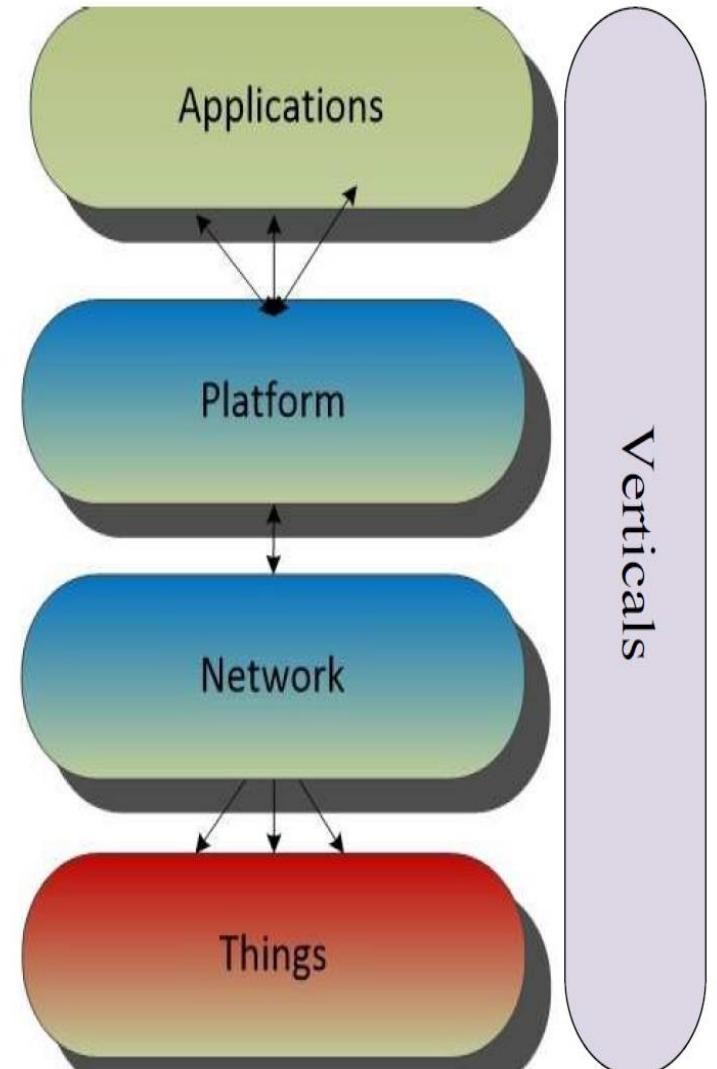


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 - Trends

IoT Ecosystem

- Things:
 - sensors and actuators
- Network:
 - communication technologies
- Platform:
 - security, process modeling and device management, data stream and information management, integration of information access mechanisms
- Applications:
 - making decisions, data analytics



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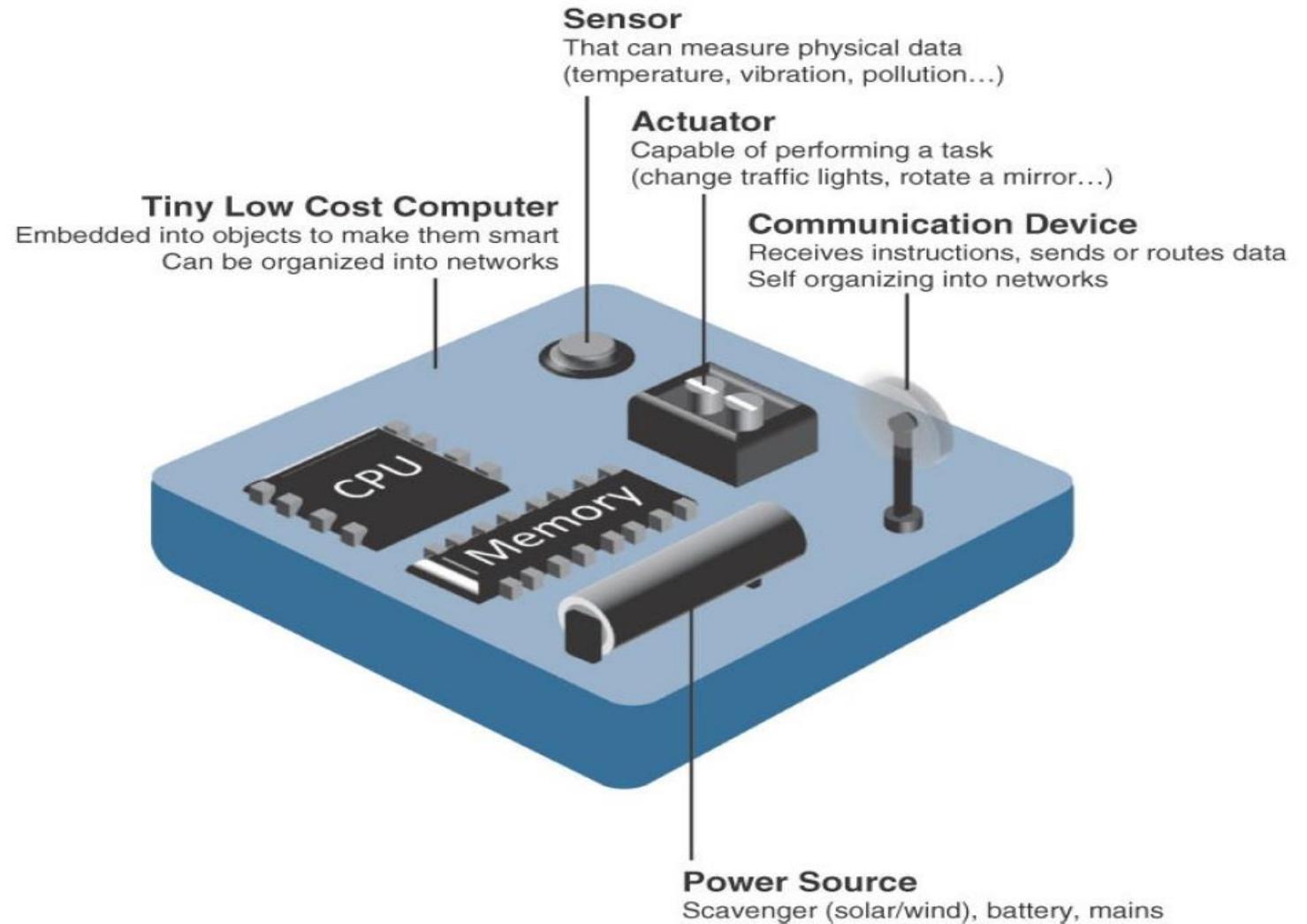


What are Things?

- Smart objects or Things are any physical objects that contain embedded technology to sense and/or interact with their environment in a meaningful way by being interconnected and enabling communication among themselves or an external agent.
- Things are
 - Sensors
 - Actuators

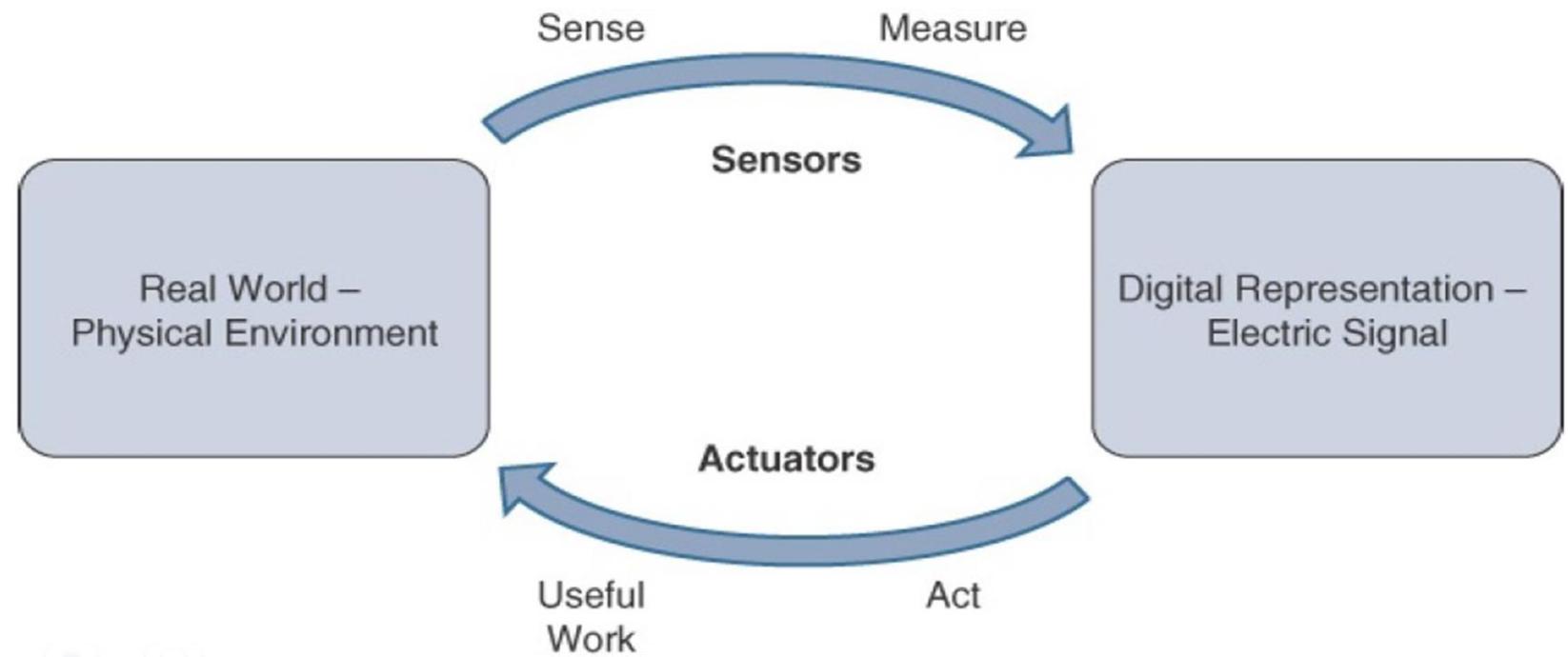
What are Things?

- Sensors
- Actuators



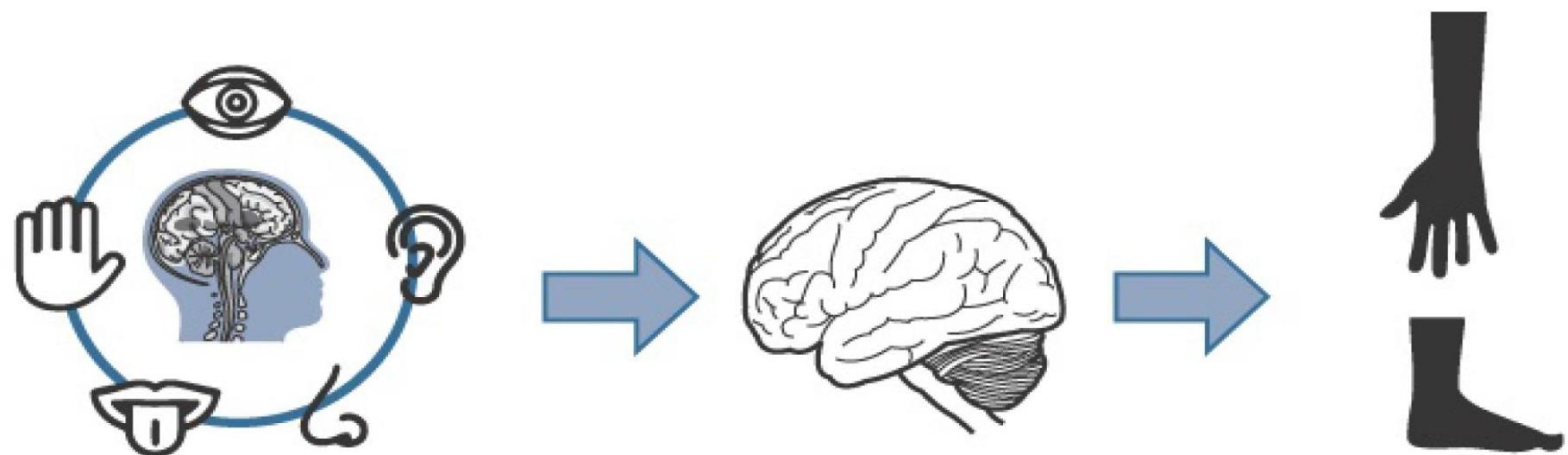
What are Things?

- How Sensors and Actuators Interact with the Physical World



What are Things?

- Comparison of Sensors and Actuators Functionality with Humans



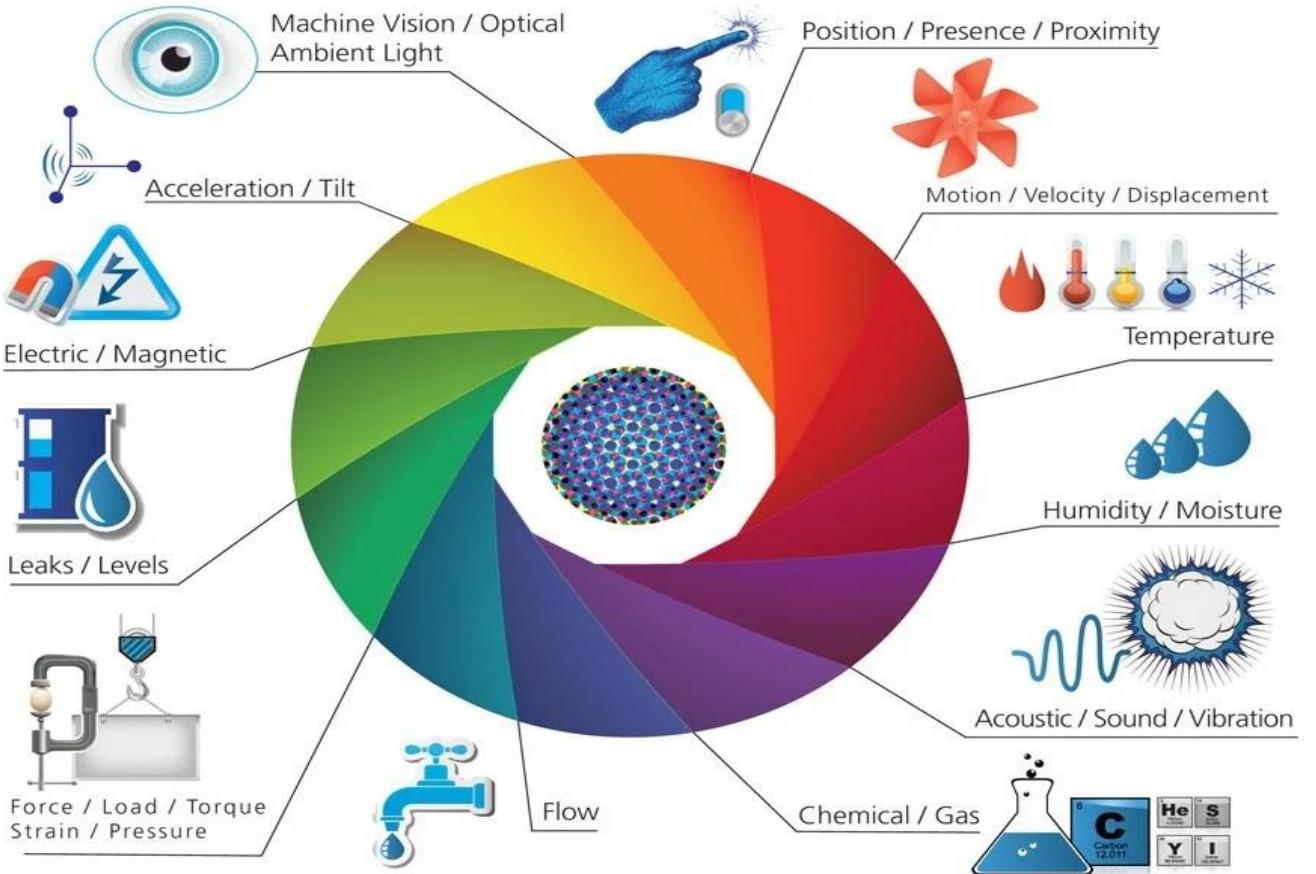
Sensor

CPU

Actuator

What are Things?

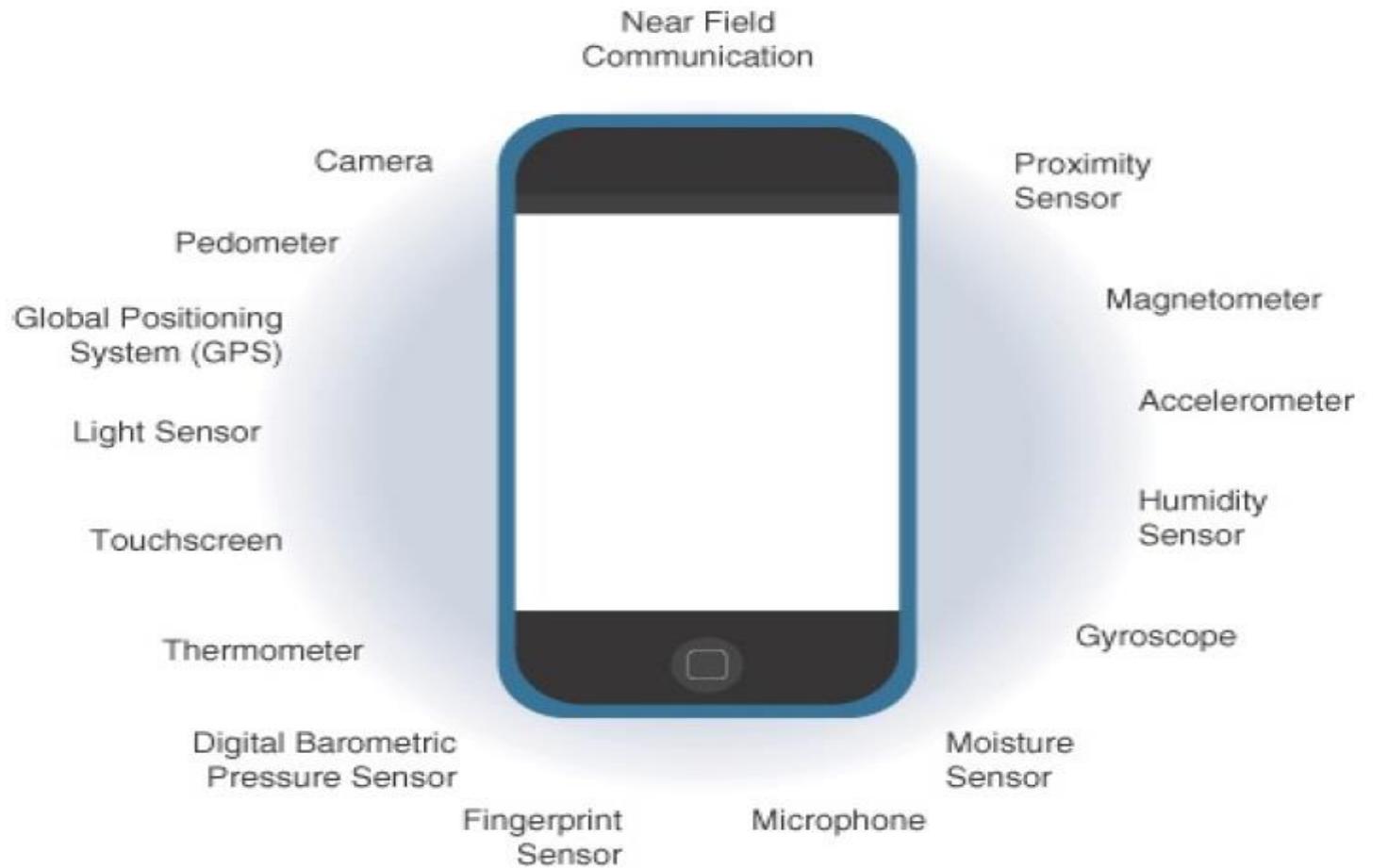
- Sensors and Actuators



* <https://www.postscapes.com/iot-sensors-actuators>

What are Things?

- Sensors in smart phones



Sensors

- Measures some physical quantity and converts it into a digital representation.
- That digital representation is typically passed to another device for transformation into useful data that can be consumed by intelligent devices or humans.
- Sensors can be readily embedded in any physical objects that are easily connected to the Internet by wired or wireless networks.
- Because these connected host physical objects with multidimensional sensing capabilities communicate with each other and external systems, they can interpret their environment and make intelligent decisions.

* IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Thing, Cisco press, 2017

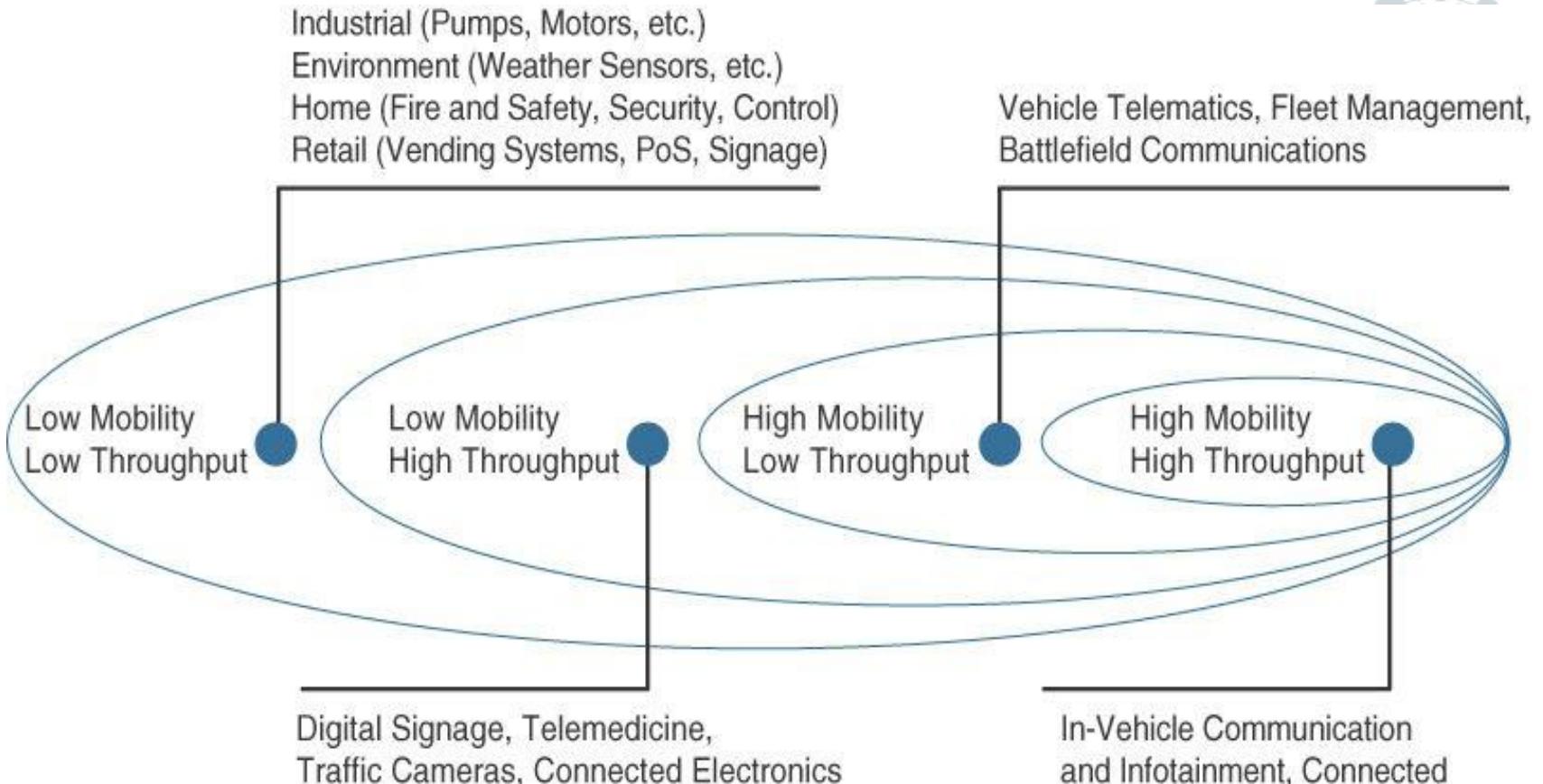
Sensors

- Different types of sensors
 - Active or passive
 - Invasive or non-invasive
 - Contact or no-contact
 - Absolute or relative
 - Area of application
 - How sensors measure
 - What sensors measure



Sensors

Example of Sensor Applications Based on Mobility and Throughput



Actuators

- Actuators receive some type of control signal (commonly an electric signal or digital command) that triggers a physical effect, usually some type of motion, force, and so on.

Actuators

- Different types of actuators
 - Type of motion
 - Power
 - Binary or continuous
 - Area of application
 - Type of energy

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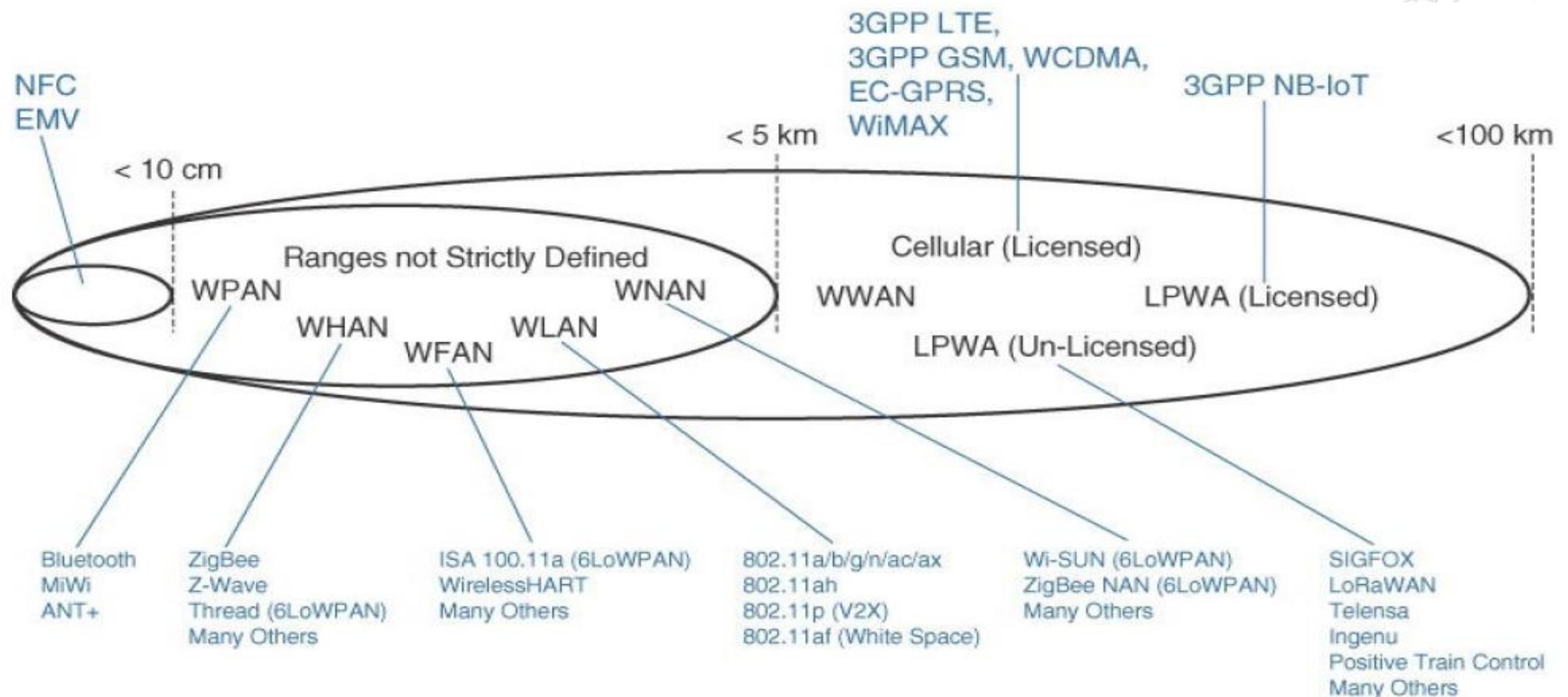
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IoT Networks

- Having determined the smart object and its required transmission capabilities (transmission range, data volume and frequency, sensor density and mobility), you are ready to connect the object and communicate.
- A first step in designing an IoT network is to examine the requirements in terms of mobility and data transmission (how much data, how often, how long, how much power).
- IoT Network is the communication domain for the IoT devices and endpoints.
- It includes the devices themselves and the communications network that links them.

Access Technologies and Distances



WPAN: Wireless Personal Area Network

WHAN: Wireless Home Area Network

WFAN: Wireless Field (or Factory) Area Network

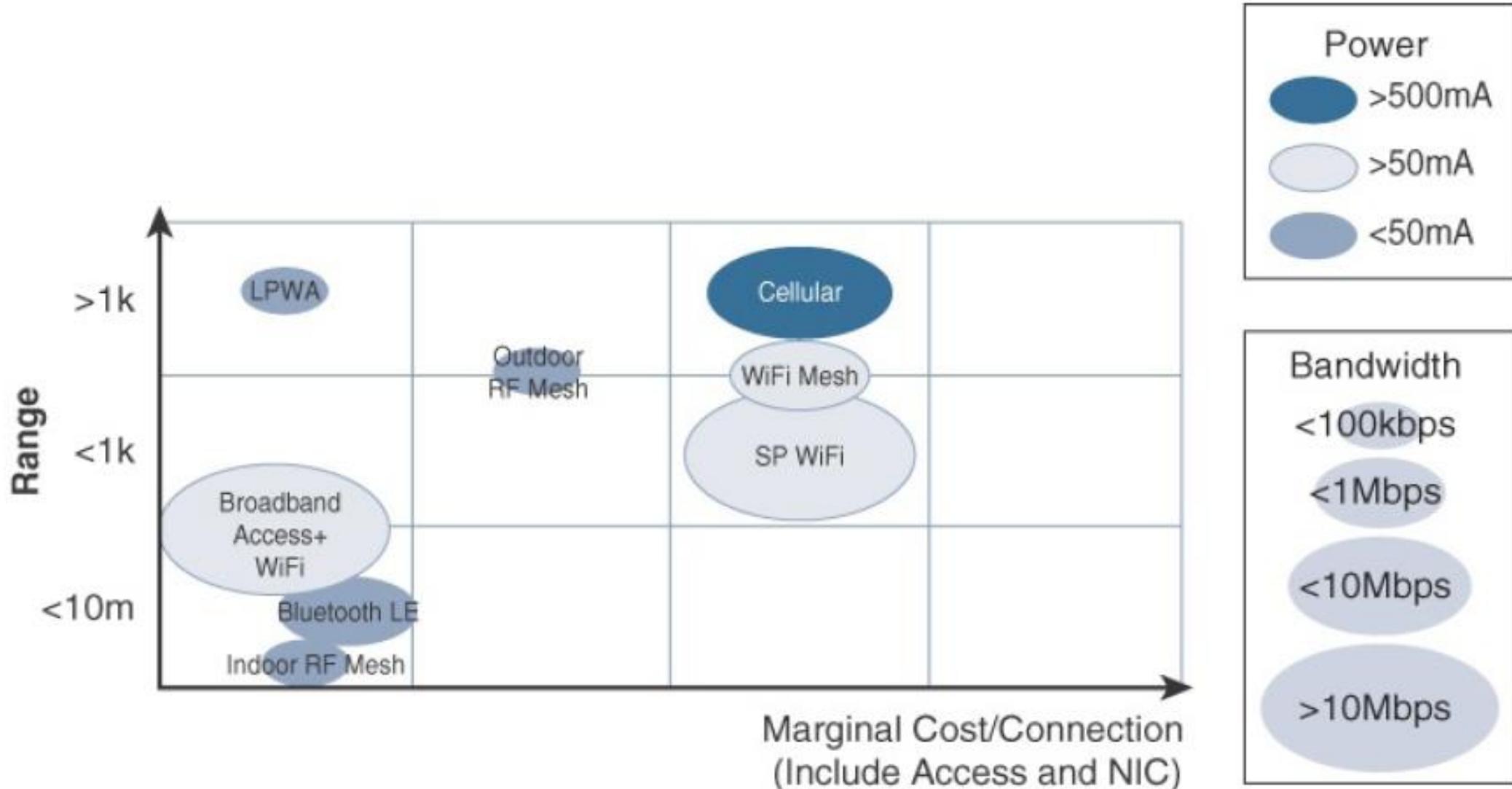
WLAN: Wireless Local Area Network

WNAN: Wireless Neighborhood Area Network

WWAN: Wireless Wide Area Network

LPWA: Low Power Wide Area

Comparison Between Common Last-Mile Technologies in Terms of Range Versus Cost, Power, and Bandwidth



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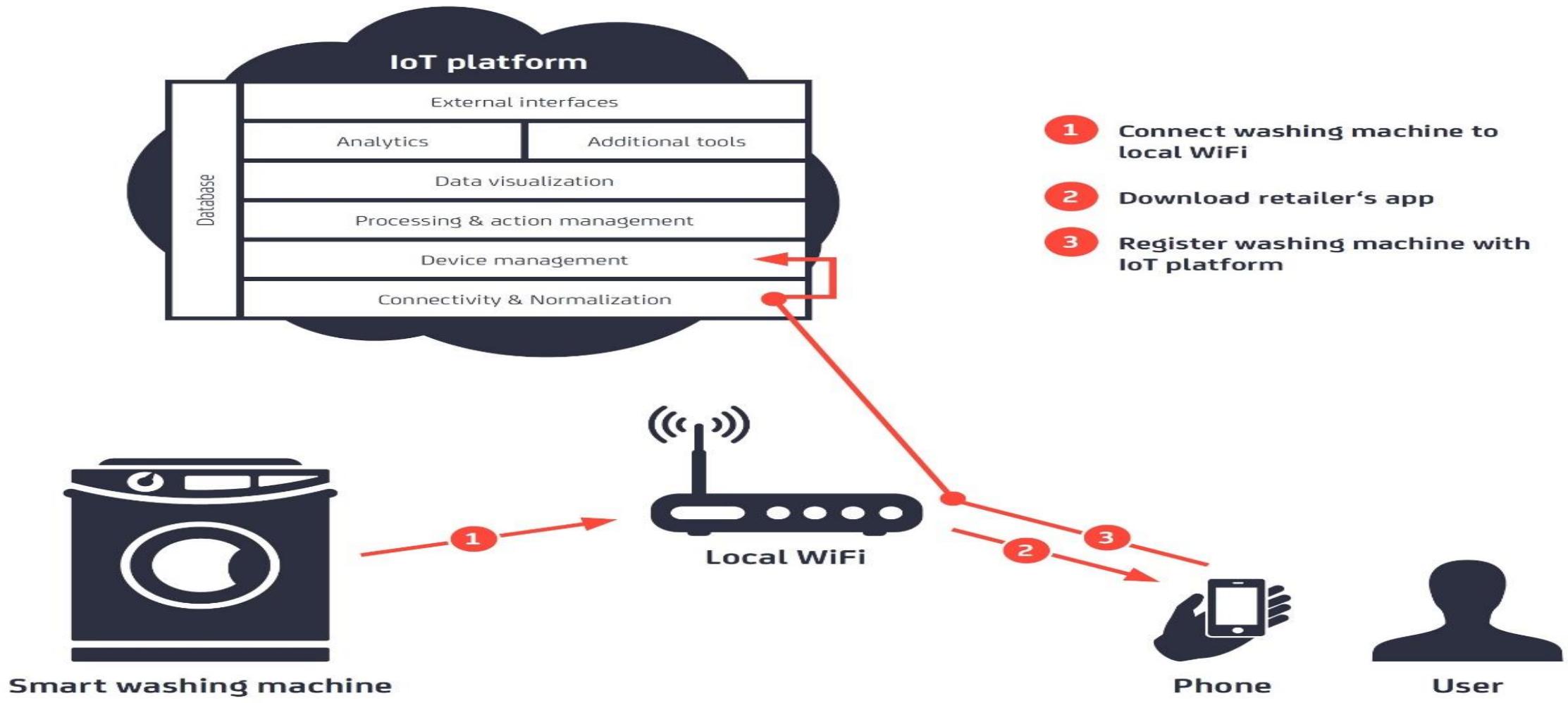
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IoT Platforms

- IoT platforms are the central piece in the Internet of Things architecture that connect the real and the virtual worlds and enable communication between objects.
- In its most simple form, an IoT platform is just about enabling connectivity between objects.
- In a more sophisticated form, the platform consists of a variety of important building blocks:
 - Connectivity and normalization,
 - device management,
 - database,
 - processing and action management,
 - analytics,
 - visualization,
 - additional tools, and
 - external interfaces

IoT Platforms

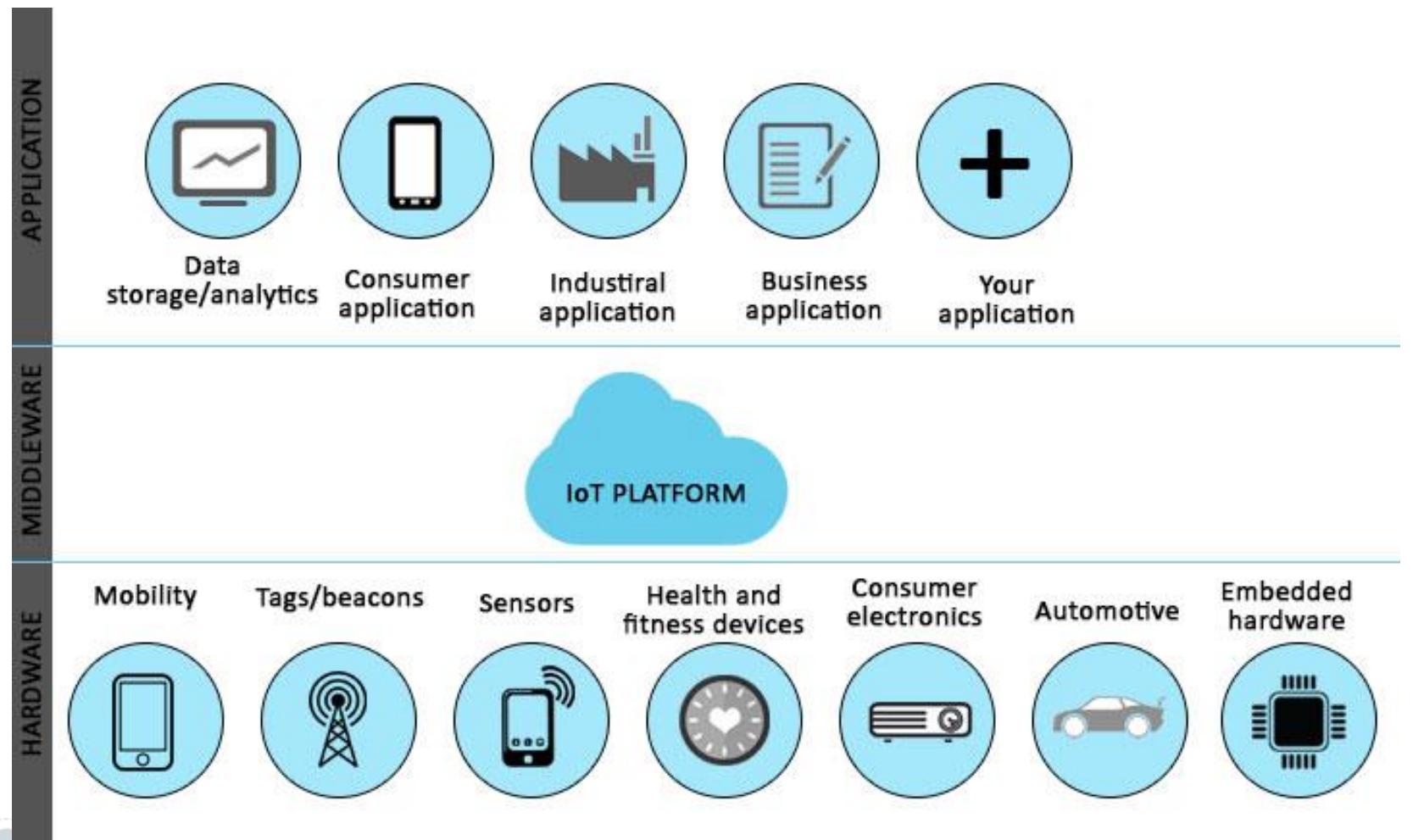


IoT Platforms

- An IoT platform is an end-to-end software framework.
- It's the glue that pulls together information from sensors, devices, networks, and software that work together to unlock valuable, actionable data.
- A platform should have the ability to:
 - manage devices
 - allow remote connections to all relevant objects or devices
 - collect and manage data and help you define business rules
 - enable analytics and visualization
 - integrate with IT and cloud services

* <https://www.business.att.com/learn/research-reports/whats-an-iot-platform-and-what-role-does-it-play.html>

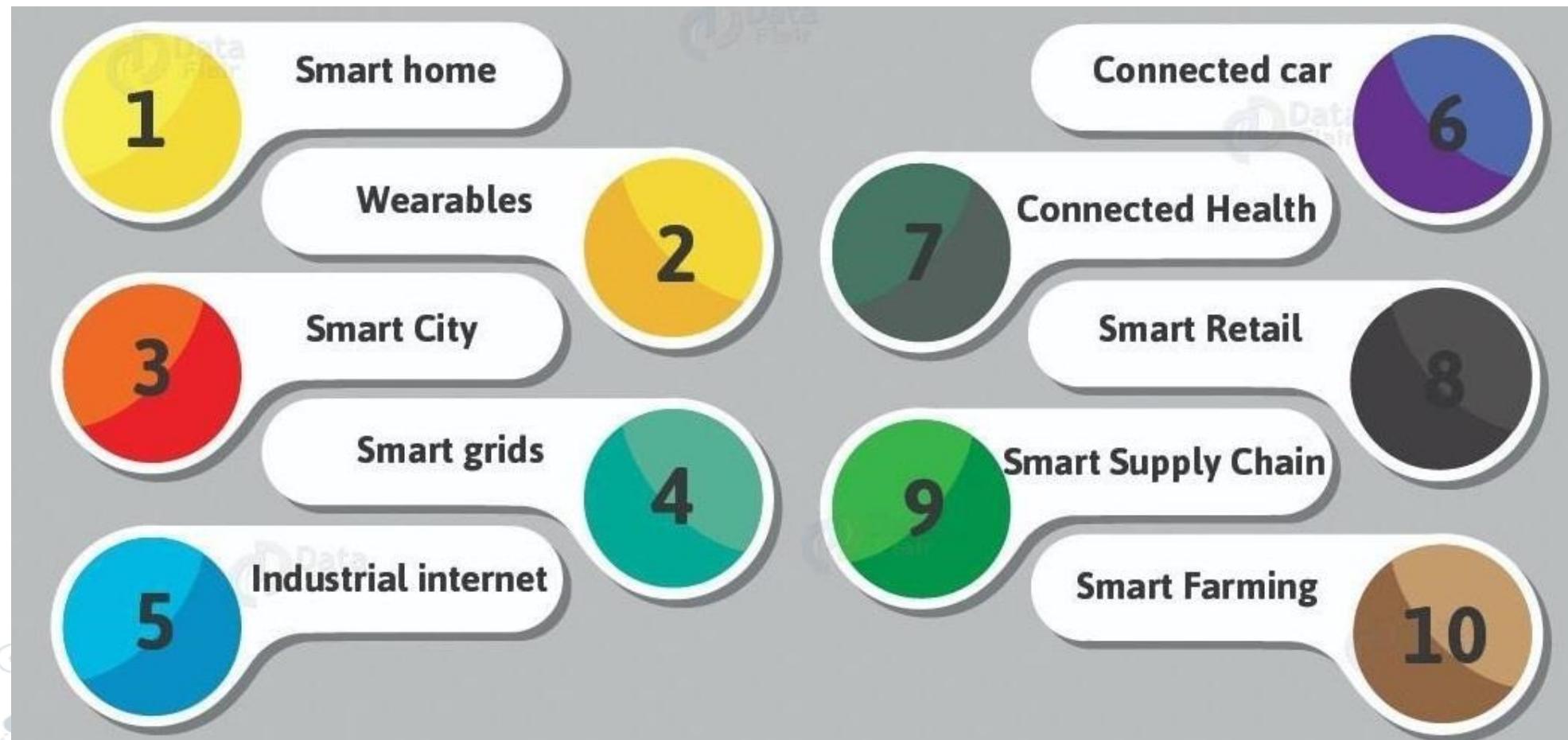
IoT Platforms



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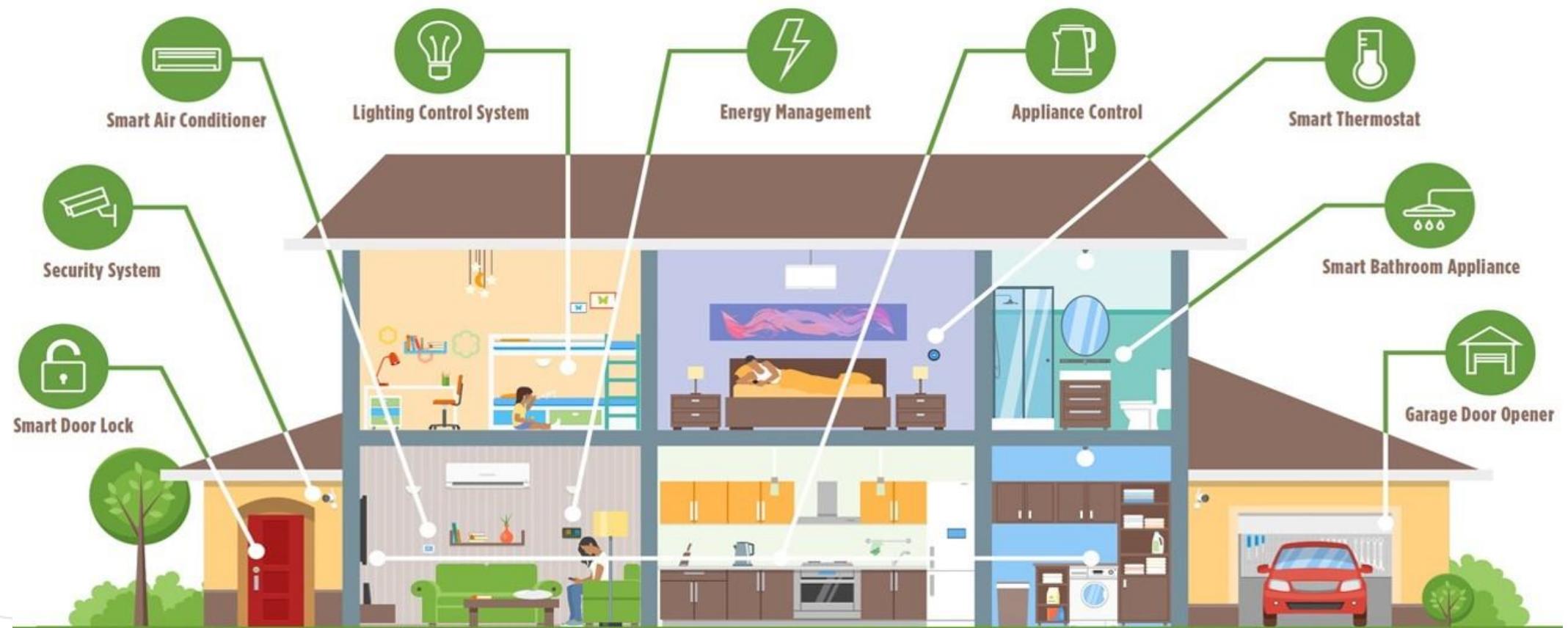
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IoT Applications and Verticals



IoT Applications and Verticals- Smart Home

Smart Home



* <https://www.bluebonnetelectric.coop/Community/News/articles/2016/Magazine-Stories/HOME,-SMART-HOME-Trends-in-residential-technology>

IoT Applications and Verticals- Smart Wearables

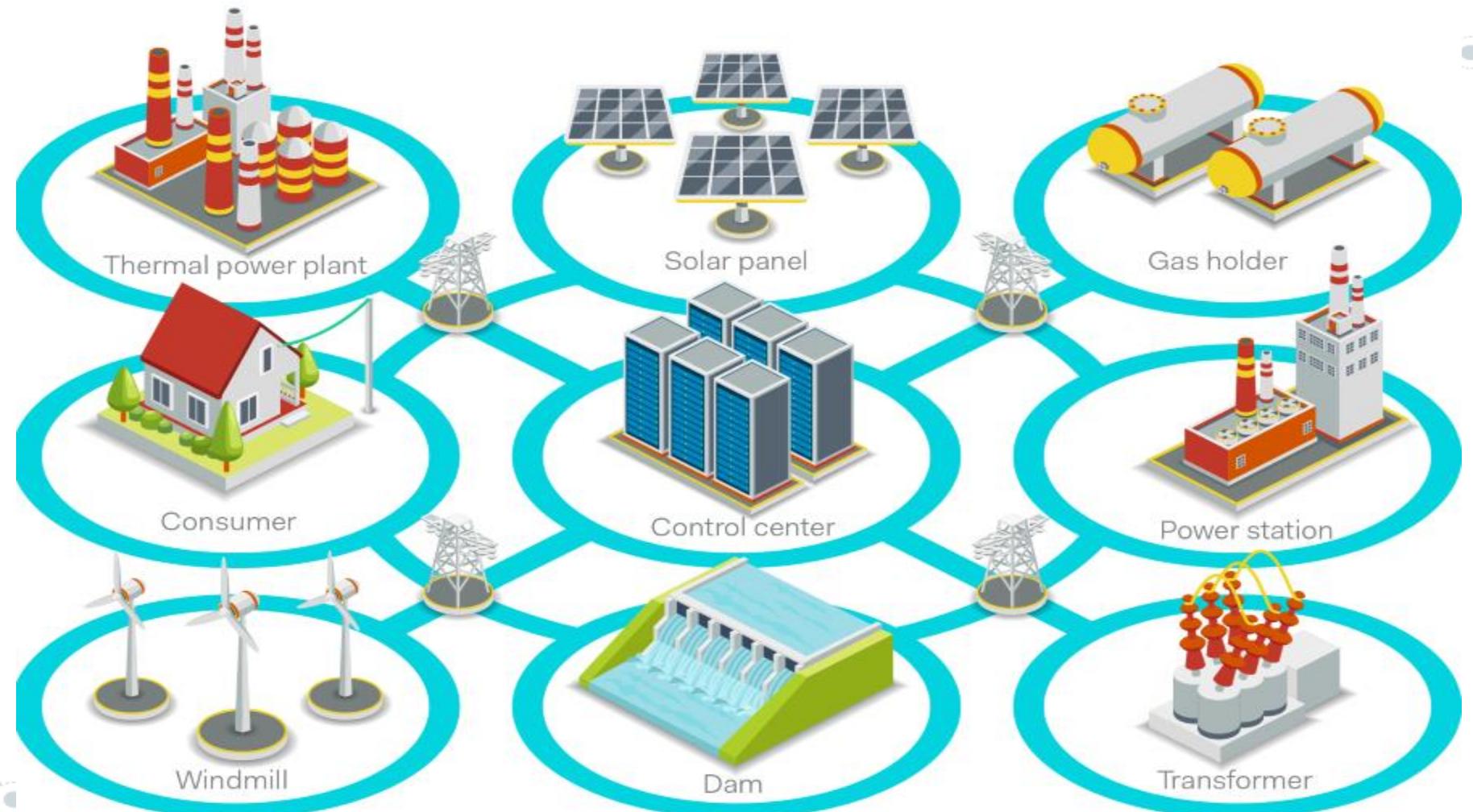


IoT Applications and Verticals- Smart City

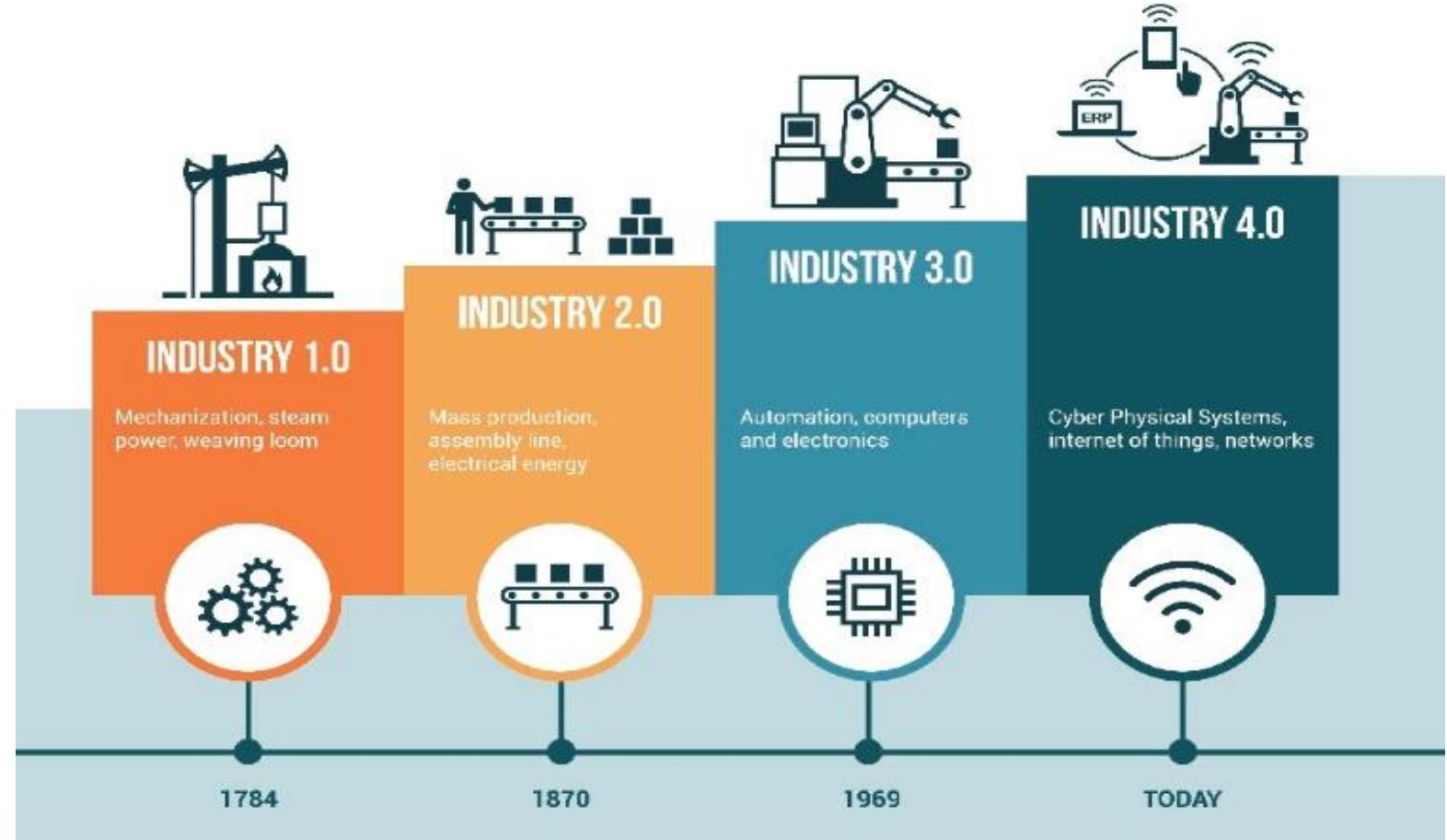
Smart City



IoT Applications and Verticals- Smart Grid



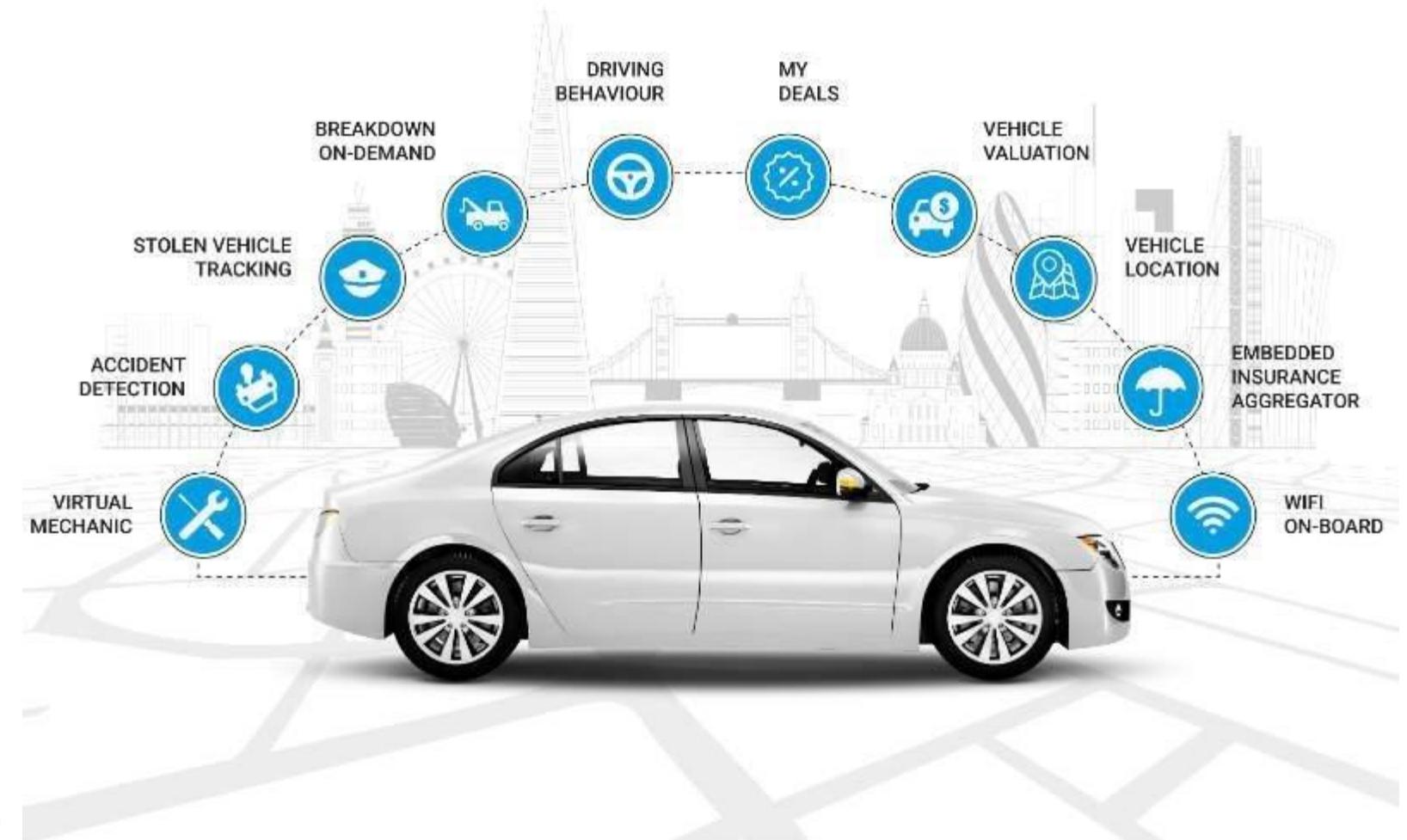
IoT Applications and Verticals- Industrial IoT



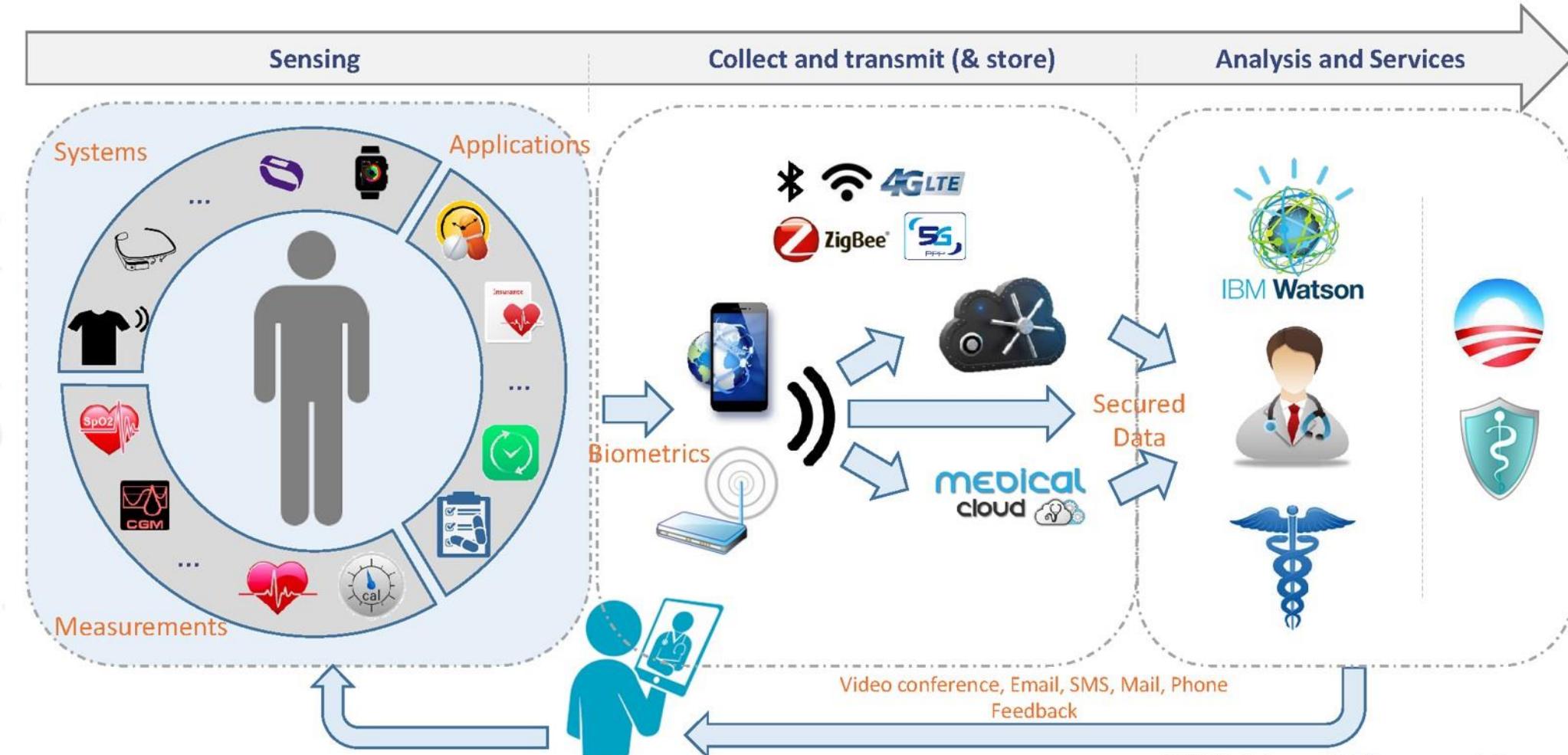
IoT Applications and Verticals- Smart Transportation



IoT Applications and Verticals- Connected Car



IoT Applications and Verticals- Connected Health



IoT Applications and Verticals- Smart Retail



IoT Applications and Verticals- Smart Supply Chain



IoT Applications and Verticals- Smart Farming



Convergence of information technology (IT) and operational technology (OT)

- Until recently, IT and OT have for the most part lived in separate worlds
- IT supports connections to the Internet along with related data and technology systems and is focused on the secure flow of data across an organization.
- OT monitors and controls devices and processes on physical operational systems. These systems include assembly lines, utility distribution networks, production facilities, roadway systems, and many more.

Comparing OT And IT

Criterion	Industrial OT Network	Enterprise IT Network
Operational focus	Keep the business operating 24x7	Manage the computers, data, and employee communication system in a secure way
Priorities	<ol style="list-style-type: none">1. Availability2. Integrity3. Security	<ol style="list-style-type: none">1. Security2. Integrity3. Availability
Types of data	Monitoring, control, and supervisory data	Voice, video, transactional, and bulk data
Security	Controlled physical access to devices	Devices and users authenticated to the network
Implication of failure	OT network disruption directly impacts business	Can be business impacting, depending on industry, but workarounds may be possible
Network upgrades (software or hardware)	Only during operational maintenance windows	Often requires an outage window when workers are not onsite; impact can be mitigated
Security vulnerability	Low: OT networks are isolated and often use proprietary protocols	High: continual patching of hosts is required, and the network is connected to Internet and requires vigilant protection

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IoT Challenges

- Scalability
- Security
- Privacy
- Big Data and Data Analytics
- Interoperability

IoT Challenges (cont'd)

- Scalability
 - The IPv4 address space has reached exhaustion and is unable to meet IoT's scalability requirements.
 - For IoT scale can be met only by IPv6.
- Security
- Privacy
- Big Data and Data Analytics



* IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Thing, Cisco press, 2017

IoT Challenges (cont'd)

- Scalability
- Security
 - With more “things” connected with other “things” and people security is an increasingly complex issue for IoT.
 - Threat surface is greatly expanded and if device gets hacked, its connectivity is a major concern.
 - A Compromised device can serve as a launching point to attack other devices and systems.
- Privacy
- Big Data and Data Analytics
- Interoperability

IoT Challenges (cont'd)

- Scalability
- Security
- Privacy
 - As sensors become more prolific in everyday lives, the data they gather will be specific to individuals and their activities.
 - For businesses, the data has monetary value.
 - Organizations discuss who owns the data and how individuals can control whether it is shared and with whom.

- Big Data and Data Analytics

Interoperability

IoT Challenges (cont'd)

- Scalability
- Security
- Privacy
- Big Data and Data Analytics
 - IoT and large number of sensors are going to trigger deluge of data that must be handled.
 - This data will provide critical information and insights if it can be processed in an efficient manner.
 - Challenge is evaluating massive amounts of data arriving from different sources in various forms and doing so in a timely manner.

• Interoperability

IoT Challenges (cont'd)

- Scalability
- Security
- Privacy
- Big Data and Data Analytics
- Interoperability
 - As with nascent technology, various protocols and architectures are jockeying for market share and standardizations within IoT.
 - Some of these protocols and architectures are based on proprietary elements and others are open.
 - Recently IoT Standards are helping minimize this problem, but there are often various protocols and implementations available for IoT networks.

* IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Thing, Cisco press, 2017

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IoT Architectural Drivers

Challenge	Description	IoT Architectural Change Required
Scale	The massive scale of IoT endpoints (sensors) is far beyond that of typical IT networks.	The IPv4 address space has reached exhaustion and is unable to meet IoT's scalability requirements. Scale can be met only by using IPv6. IT networks continue to use IPv4 through features like Network Address Translation (NAT).
Security	IoT devices, especially those on wireless sensor networks (WSNs), are often physically exposed to the world.	Security is required at every level of the IoT network. Every IoT endpoint node on the network must be part of the overall security strategy and must support device-level authentication and link encryption. It must also be easy to deploy with some type of a zero-touch deployment model.
Devices and networks constrained by power, CPU, memory, and link speed	Due to the massive scale and longer distances, the networks are often constrained, lossy, and capable of supporting only minimal data rates (tens of bps to hundreds of Kbps).	New last-mile wireless technologies are needed to support constrained IoT devices over long distances. The network is also constrained, meaning modifications need to be made to traditional network-layer transport mechanisms.

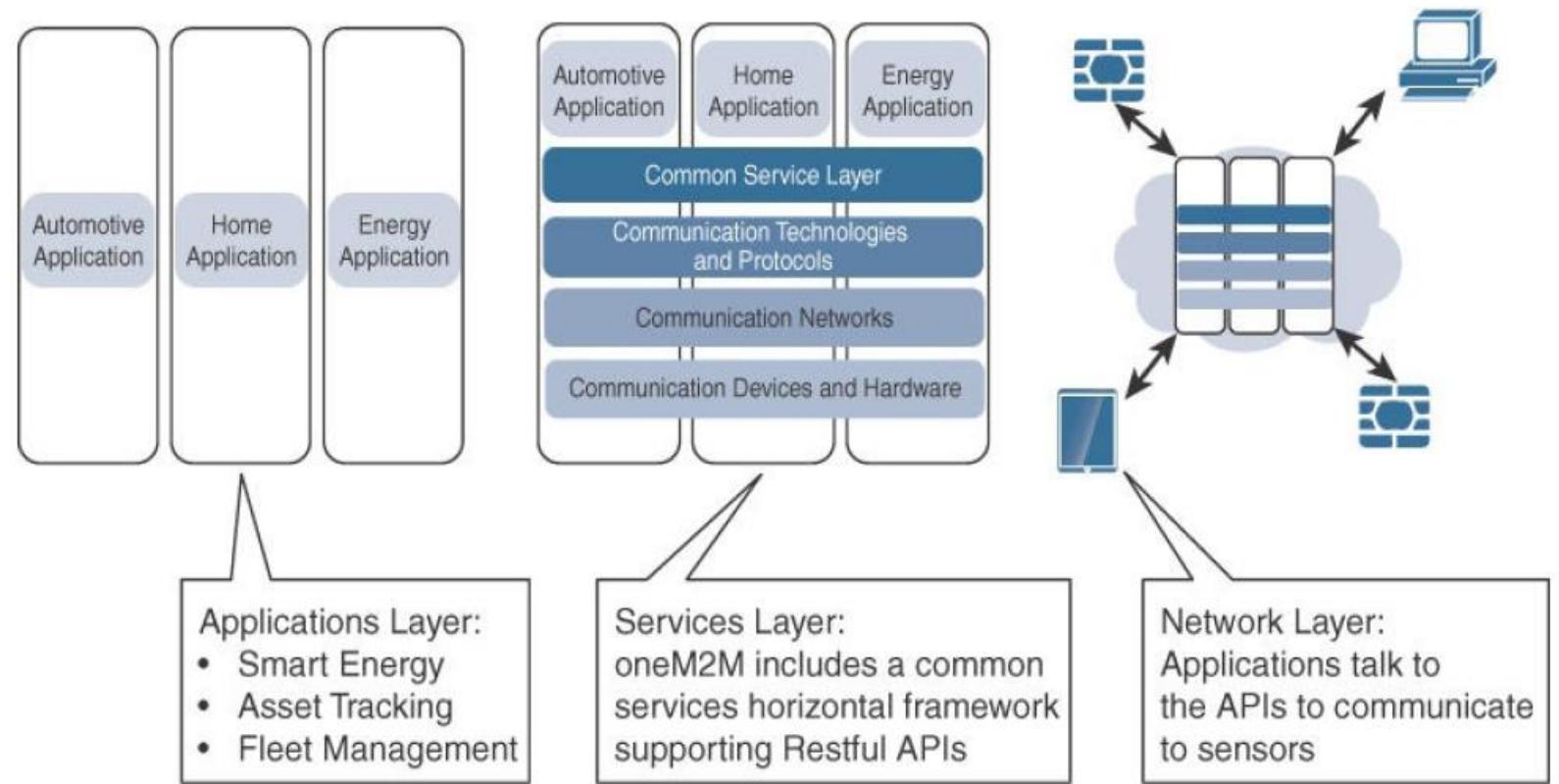
IoT Architectural Drivers (cont.)

The massive volume of data generated	The sensors generate a massive amount of data on a daily basis, causing network bottlenecks and slow analytics in the cloud.	Data analytics capabilities need to be distributed throughout the IoT network, from the edge to the cloud. In traditional IT networks, analytics and applications typically run only in the cloud.
Support for legacy devices	An IoT network often comprises a collection of modern, IP-capable endpoints as well as legacy, non-IP devices that rely on serial or proprietary protocols.	Digital transformation is a long process that may take many years, and IoT networks need to support protocol translation and/or tunneling mechanisms to support legacy protocols over standards-based protocols, such as Ethernet and IP.
The need for data to be analyzed in real time	Whereas traditional IT networks perform scheduled batch processing of data, IoT data needs to be analyzed and responded to in real-time.	Analytics software needs to be positioned closer to the edge and should support real-time streaming analytics. Traditional IT analytics software (such as relational databases or even Hadoop), are better suited to batch-level analytics that occur after the fact.

IoT Architectures

- Two of the best-known architectures are those supported by
 - oneM2M by European Telecommunications Standards Institute (ETSI) in 2008
 - IoT World Forum (IoTWF) led by CISCO, IBM, and others in 2014

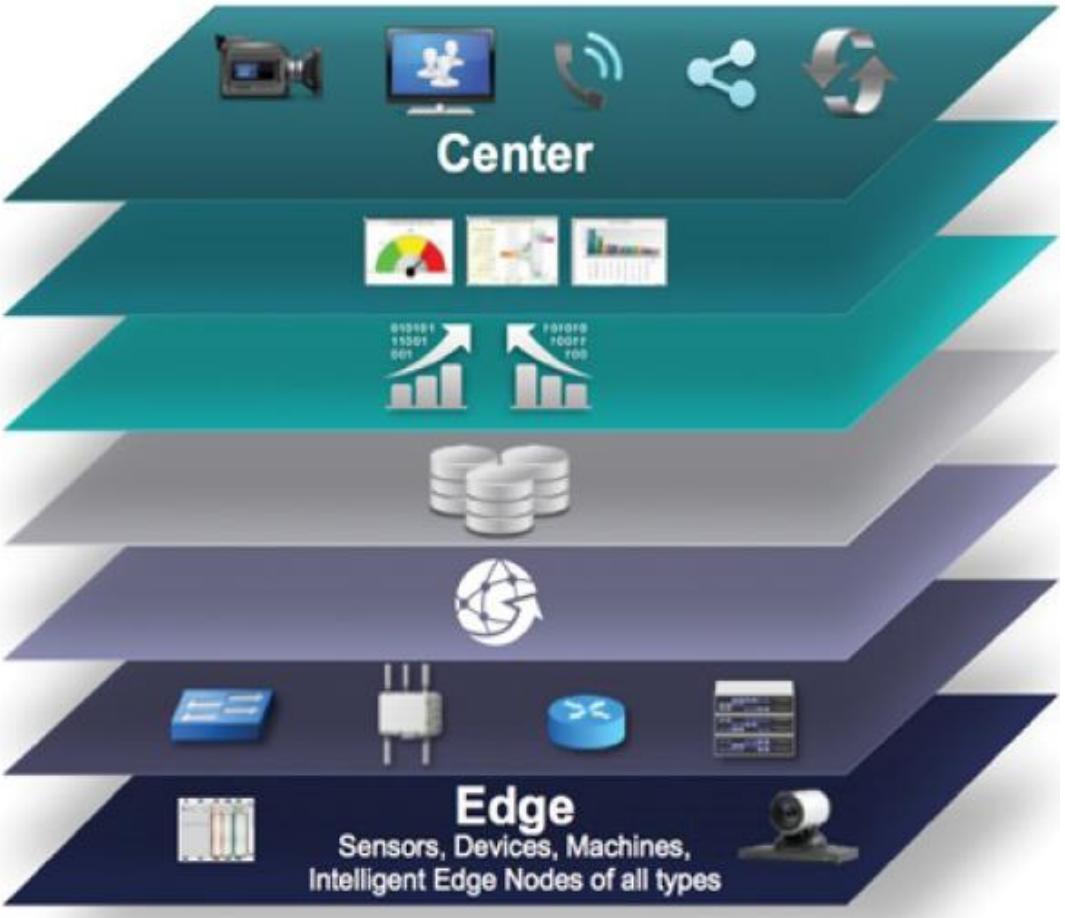
The Main Elements of the oneM2M IoT Architecture



The IoT World Forum (IoTWF) Standardized Architecture

Levels

- 7 **Collaboration & Processes**
(Involving People & Business Processes)
- 6 **Application**
(Reporting, Analytics, Control)
- 5 **Data Abstraction**
(Aggregation & Access)
- 4 **Data Accumulation**
(Storage)
- 3 **Edge Computing**
(Data Element Analysis & Transformation)
- 2 **Connectivity**
(Communication & Processing Units)
- 1 **Physical Devices & Controllers**
(The "Things" in IoT)

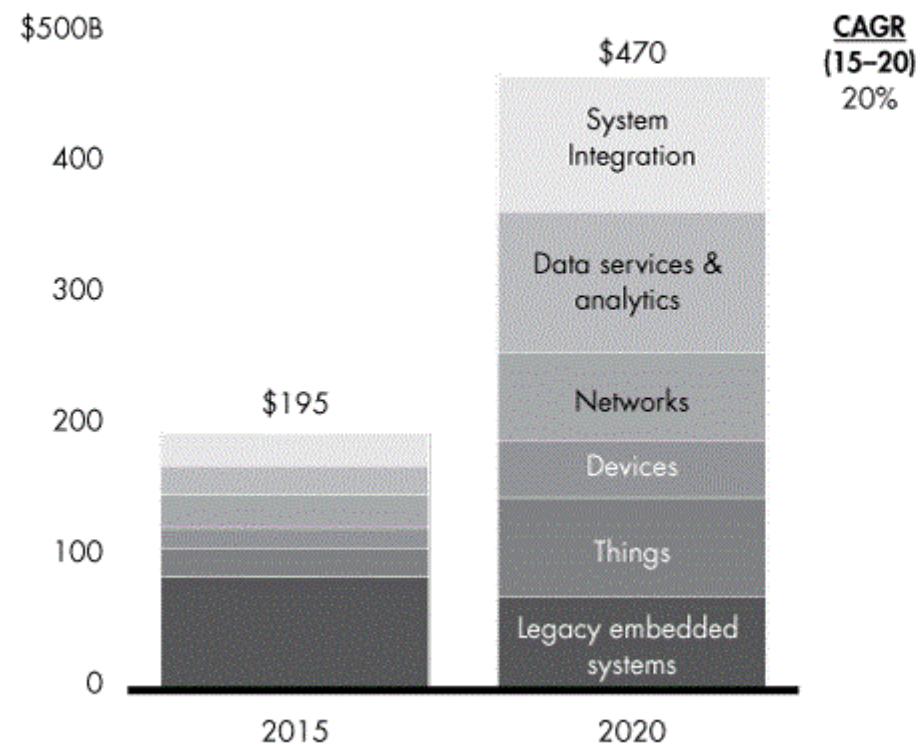


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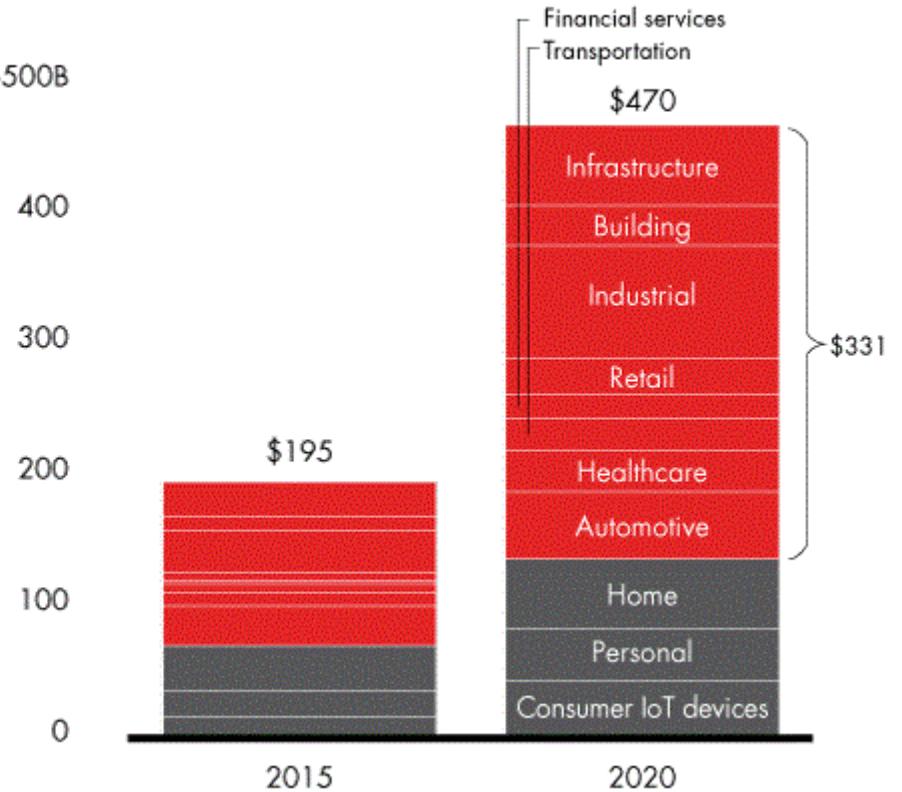
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- **Business and Market Opportunities**

IoT Business and Market Opportunities

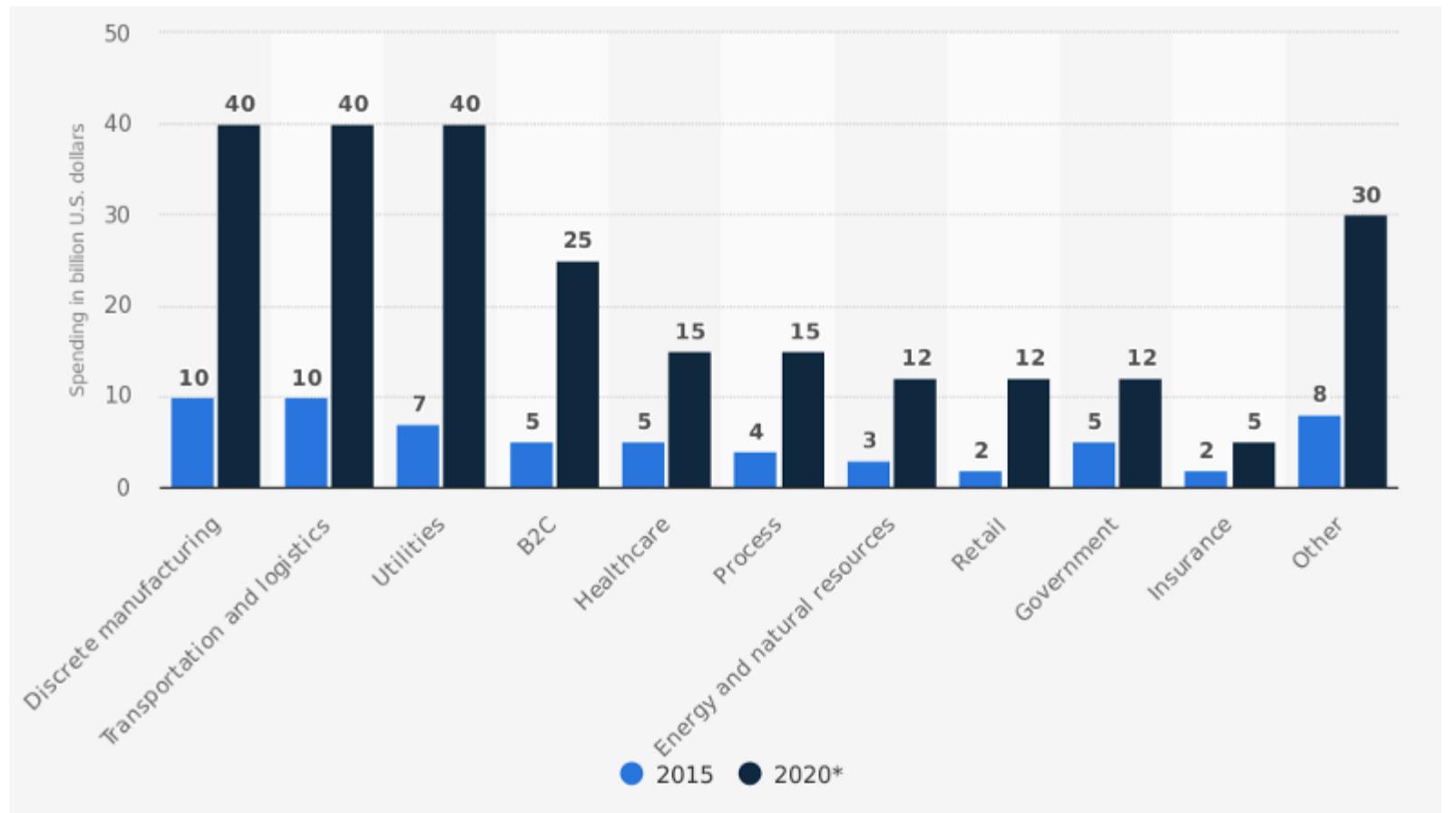
IoT and analytics revenue



IoT and analytics revenue by segment

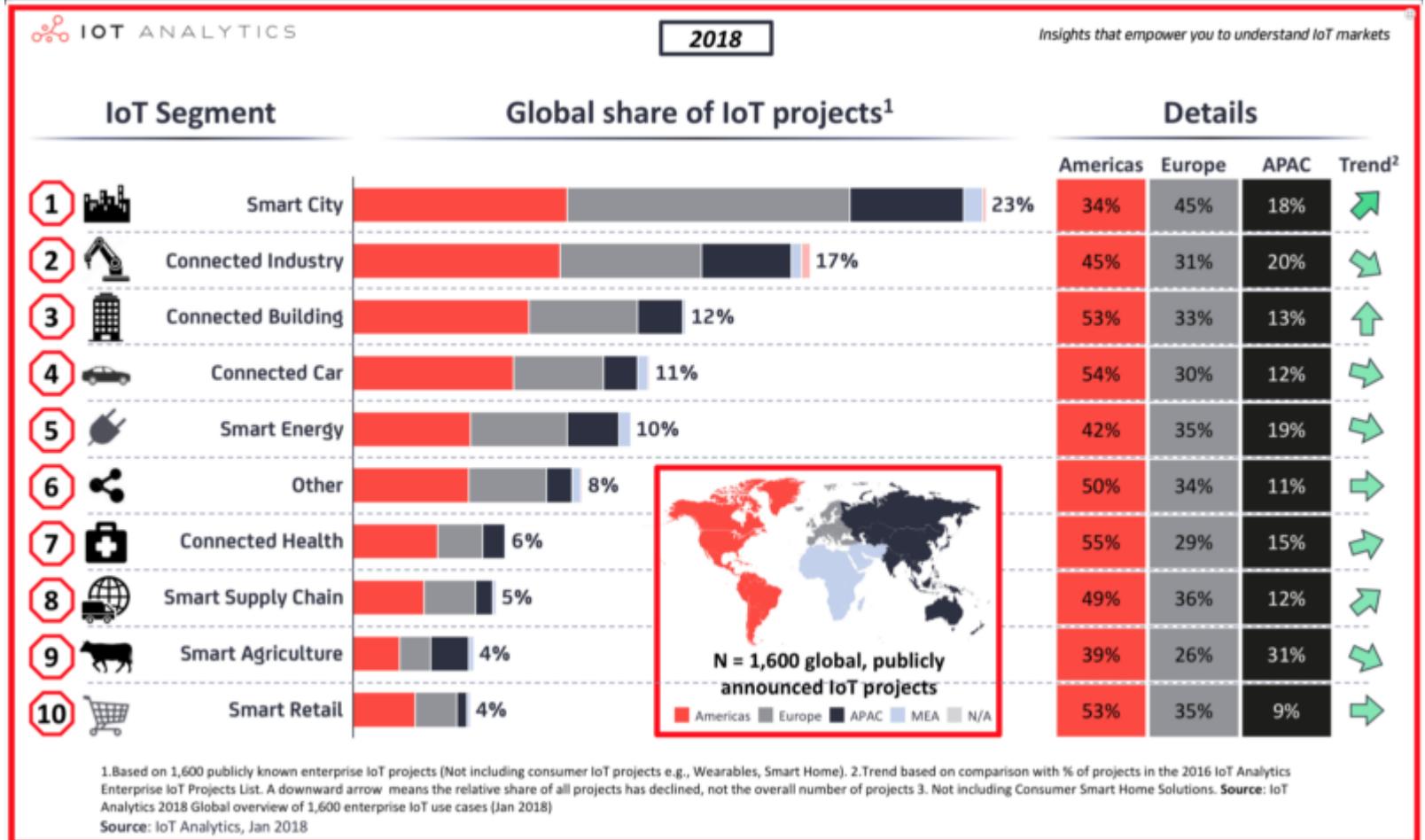


IoT Business and Market Opportunities



* https://discoveri.com/iot_devices_market/

IoT Business and Market Opportunities

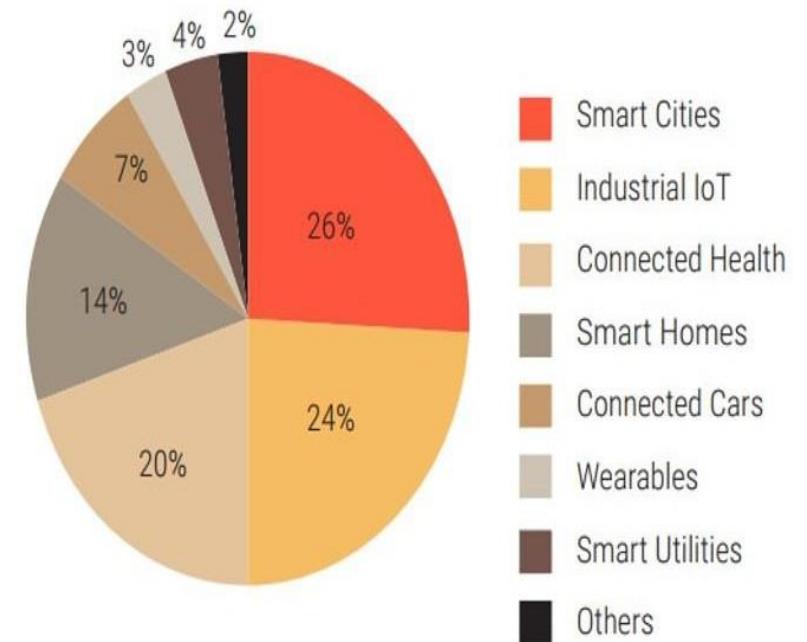


* https://discoveri.com/iot_devices_market/

IoT Business and Market Opportunities



Global IoT Market Share by Sub-Sector



IoT- Products



Kasa Smart Wi-Fi LED Bulb with
Multicolour
\$29.99



Google Nest Learning Thermostat
\$249



All-new Echo (3rd Gen)- Smart
speaker with Alexa
\$89.99



August Smart Lock
\$ 220

IoT- Products



Rachio 3, Smart Sprinkler Controller
\$229.99



Aladin home, A magic lamp designed for
comfort at home
49,50 €/month



MyMDband, Medical Bracelet
\$99.99

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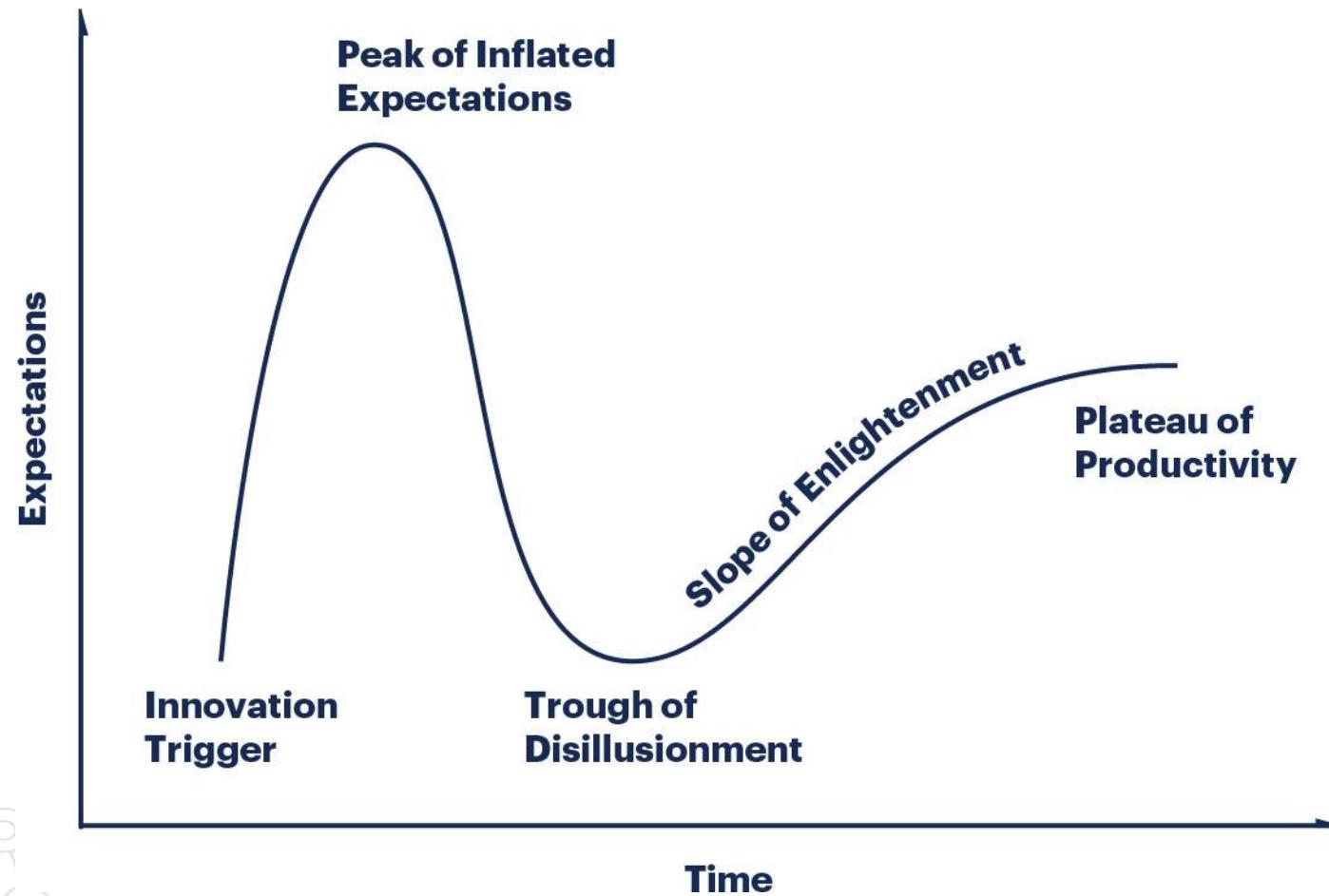
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IoT Trends

1. Artificial Intelligence
2. Social, Legal, and Ethical IoT
3. Infonomics and Data Broking
4. The Shift from Intelligent Edge to Intelligent Mesh
5. IoT Governance
6. Sensor Innovation
7. Trusted Hardware and Operating System
8. Novel IoT User Experiences
9. Silicon Chip Innovation
10. New Wireless Networking Technologies for IoT

* <https://www.gartner.com/en/newsroom/press-releases/2018-11-07-gartner-identifies-top-10-strategic-iot-technologies-and-trends>

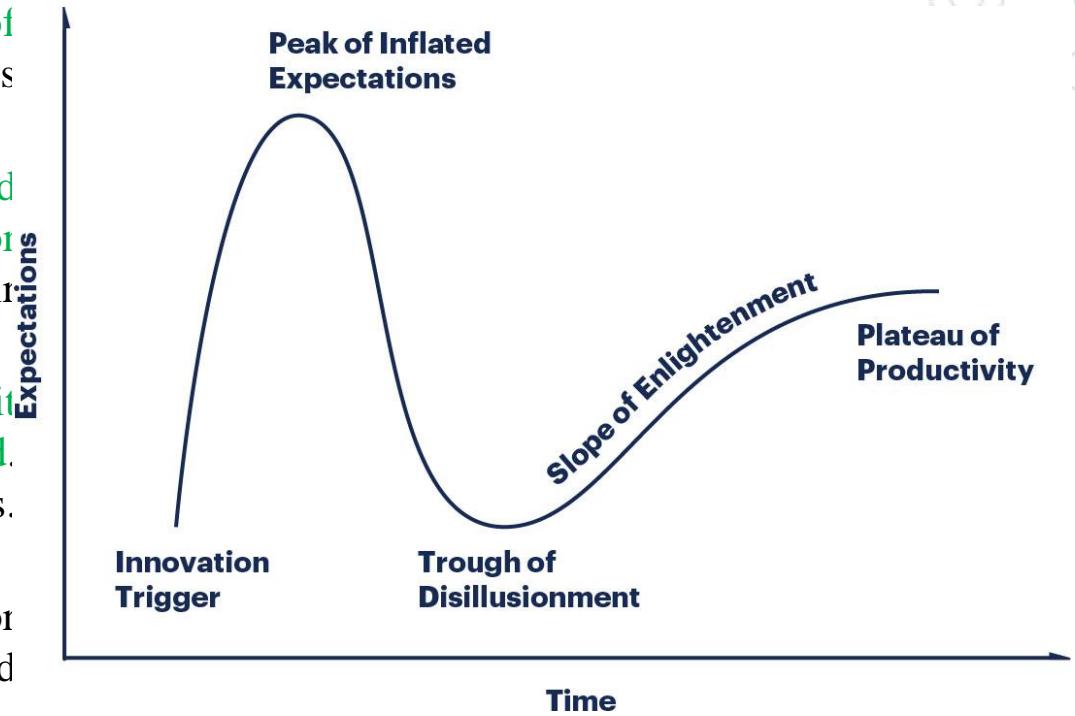
IoT Trends



*<https://www.gartner.com/en/research/methodologies/gartner-hype-cycle>

Hype Cycle: five key phases of a technology's life cycle.

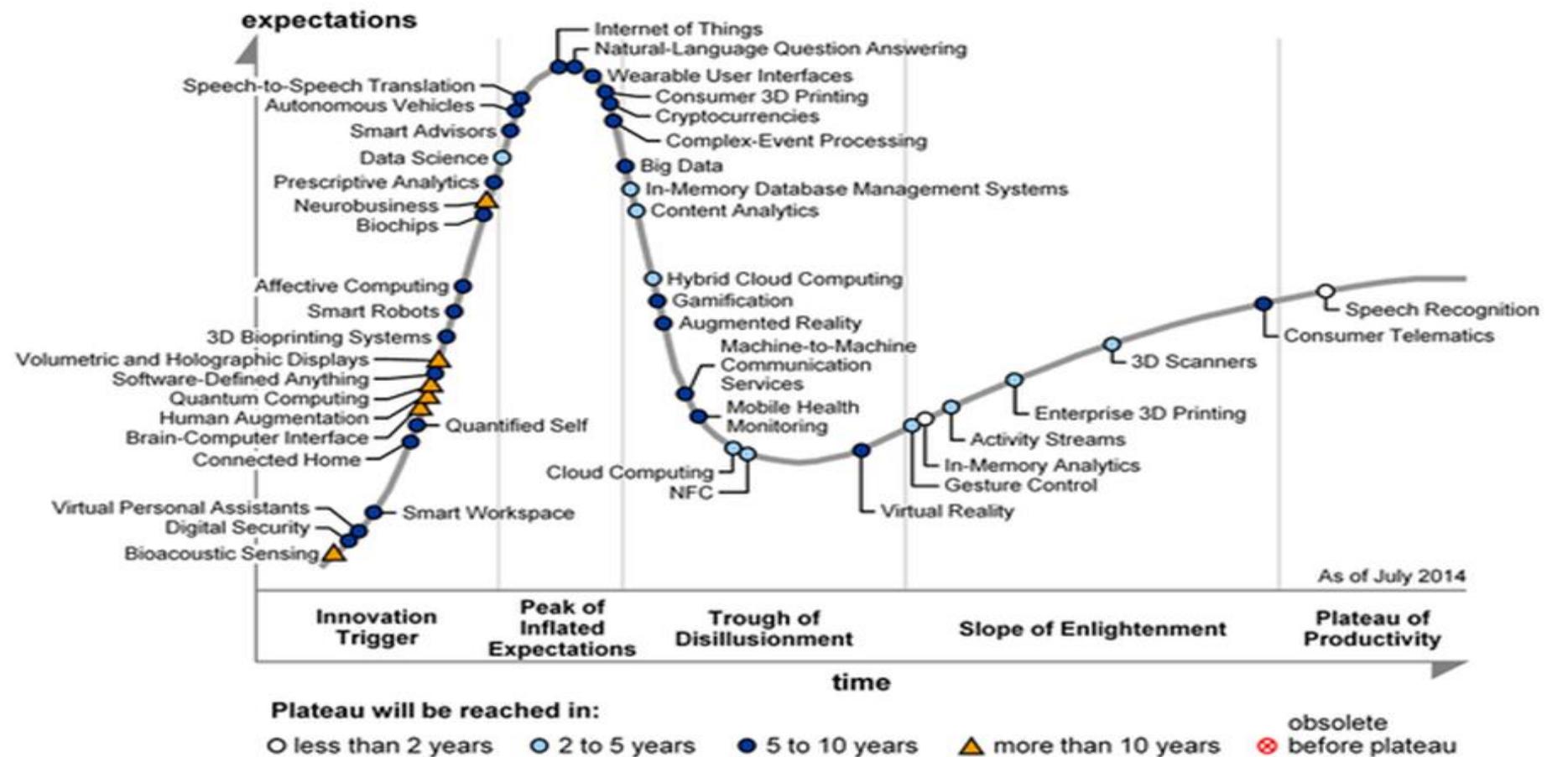
- **Innovation Trigger:** A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.
- **Peak of Inflated Expectations:** Early publicity produces a number of success stories — often accompanied by scores of failures. Some companies take action; many do not.
- **Trough of Disillusionment:** Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.
- **Slope of Enlightenment:** More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.
- **Plateau of Productivity:** Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off.



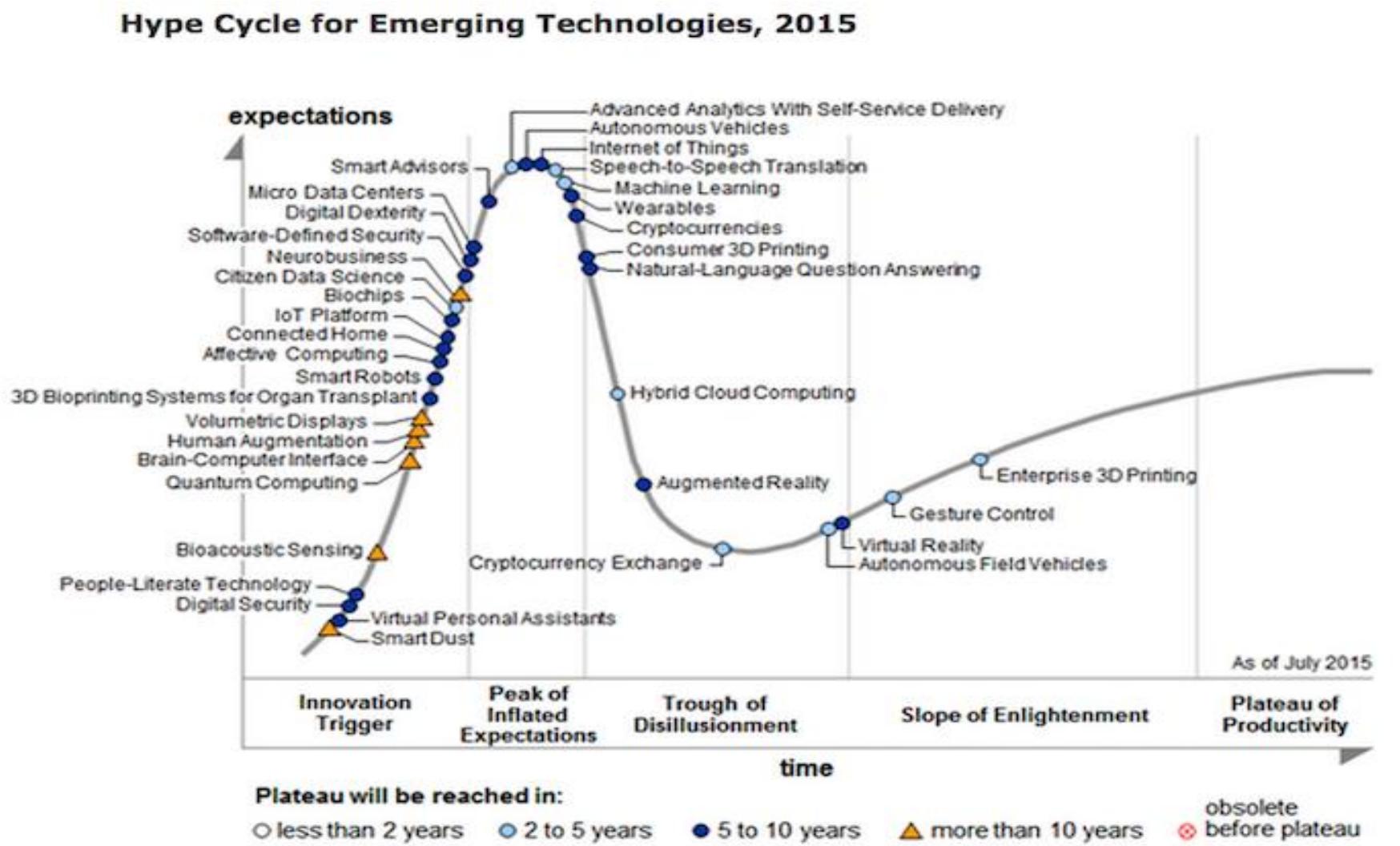
IoT Trends

Gartner

Gartner Hype Cycle for Emerging Technologies, 2014

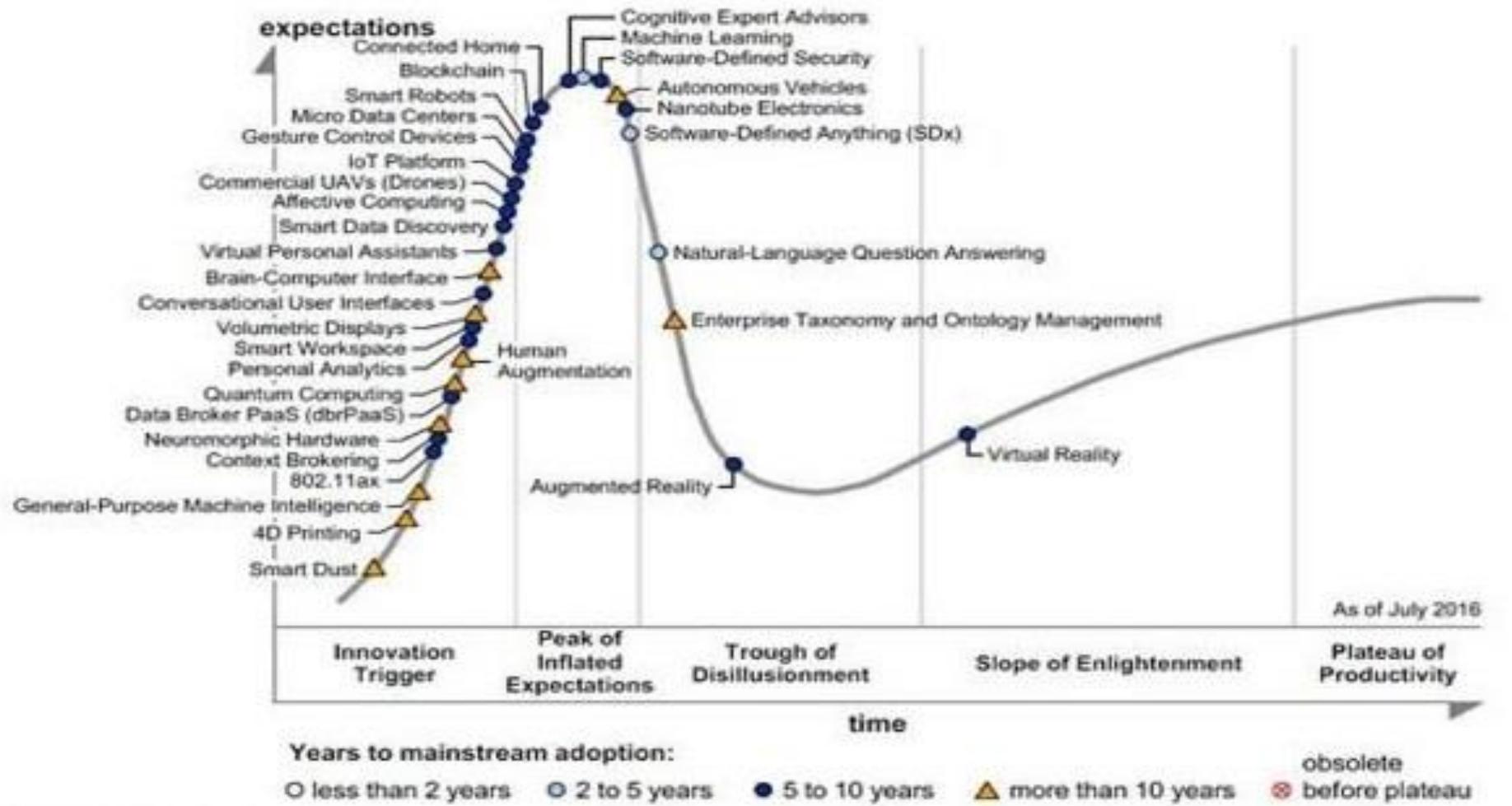


IoT Trends



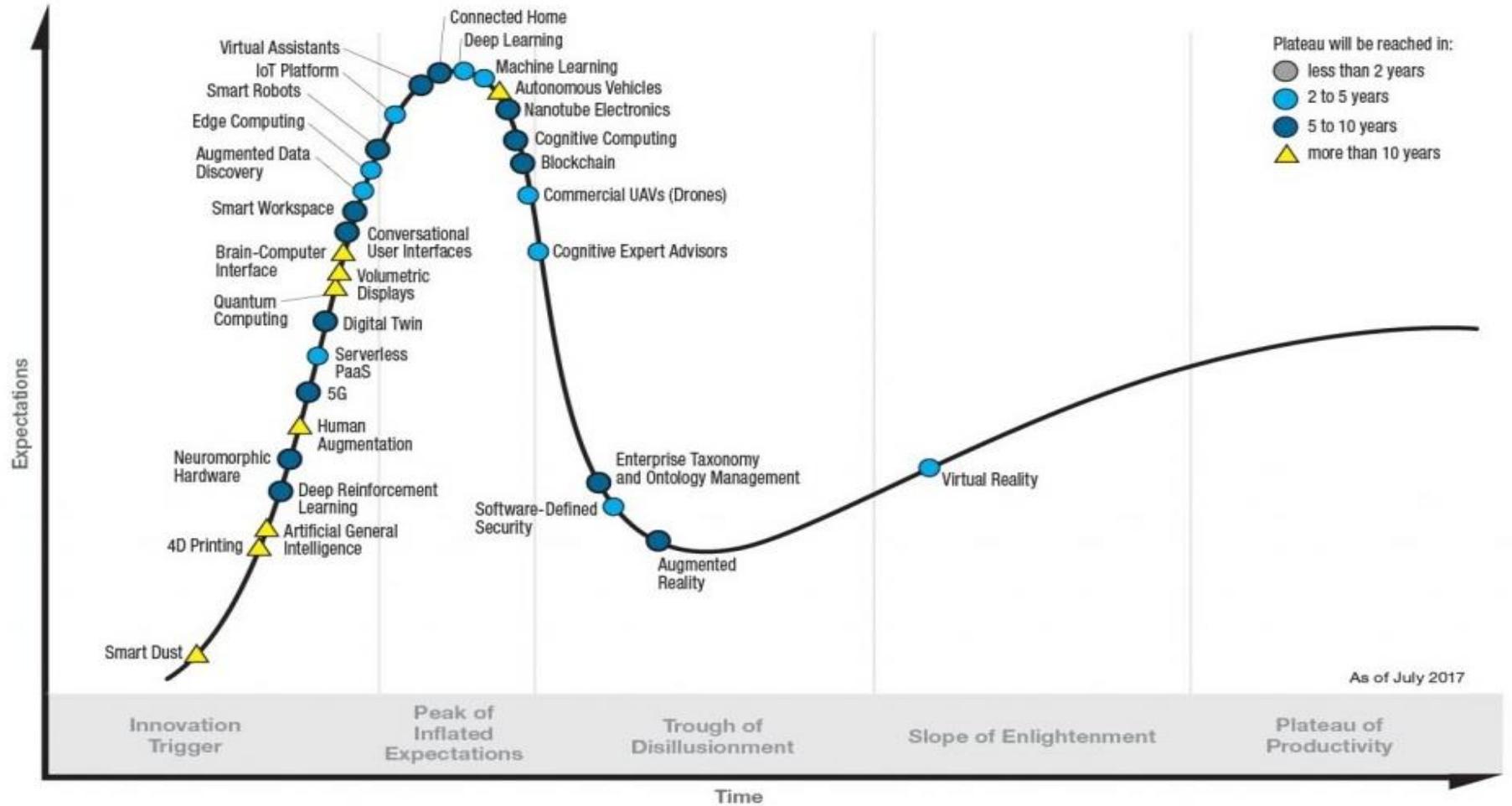
IoT Trends

Hype Cycle for Emerging Technologies, 2016



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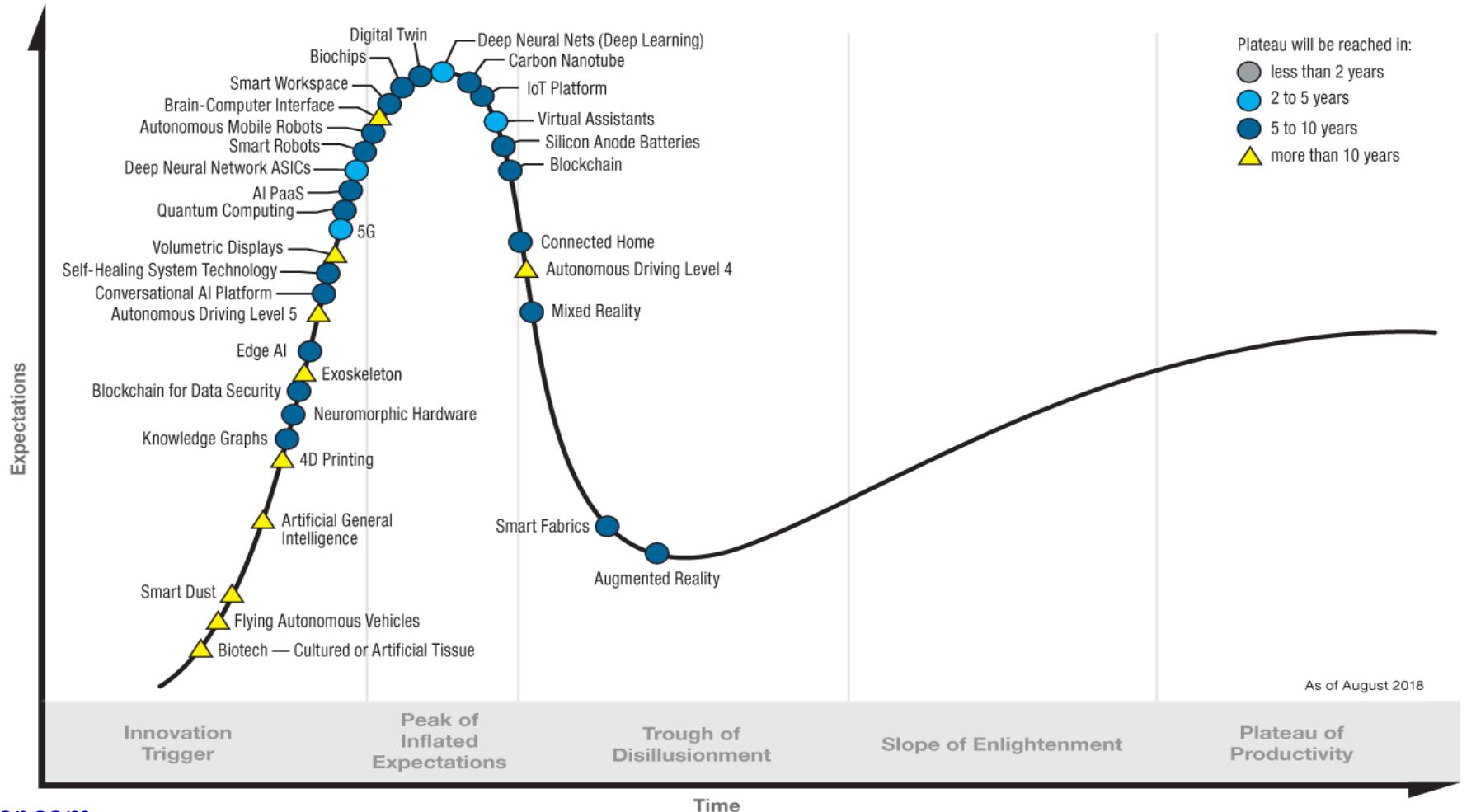
Gartner Hype Cycle for Emerging Technologies, 2017



* <https://ga...>

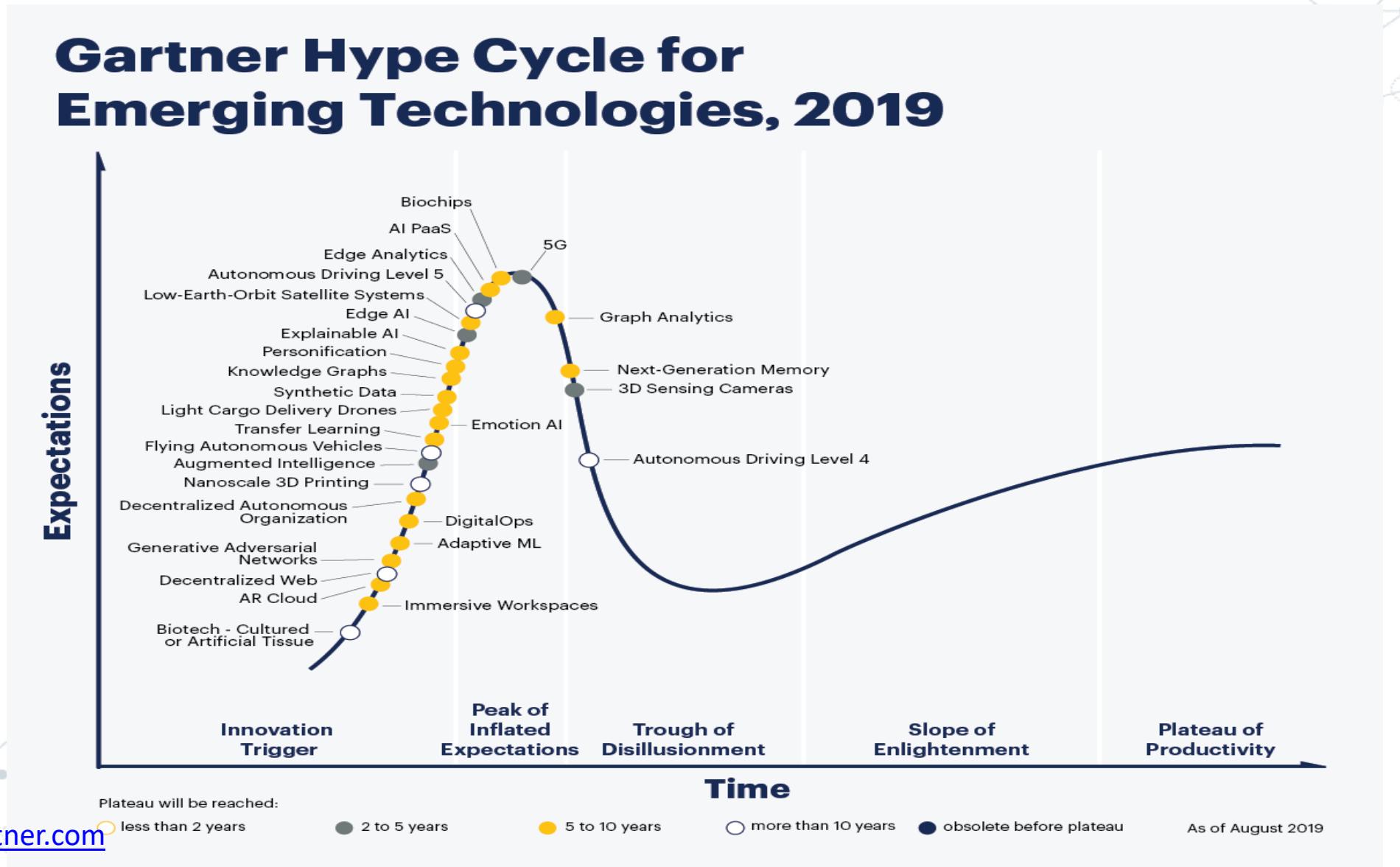
IoT Trends

Hype Cycle for Emerging Technologies, 2018



* <https://gartner.com>

IoT Trends



Next Lecture

- An overview of
 - Electronic
 - Microcontrollers
 - Things (sensors and actuators)
 - gateways

