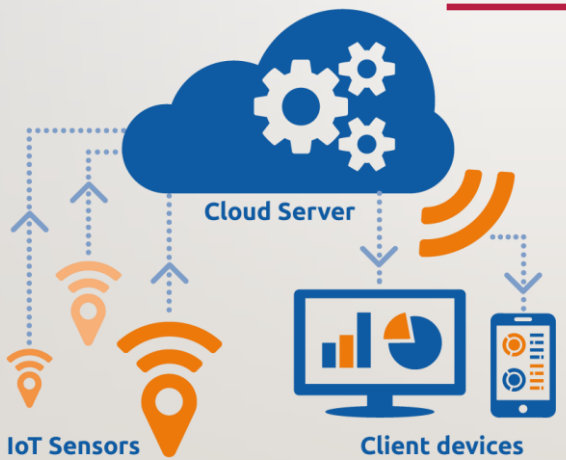
INTERNET OF THINGS (IOT)

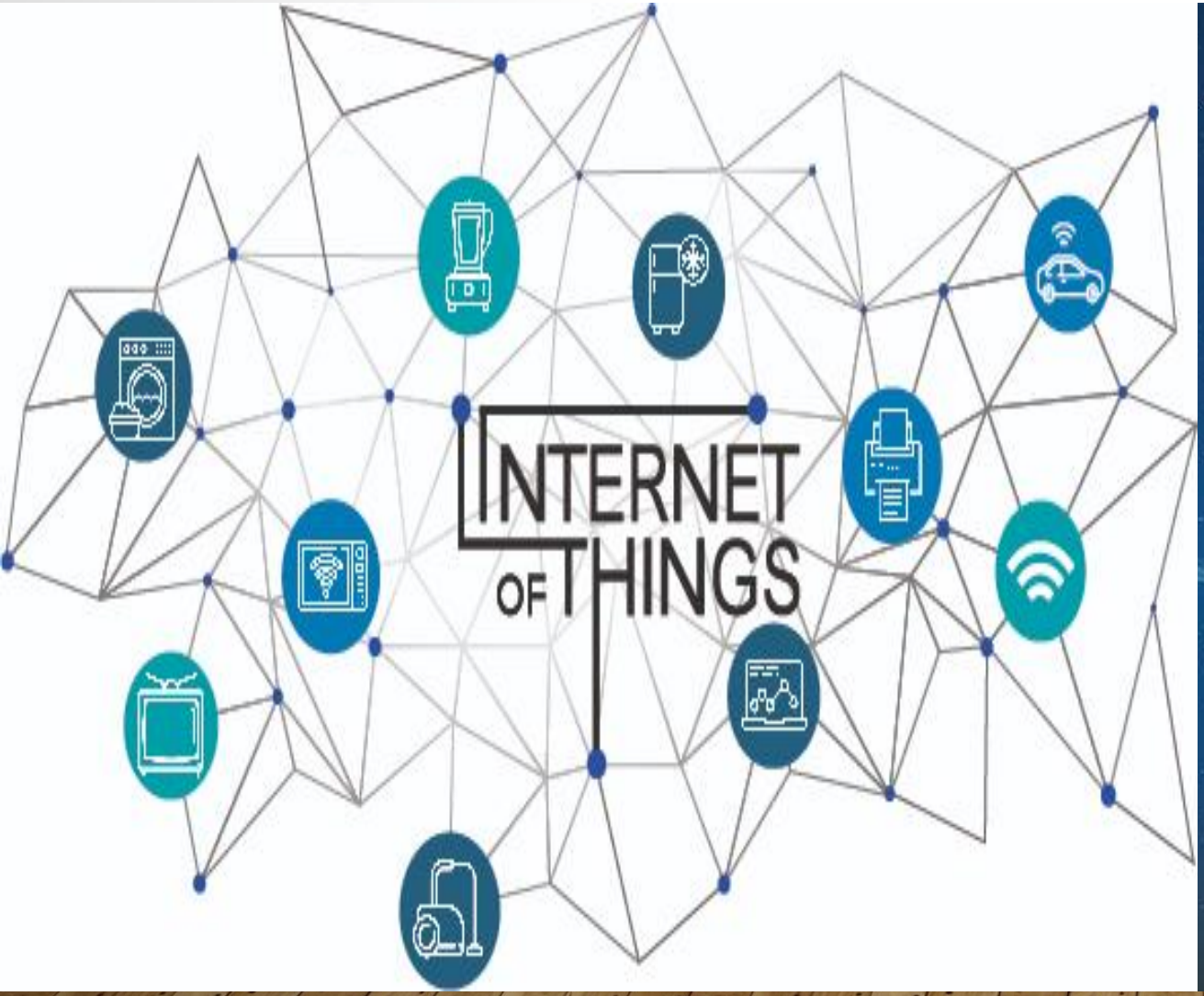
"CONNECTING THE UNCONNECTED"

"CONNECTING THINGS TOGETHER FOR BETTER TOMORROW"



mosquitto

Bhupendra Pratap Singh

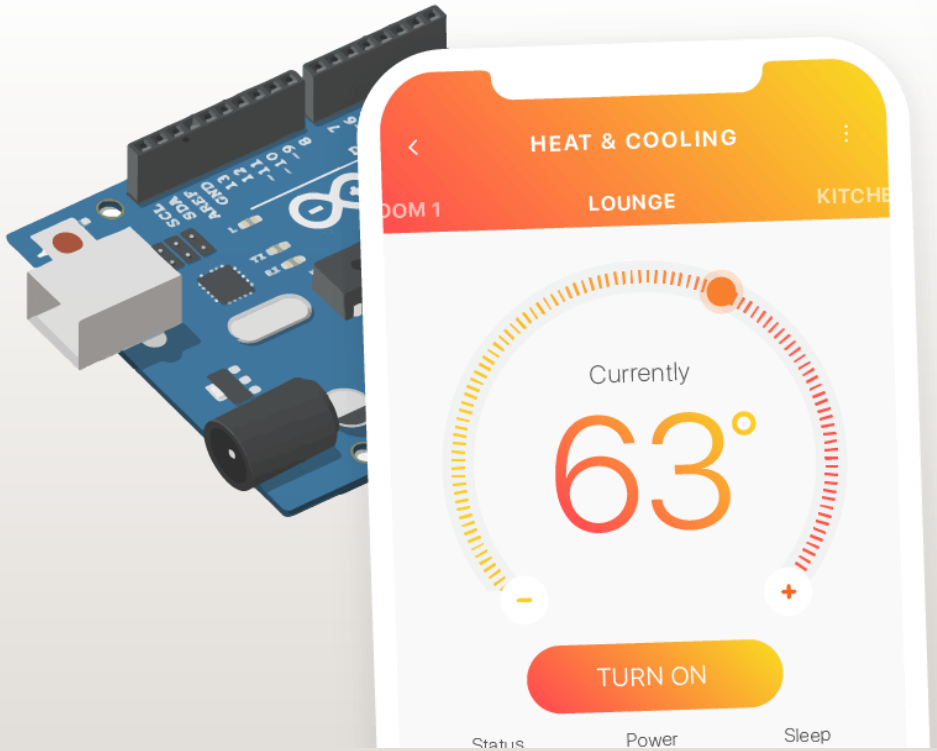


AGENDA

- What is Internet of Things ?
- Major IoT standards
- Enabling Technologies
- Chaos theory of IoT standardization
- Things to cloud continuum
- Challenges
- Business Trends
- Use cases

VARIOUS NAMES, ONE CONCEPT

- M2M (Machine to Machine)
- “Internet of Everything”
- “Web of Things”

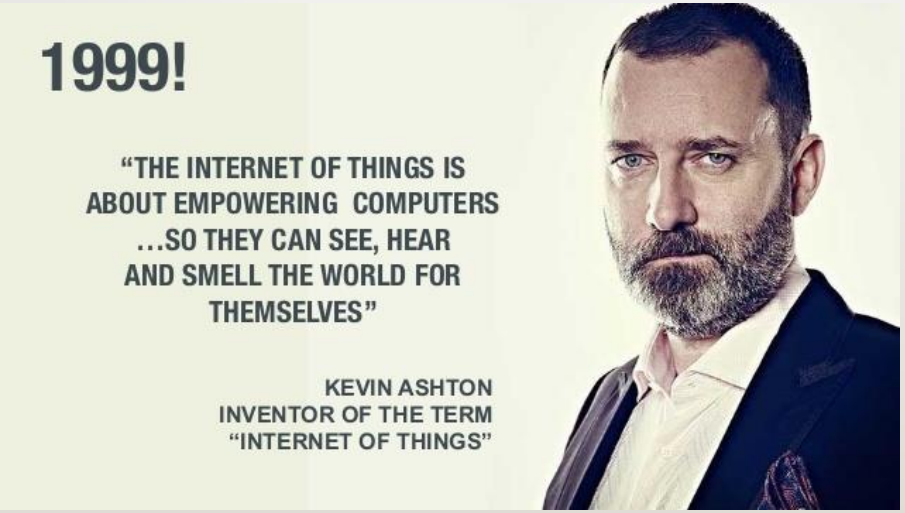


HISTORY OF IOT

- It all started with lipstick.
- A particularly popular color of **Oil of Olay lipstick** that **Kevin Ashton** had been pushing as a **brand manager** at Procter & Gamble was **perpetually out of stock**.
- He decided to **find out why**, and **found holes in data** about the supply chain that eventually led him to drive the early deployment of RFID chips on inventory.

HISTORY OF IOT

- The idea of connected devices had been around since 70s.
- The idea was often called pervasive computing or embedded Internet
- IoT term was coined by Kevin Ashton in 1999



- Originally for RFID – Talking about RFID in a presentation he used the term "IoT"

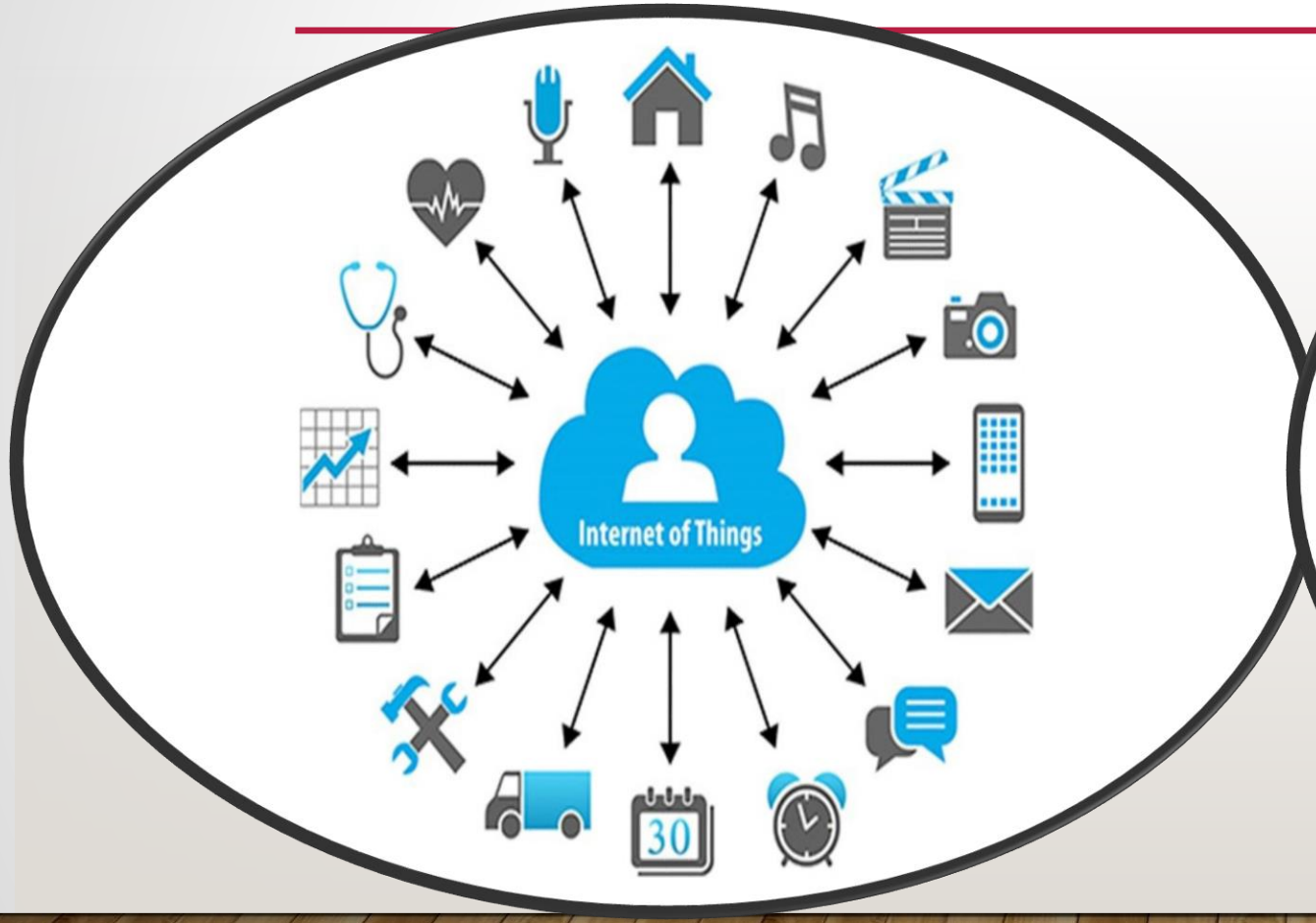
Cofounded the Auto-ID Center at the Massachusetts Institute of Technology (MIT), which created a global standard system for **RFID** and other sensors

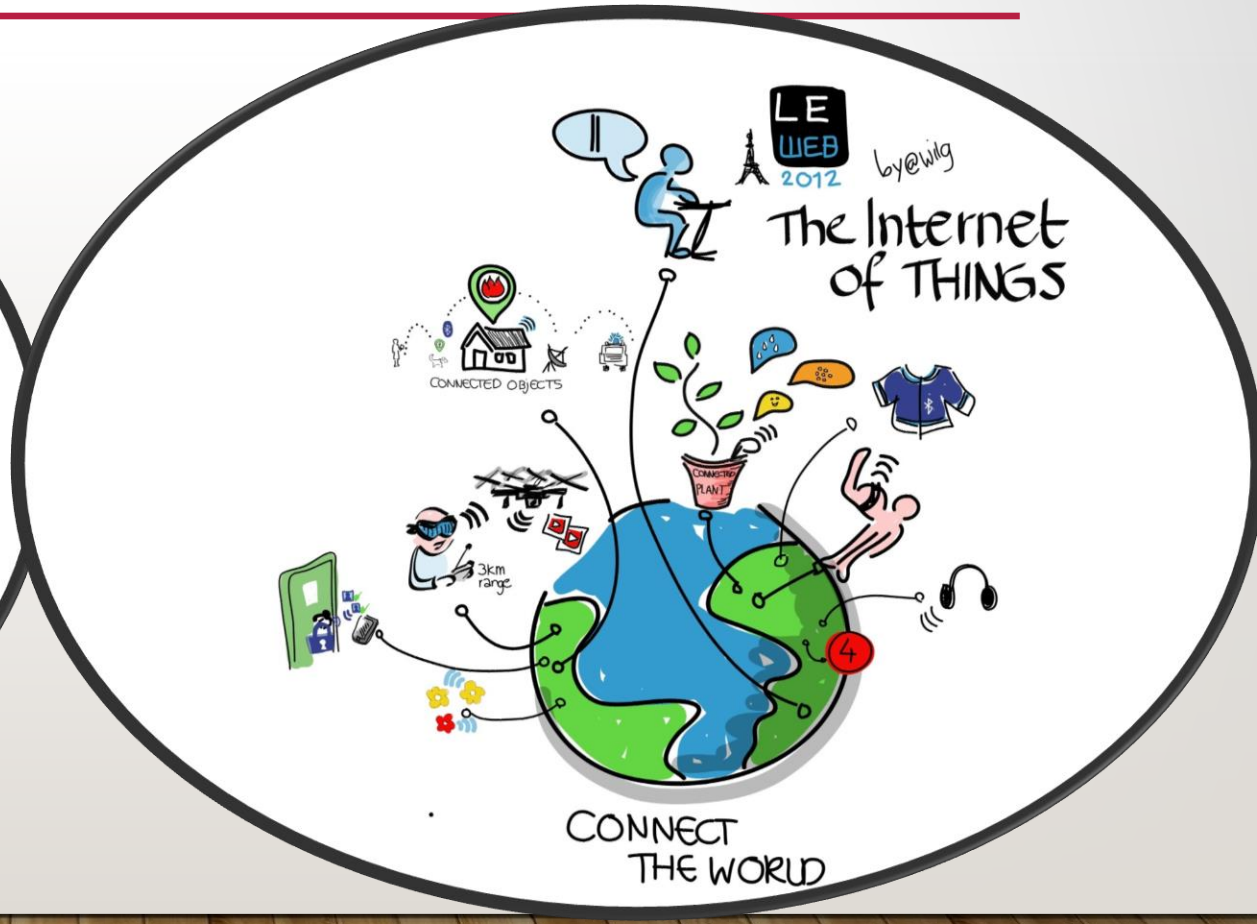
Figure ref: https://iot-analytics.com/internet-of-things-definition/

WHAT IS INTERNET OF THINGS (IOT) ??

The **Internet of Things (IoT)** is the network of physical objects—devices, vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity—that enables these objects to collect and exchange data.

INTERNET OF THINGS – A PICTORIAL REPRESENTATION





VARIOUS DEFINITIONS OF IOT

- Wikipedia says –

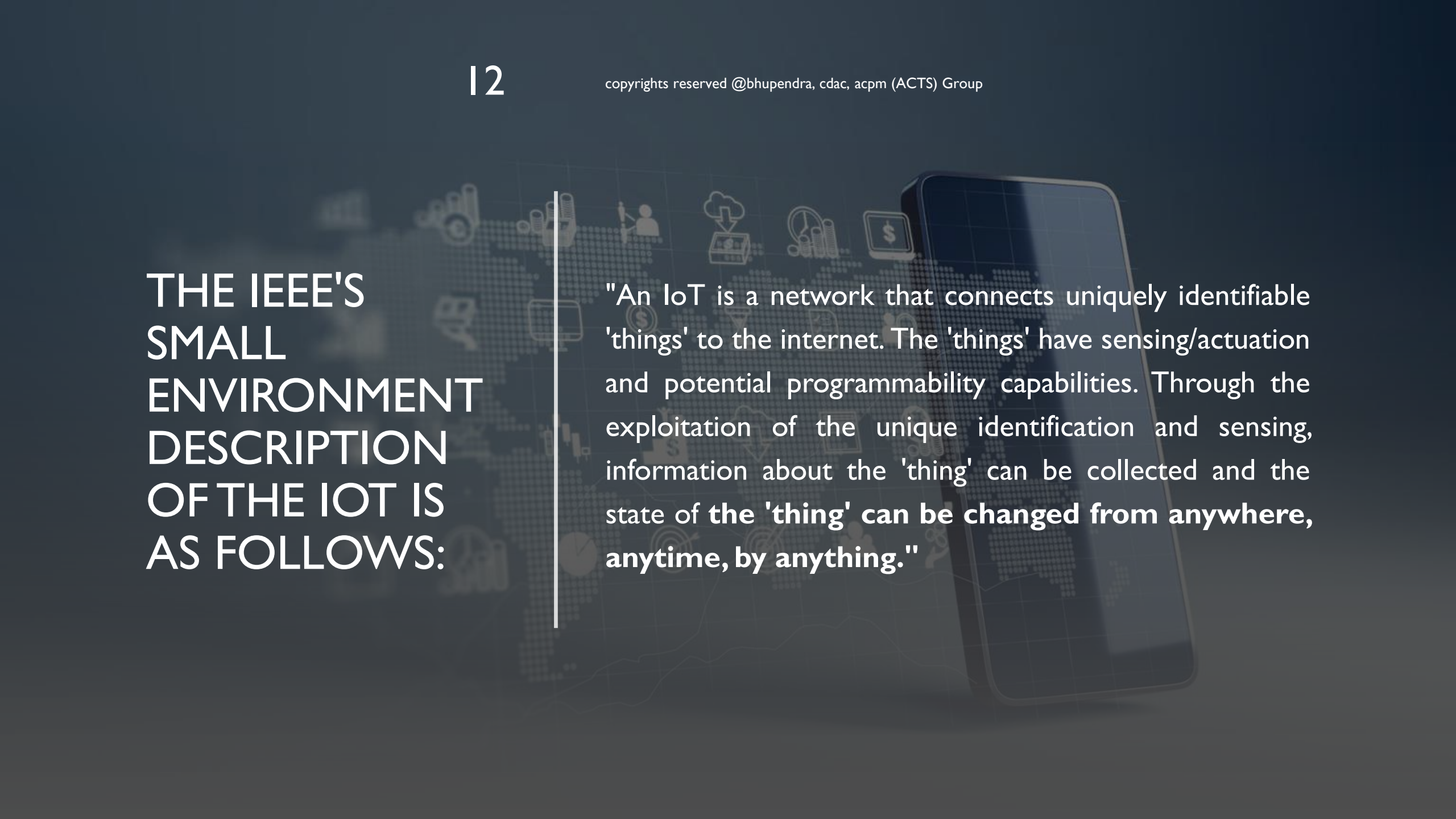
The Internet of Things (IoT) is the network of **physical devices**, vehicles, home appliances and other items **embedded with electronics, software, sensors, actuators**, and **connectivity** which enables these objects to connect and exchange data. Each thing is **uniquely identifiable** through its embedded computing system but is able to **inter-operate within the existing Internet infrastructure**.

WSO2 SAYS -

- The Internet of Things, or IoT, refers to the **set of devices** and **systems** that interconnect **real-world sensors** and actuators to the **Internet.**

THE ITU'S MEMBER-APPROVED DEFINITION DEFINES THE IOT AS FOLLOWS

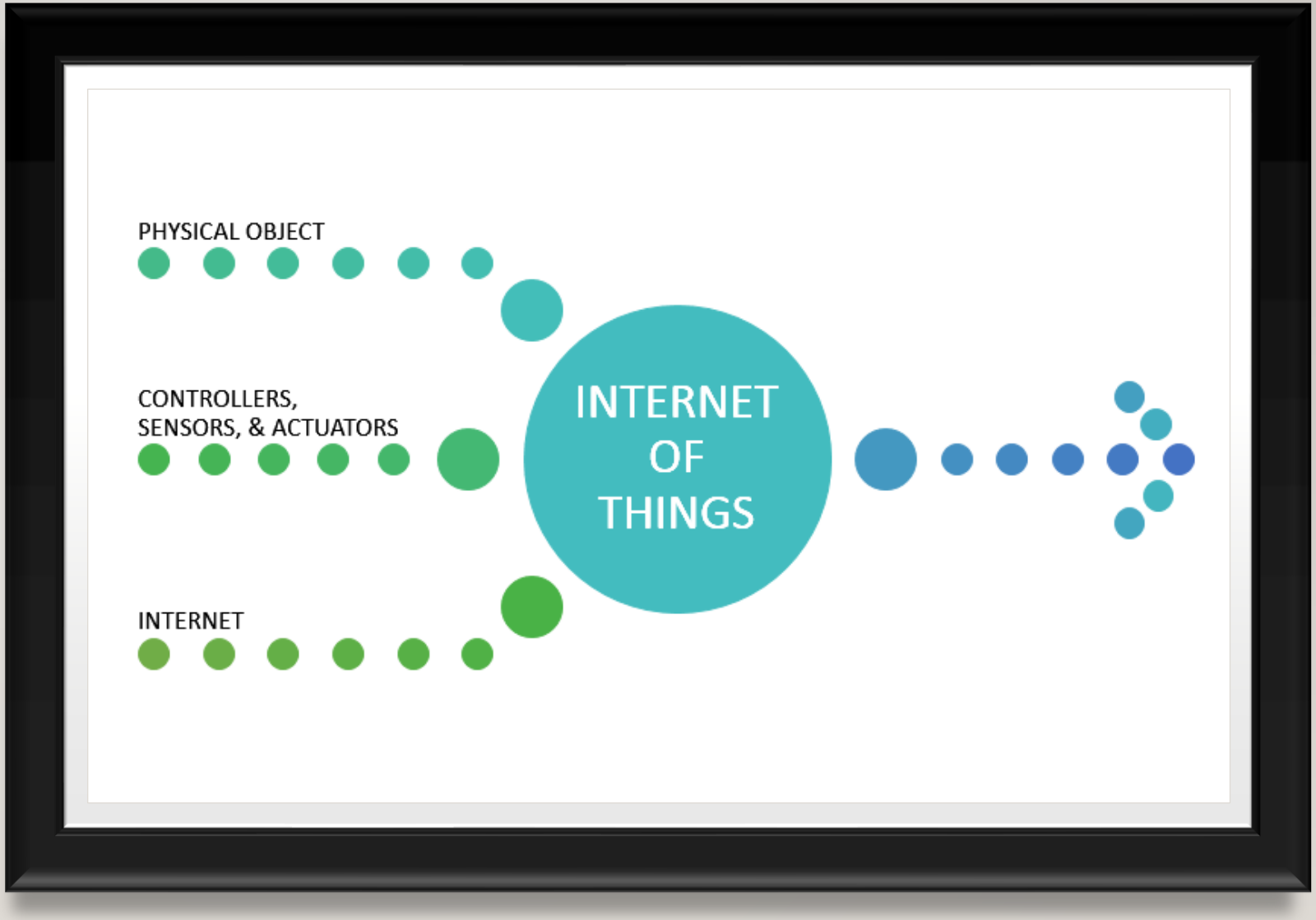
"A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving, interoperable information and communication technologies."



THE IEEE'S SMALL ENVIRONMENT DESCRIPTION OF THE IOT IS AS FOLLOWS:

"An IoT is a network that connects uniquely identifiable 'things' to the internet. The 'things' have sensing/actuation and potential programmability capabilities. Through the exploitation of the 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."**

IOT EQUATION



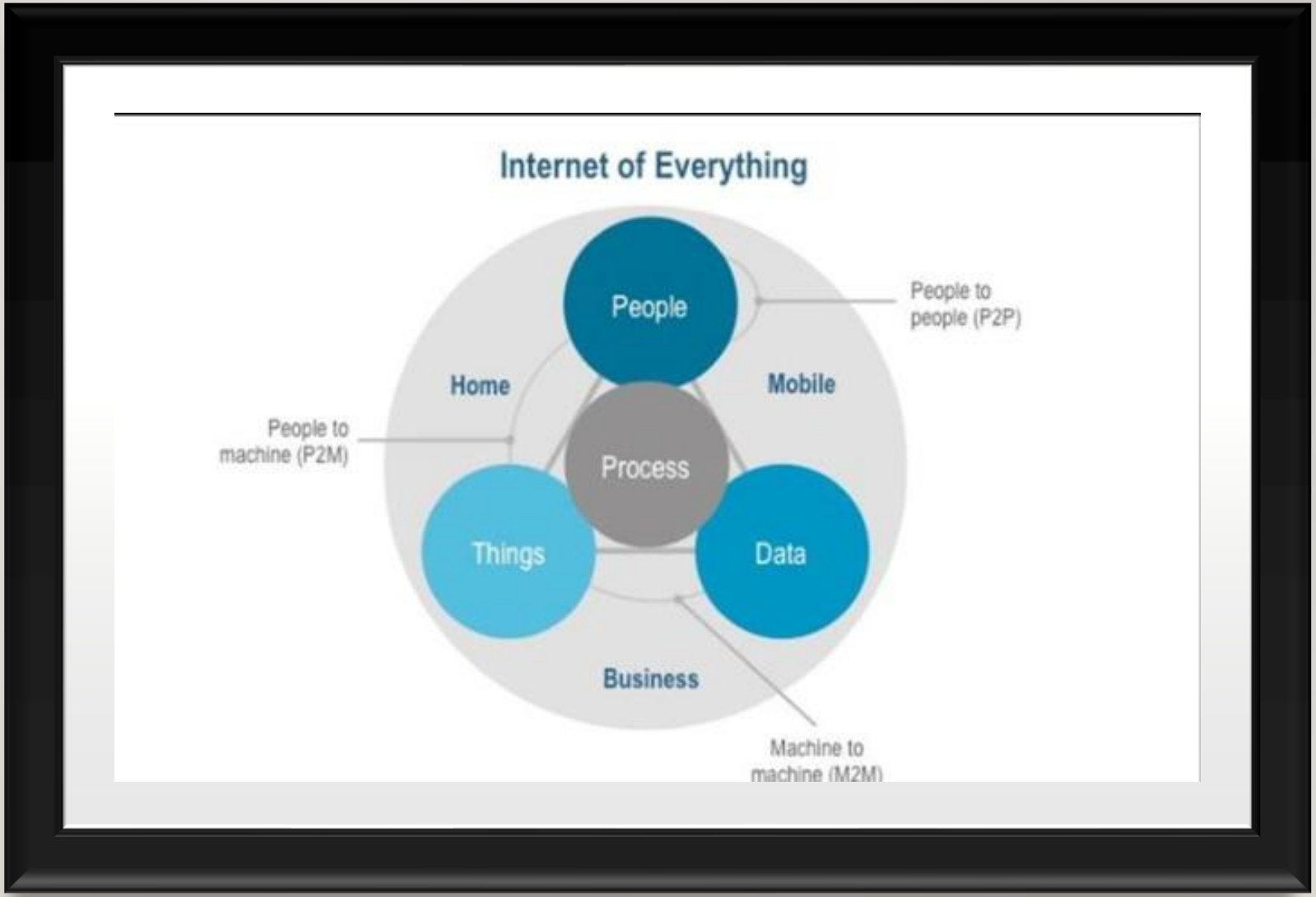
M2M VS IOT

M2M	IoT
Point-to-point communication usually embedded within hardware at the customer site	Devices communicate using IP Networks, incorporating with varying communication protocols
Many devices use cellular or wired networks	Data delivery is relayed through a middle layer hosted in the cloud
Devices do not necessarily rely on an Internet connection	In the majority of cases, devices require an active Internet connection
Limited integration options, as devices must have corresponding communication standards	Unlimited integration options, but requires a solution that can manage all of the communications

INTERNET OF EVERYTHING VS IOT

- Both CISCO and Qualcomm have been using the term 'Internet of Everything' (IoE). However, Qualcomm's use of the term has been replaced by the 'Internet of Things' (IoT).
- IoE is built upon the "four pillars" of people, data, process and things. Whereas IoT is only composed of "things", IoE also extends business and industrial processes to enrich the lives of people.

INTERNET OF EVERYTHING



WEB OF THINGS VS IOT

- The Web of Things is software architectural styles and programming patterns that allow real-world objects to be part of the World Wide Web. Similarly, to what the Web is to the Internet, the Web of Things provides an Application Layer that simplifies the creation of Internet of Things applications.
  - **(Source – Wikipedia)**

WEB OF THINGS

Sensors

- Temperature
- Humidity
- Light
- Switch
- etc

WoT Server

- WoT Service Framework
- RESTful resource management
- Device management
- Application management
- URI/IRI access scheme
- Integrated external web resources

Web Application

- HTML5 based application
- Web standards

Source : hollobit.github.io

MAJOR STANDARD BODIES / CONSORTIUMS

OASIS - Organization for the Advancement of Structured Information Standards

IETF – Internet Engineering Task Force (Maintains its documents in form of Request for Comments(RFC)

IEEE – Institute of Electrical and Electronics Engineers

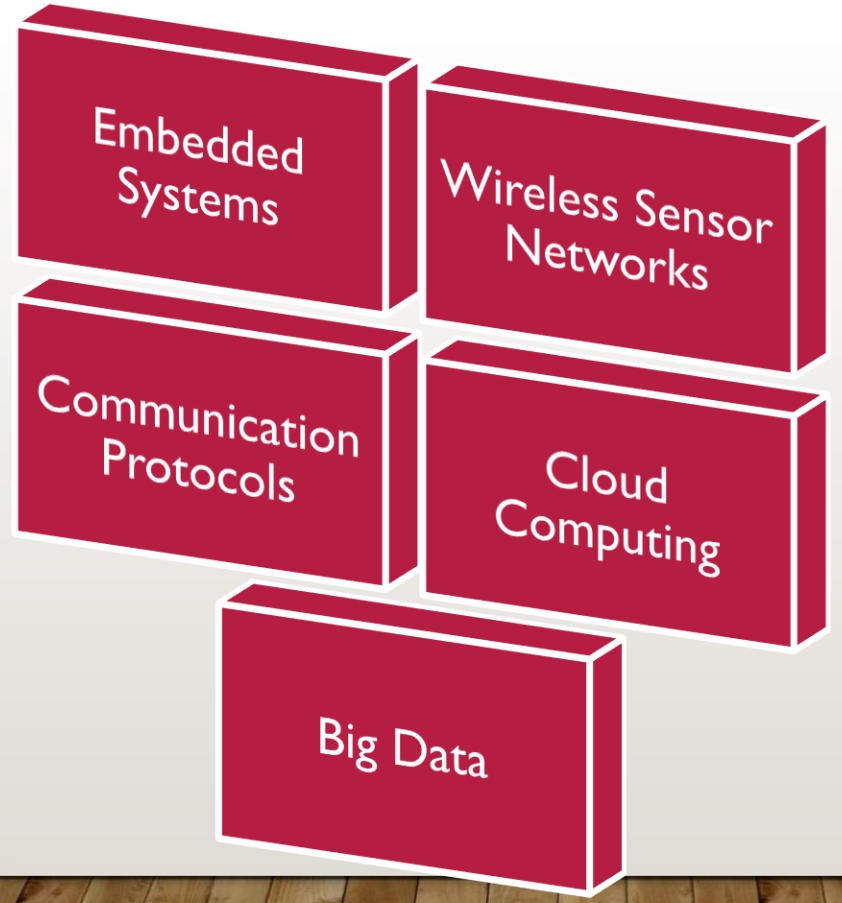
WHY IOT IS EVERYWHERE – WHETHER IT IS WORKPLACE OR OUTSIDE OF IT

- It is the concept that not only has the potential to impact how we live but also how we work.

What are the things that have created perfect storm for IoT

- Broadband Internet is become more widely available.
- More devices are being created with Wi-Fi capabilities sensors built into them.
- Technology costs are going down.
- Smartphone penetration is sky-rocketing.

21 ENABLING TECHNOLOGIES

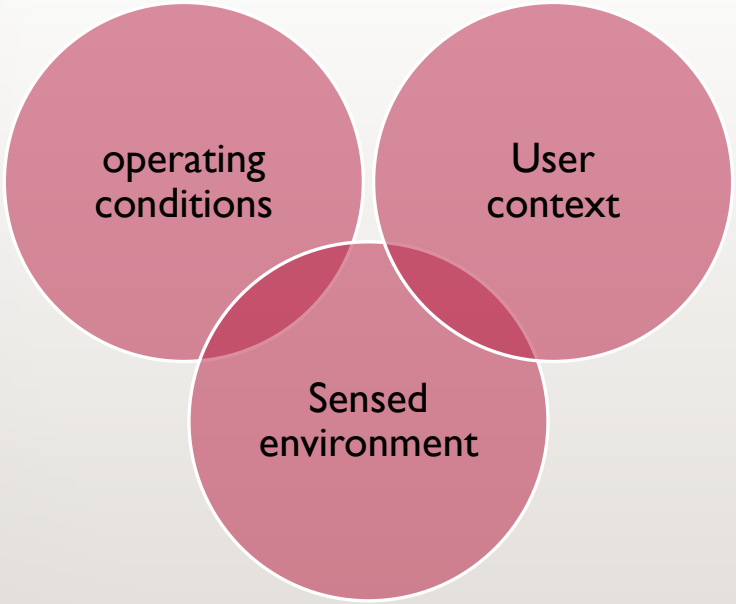


CHARACTERISTICS

THINGS CHARACTERISTICS

DYNAMIC

- Adapt changing context and take actions based on :



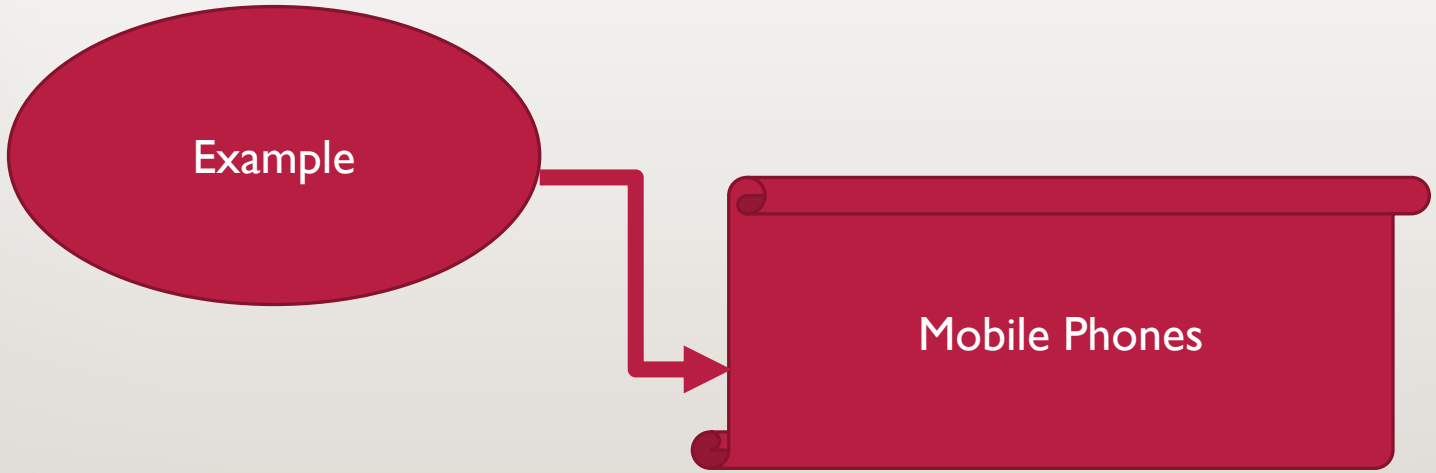
Example

automatic adjustment of surveillance image quality based on motion detection

User context is any relevant information that can be used to characterize the situation of a **user** where the **user** is, whom the **user** is with, and what resources are nearby. Ref: igi-global

Self-configuring

To configure themselves (with respect to the IoT infrastructure), setup the network, upgrade, etc. with minimal user intervention



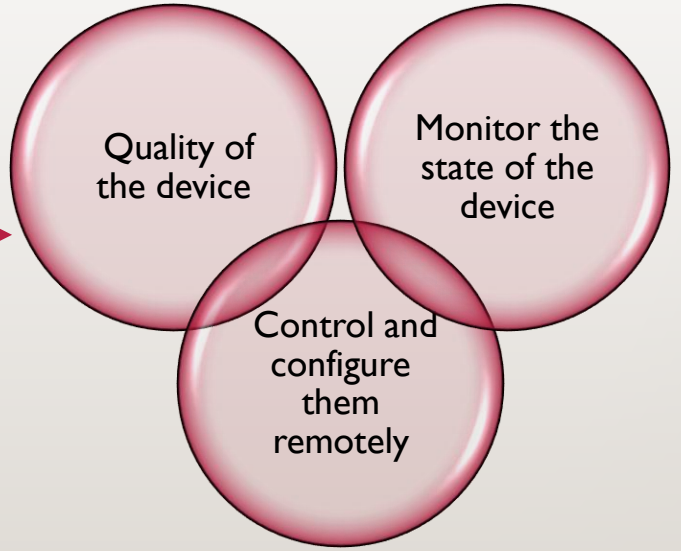
Interoperable protocols

communication with other IoT devices and with the IoT infrastructure

Identities

Each IoT device has a unique identity and a unique identifier(e.g., IP addressor URI)

Allowing



Integrating into network

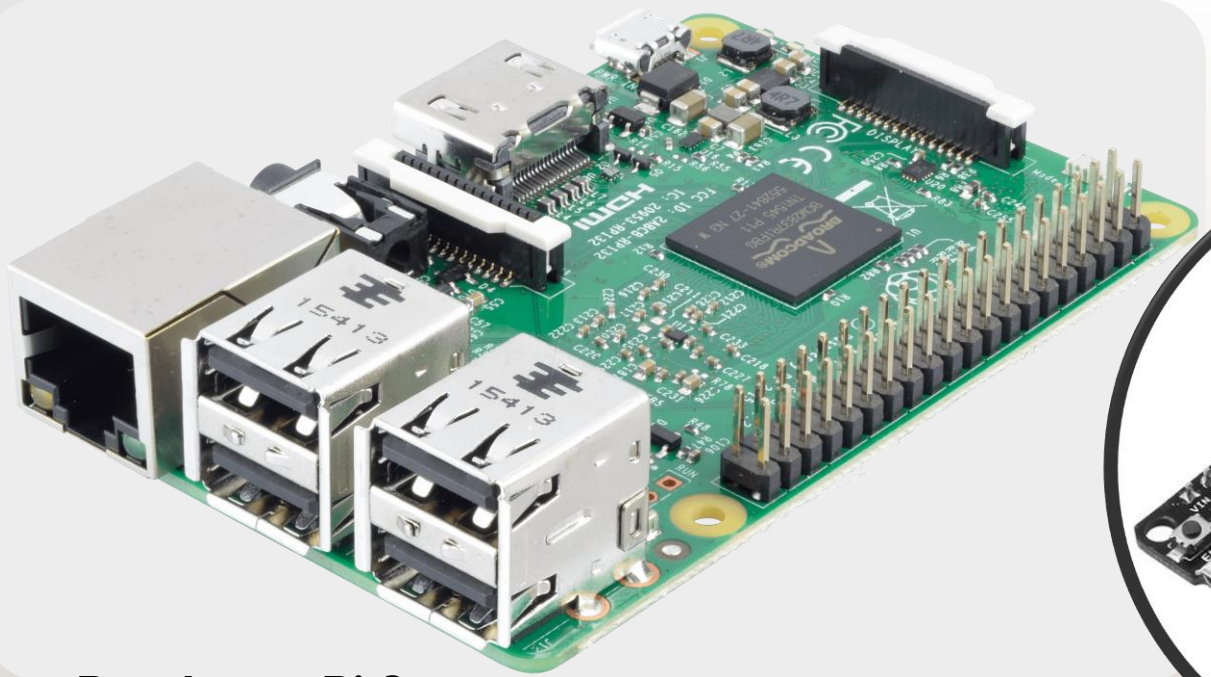
in order to communicate and exchange
data with other devices and systems

- Dynamic discovery of other devices
- Capability of describing itself and understanding others
- Capability to interact with others

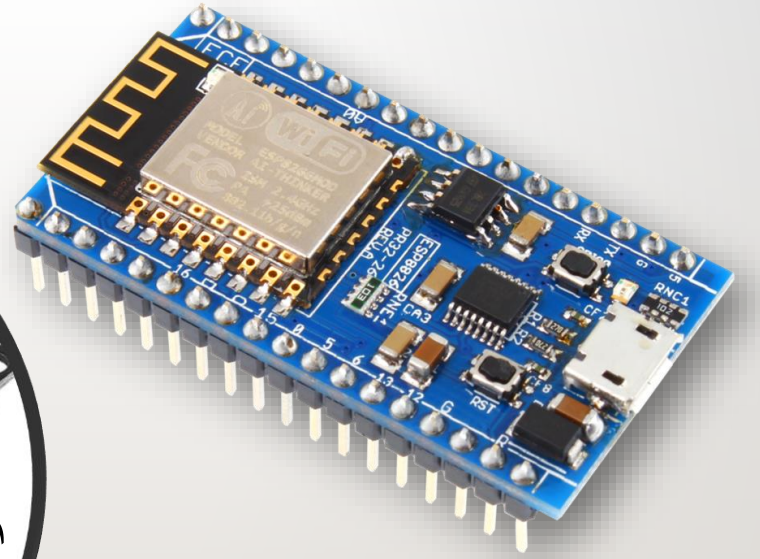
IN NUTSHELL – THINGS USUALLY HAVE

- Unique identities
- Sensors and actuators
- Capabilities for :
  - Exchange data and connect to other devices
  - Collect data
  - Process data or send data to be processed centralized
- Perform tasks locally with some temporal and space constraints
  - Memory, processing capability, communication, latencies, speeds and deadlines

30 SOME POPULAR IOT DEVICES



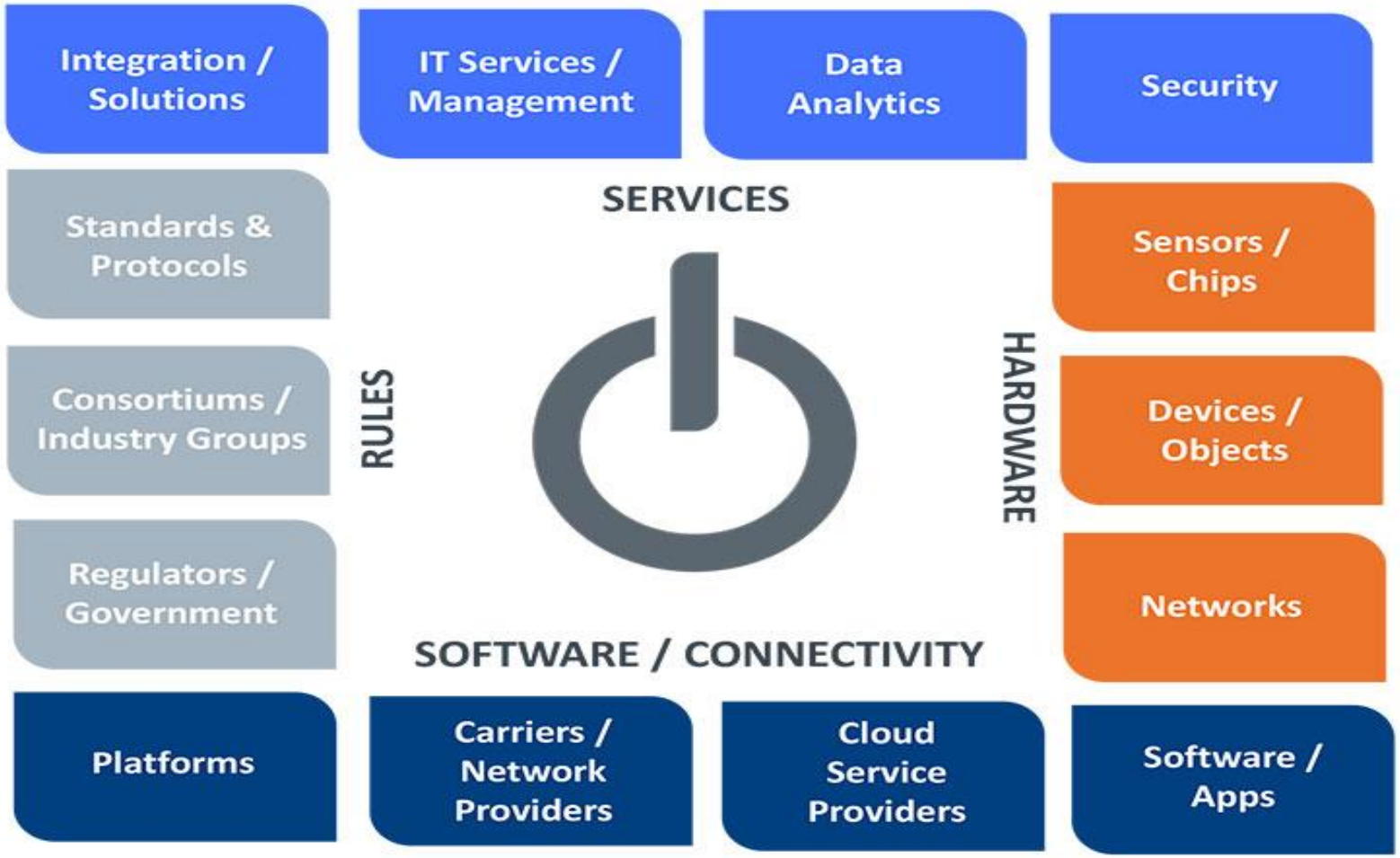
Raspberry-Pi-3 (BLE+Wi-Fi+Ethernet)



Esp8266 – NodeMCU (Wi-Fi)

The Evolving Internet of Things Ecosystem

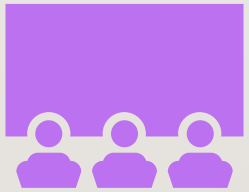
As with most recent trends in technology, the Internet of Things is composed of many different pieces working in concert to create a new model.



http://www.soundandcommunications.com/opportunities-internet-things/

AAA(S) IN IOT

Acquire



Act

Analysis

The Internet of Things

From connecting devices to human value

01 Device connection

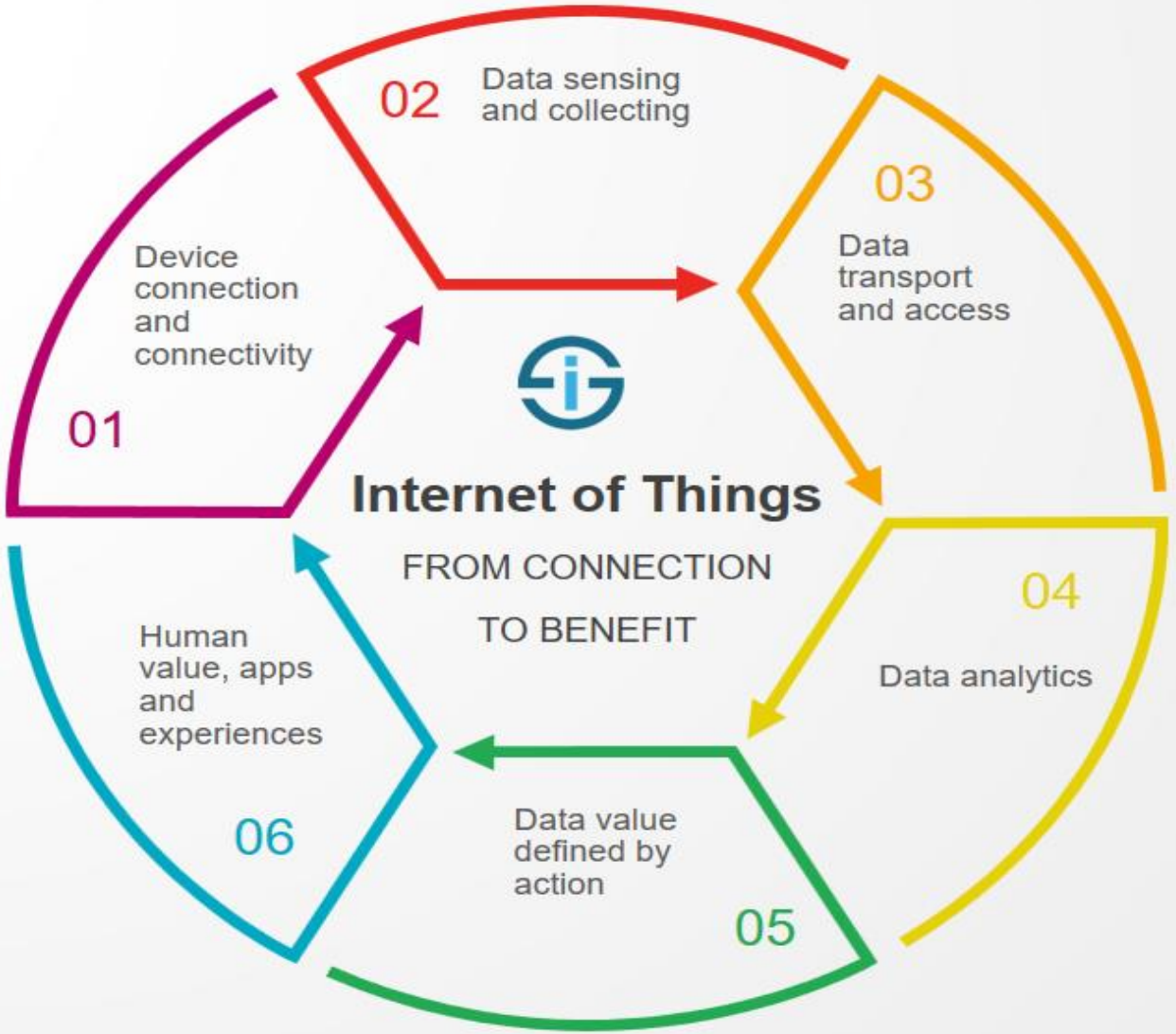
IoT devices
IoT connectivity
Embedded intelligence

02 Data sensing

Capture data
Sensors and tags
Storage

01 Communication

Focus on access
Networks, cloud, edge
Data transport



Data analytics 04

Big data analysis
AI and cognitive
Analyis at the edge

Data value 05

Analysis to action
APIs and processes
Actionable intelligence

Human value 06

Smart applications
Stakeholder benefits
Tangible benefits

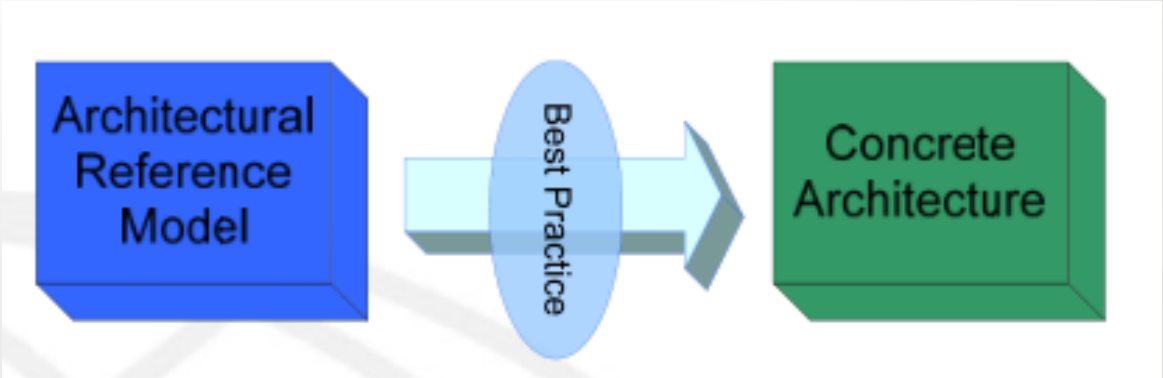
Source: i-scoop.eu

MOTIVATIONS FOR IOT REFERENCE ARCHITECTURE

The interoperability of solutions at the **communication level** as well as the **service level**, has to be ensured across various platforms

IOT REFERENCE ARCHITECTURE

- **Requirements for a Reference Architecture**
  - Connectivity and communications
  - Device management
  - Data collection, analysis, and actuation
  - Scalability
  - Security
  - Integration
  - Provide a strong point for architects looking to create IoT solutions as well as a strong basis for a further development.

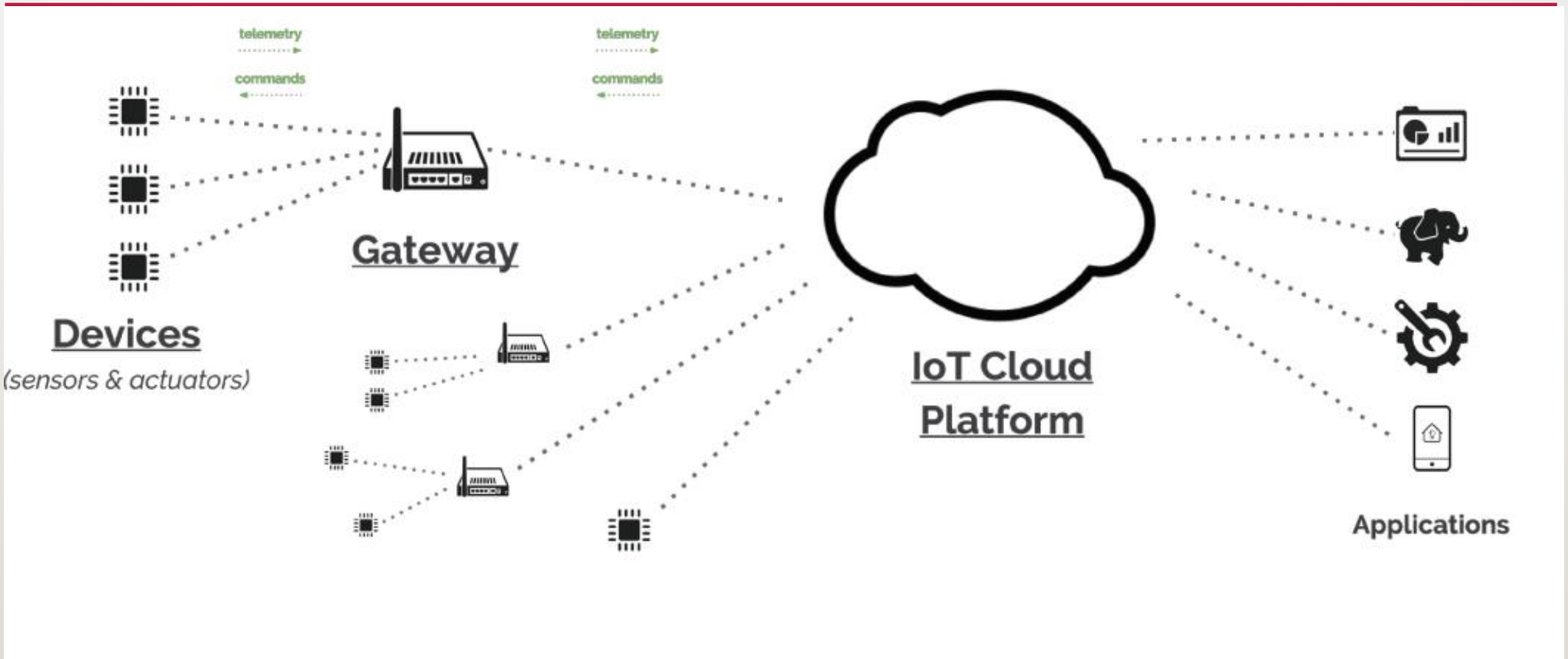


Ref : IoT-A

IOT REFERENCE ARCHITECTURE CONT.

- There is no reference architecture that is unanimously acceptable & practiced in the Industry .
- Every company has its **own reference architecture** depending on their requirements such as Oracle, Intel, Cisco, Google, WSO2, Intel etc..
- In next slide
  - I have summarized the core architecture of IoT, which is of three level named as- Edge Devices, Gateways and Cloud .

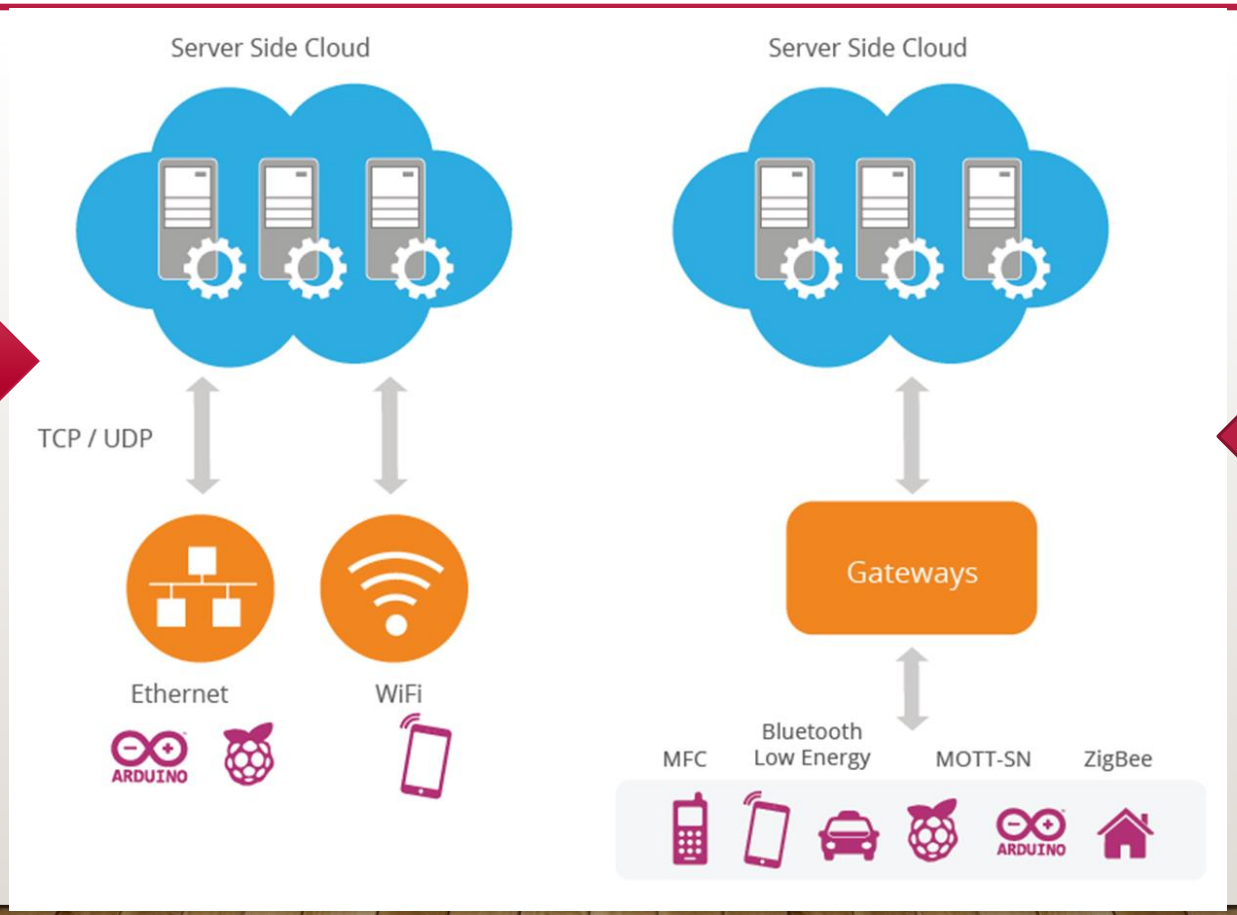
IOT REFERENCE ARCHITECTURE CONT.



Ref: Eclipse IoT

DEMYSTIFYING THE LAYER -2 & LAYER -3 ARCHITECTURE

Layer -2 Architecture



Layer -3 Architecture

When objects are uniquely identifiable – Gateways are not required

Ref :WSO2

KEY POINTS TO REMEMBER

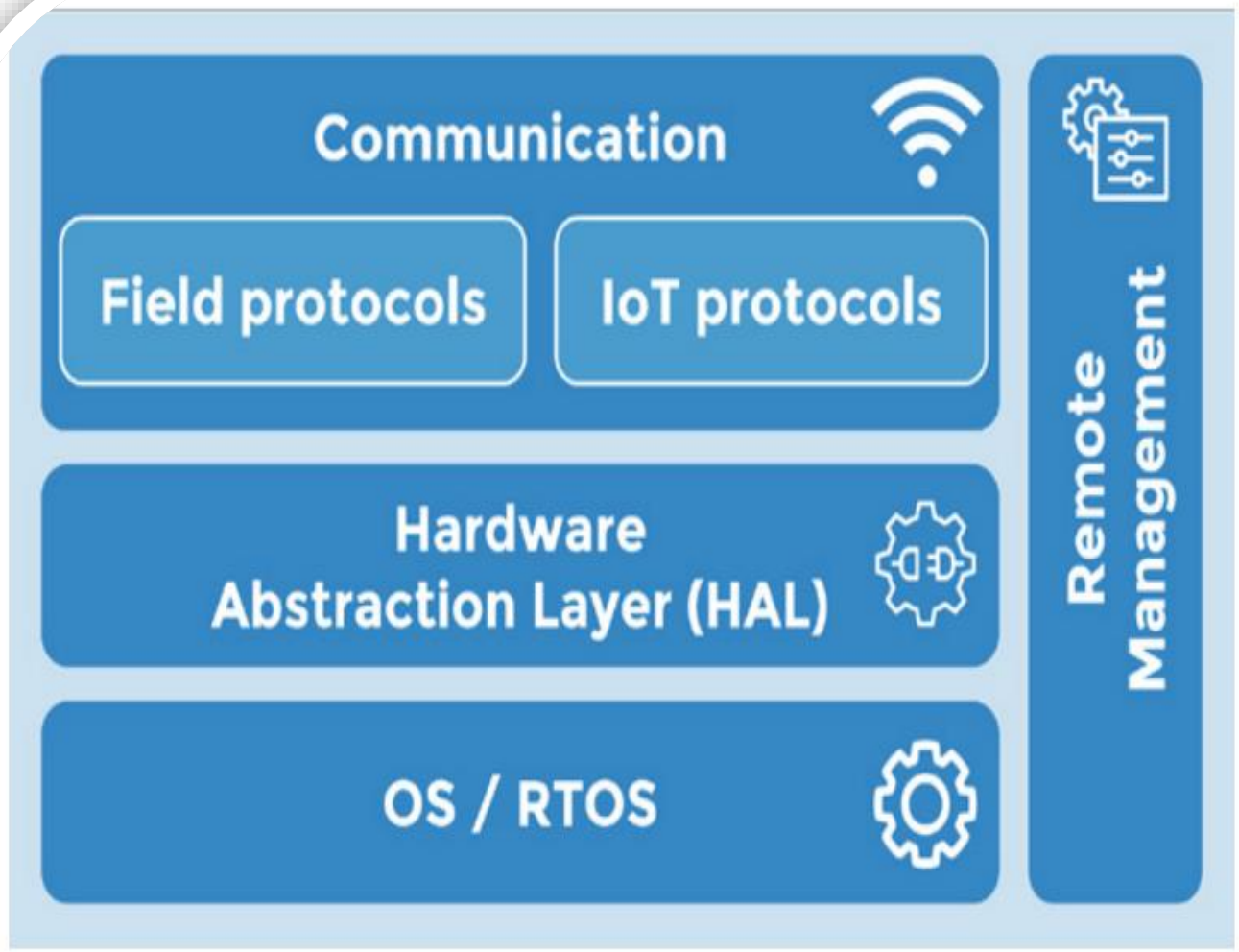
- There are devices that connect directly and those that connect via gateways. The devices that connect via a gateway potentially require two protocols:
  - one to connect to the gateway,
  - another from the gateway to the cloud.
- There is obviously a requirement for our architecture to support transport and protocol bridging, e.g. we **may wish to offer a binary protocol to the device, but allow an HTTP-based API to control the device** that we expose to third parties.
    - (such as QEST and Eclipse Ponte)

KEY CHARACTERISTICS FOR IOT STACKS

- Loosely coupled
- Modular
- Platform-Independent
- Based on open standards
- Defined APIs

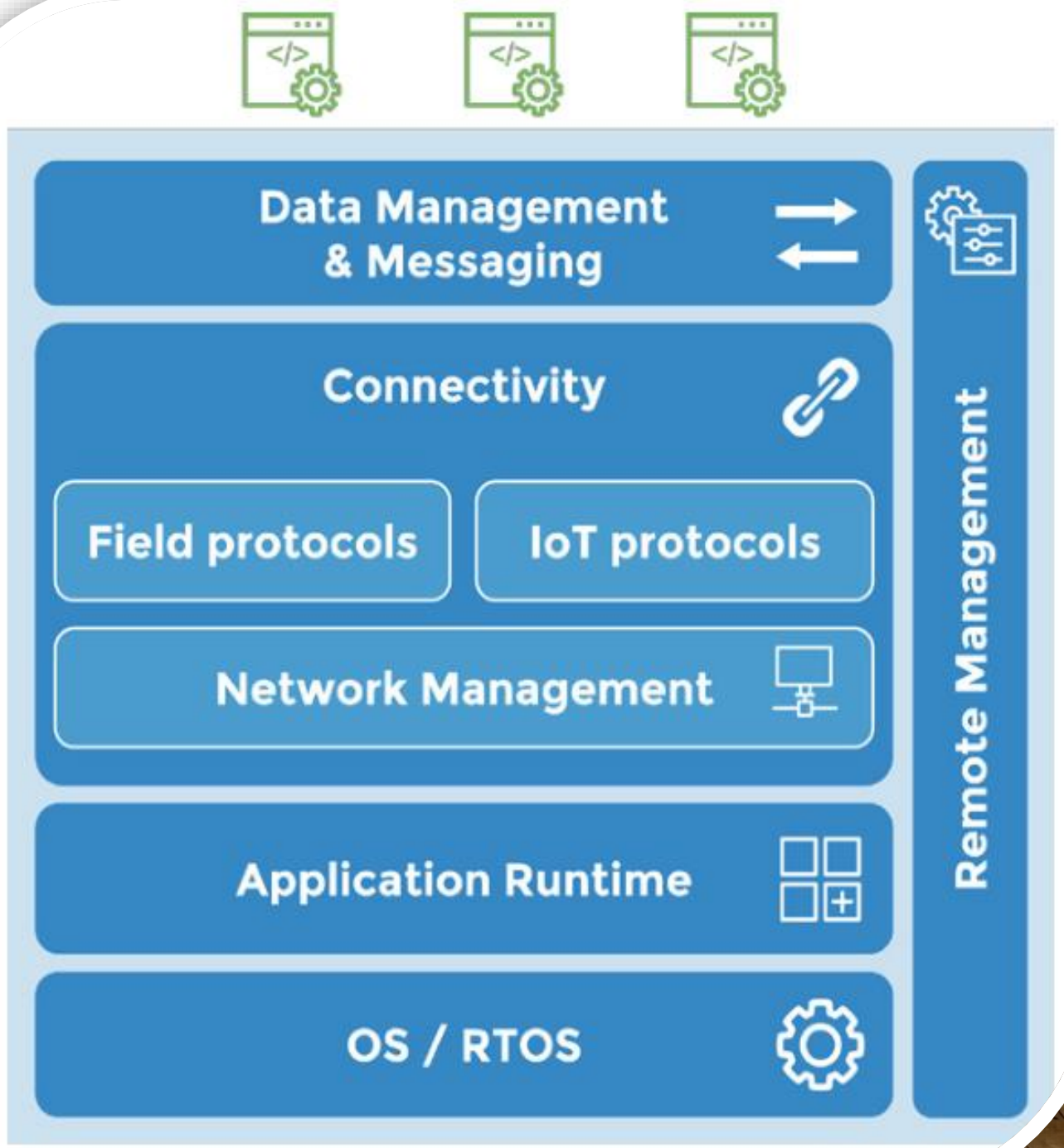
Three main stacks in IoT

SOFTWARE STACKS FOR CONSTRAINED DEVICES

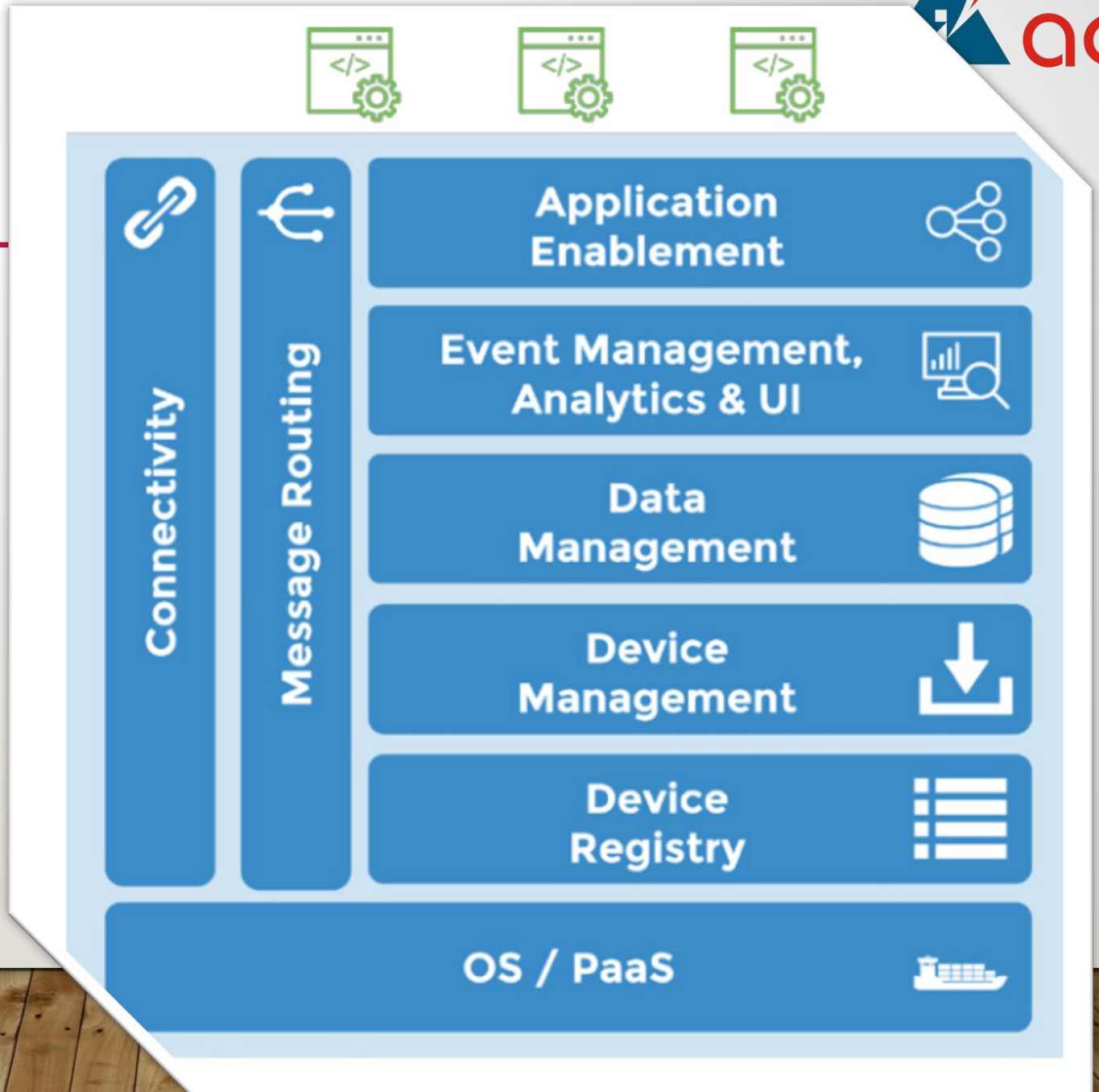


Software stack for constrained devices

SOFTWARE STACKS FOR AN IOT GATEWAY



IOT CLOUD PLATFORM STACKS



DEVICE MANAGEMENT

- The ability to disconnect a rogue or stolen device
- The ability to update the software on a device
- Updating security credentials
- Remotely enabling or disabling certain hardware capabilities
- Locating a lost device
- Wiping secure data from a stolen device
- Remotely re-configuring Wi-Fi, GPRS, or network parameters

Operations Technology

Information Technology

THE EDGE

The Things

- Wearables
- Mobile Devices
- Cars
- Meters
- Motors
- Robotics
- Buildings
- Generators

Sensors & Actuators

Data Aggregation & Gateways

Edge IT

Data Center & Cloud IT

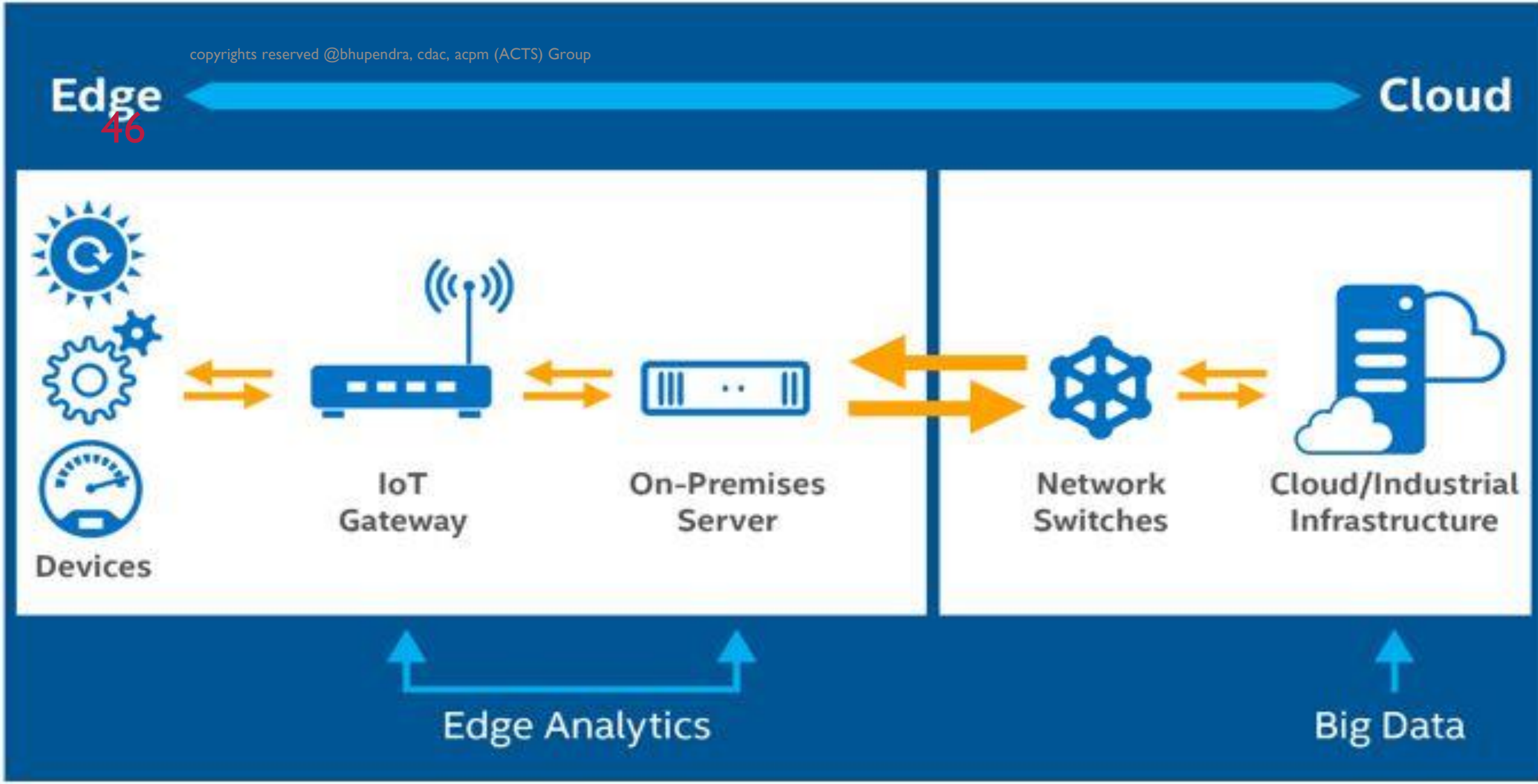
DATA GENERATION

DATA SENSING

DATA COLLECTION AGGREGATION

EARLY DATA ANALYTICS

DEEP DATA ANALYTICS



Information Flow between Edge and Cloud Source: Intel

Sensor | Control Center | Actuator

Temperature sensor detects heat.

Sends this detect signal to the control center.

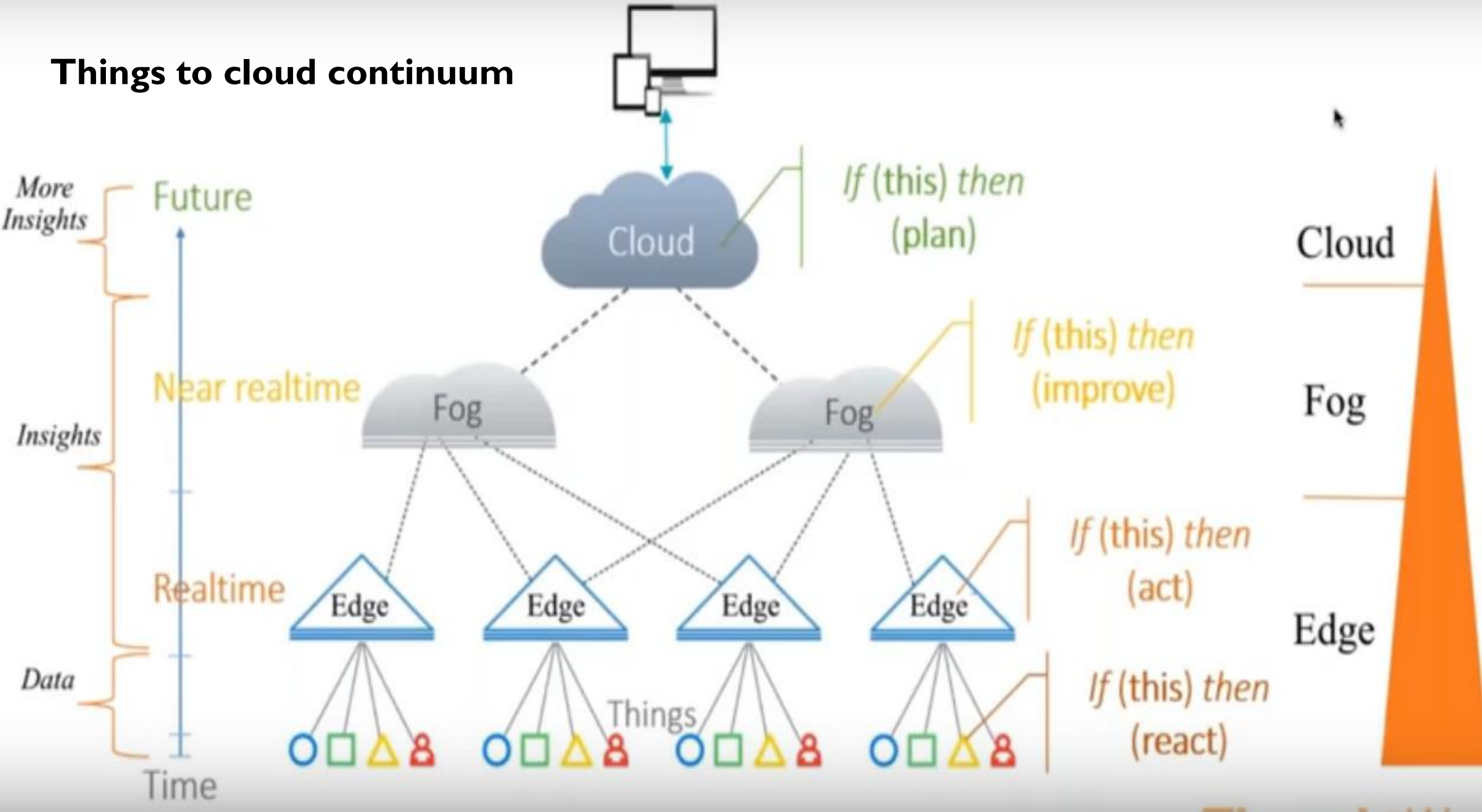
Control center sends command to sprinkler.

Sprinkler turns on and puts out flame.

Image Ref : https://bridgera.com/iot-system-sensors-actuators/

Sensor to **Actuator** Flow

Things to cloud continuum



CONSUMER IOT VS INDUSTRIAL IOT

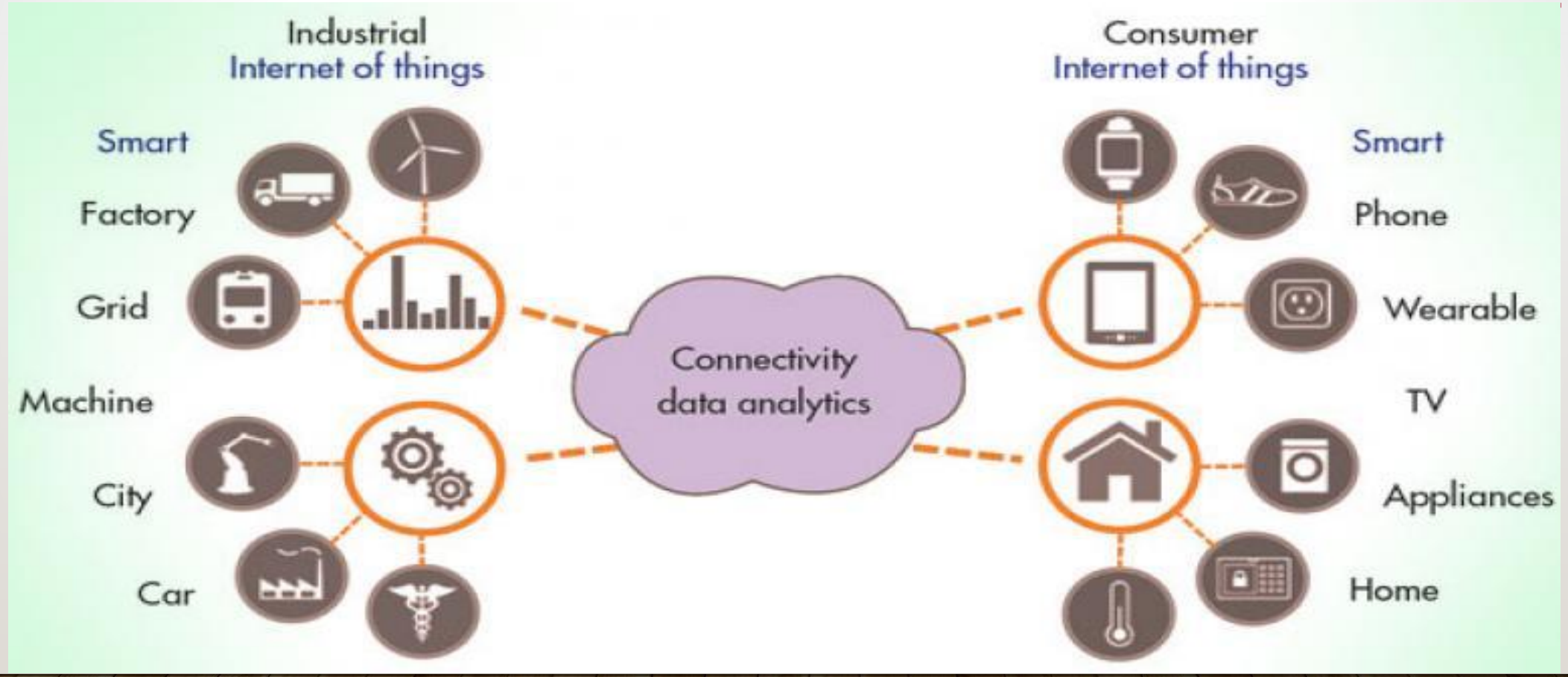


Image Ref: https://www.electronicdesign.com/iot/designing-industrial-internet-things

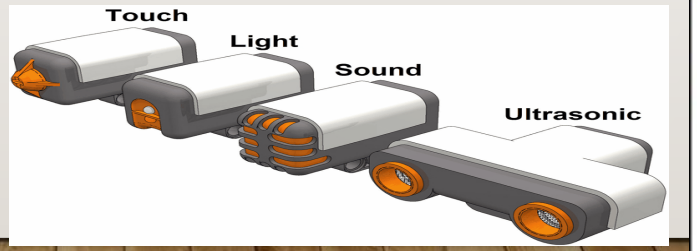
IoT vs IIoT

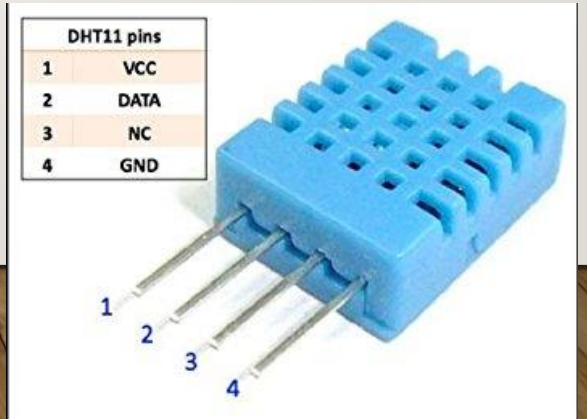
	IoT	IIoT
Human Interaction	Extensive	Limited
Harsh Operating Environment	Less Likely	More Likely
Operating Life	Short	Long
Access to Power Supply	Generally available	Constrained
Communication	LAN	WAN
Reliability	Medium	High
Security	Medium	High

END DEVICES/MOTES

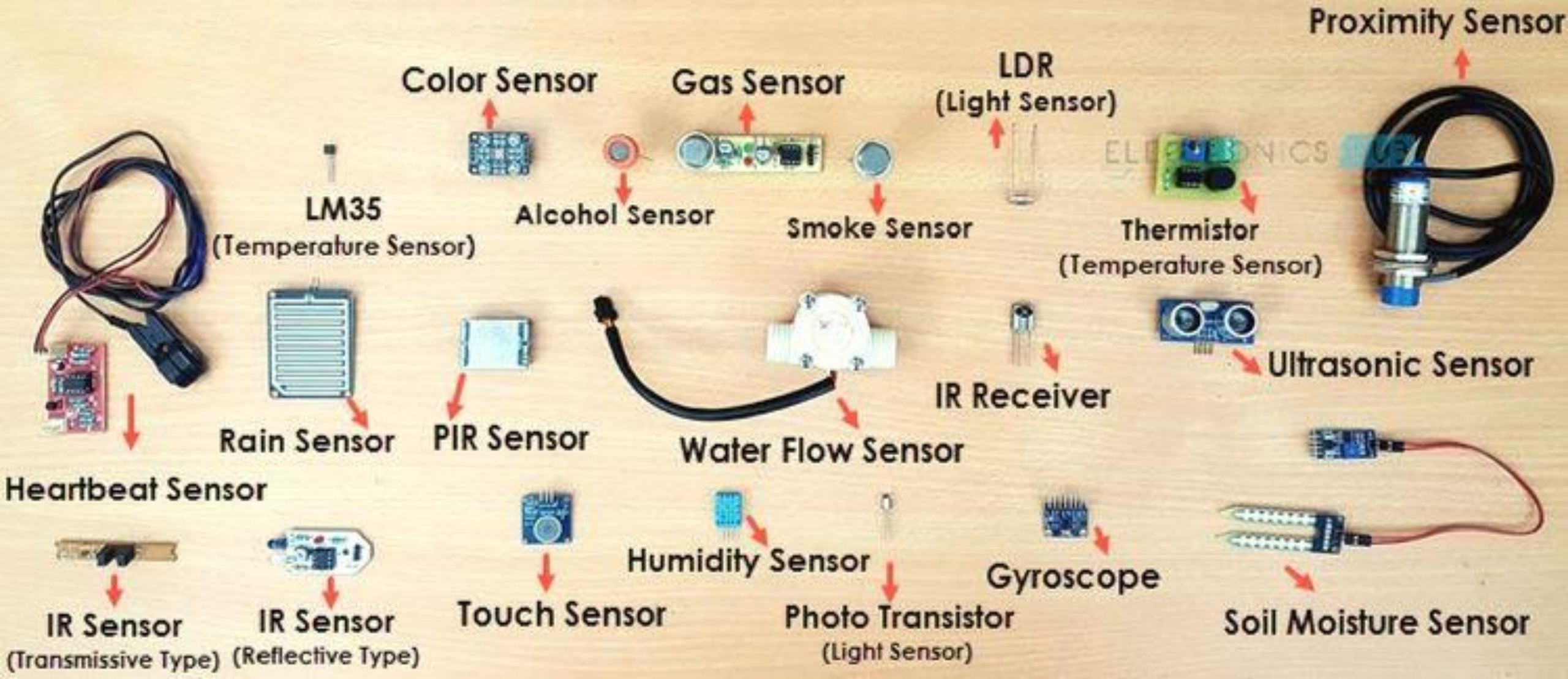
- **Sensors –**

Sensors are sophisticated devices that are frequently used to detect and respond to electrical or optical signals. A Sensor converts the physical parameter (for example: **Weight, Temperature, Pressure, Percentage Composition, Force, Electric or Magnetic or Electromagnetic, Position and Orientation, etc.)** into a signal which can be measured electrically.

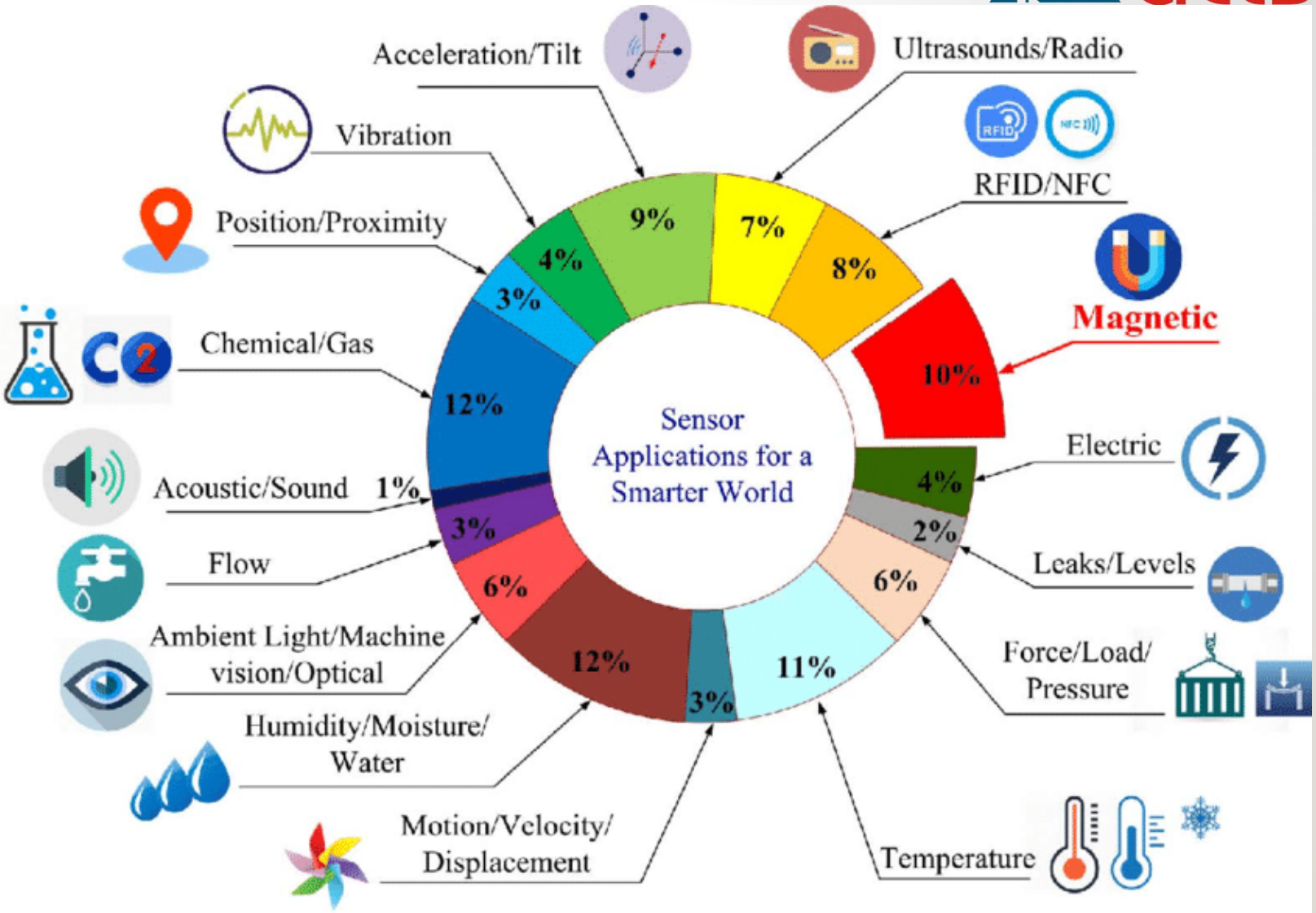




DIFFERENT TYPES OF SENSORS



COMMON SENSOR CATEGORIES



Reference : X. Liu et al., "Overview of Spintronic Sensors With Internet of Things for Smart Living," in IEEE Transactions on Magnetics, vol. 55, no. 11, pp. 1-22, Nov. 2019, Art no. 0800222.

ACTUATORS

- An actuator is a mechanism for turning energy into motion.
- Actuators can be- categorized by the energy source they require to generate motion-

a) Pneumatic actuators use compressed air to generate motion.

b) Hydrolic actuators use liquid to generate motion.

c) Electric actuators use an external power source, such as a battery, to generate motion.

d) Thermal actuators use a heat source to generate motion.

GATEWAYS/MIDDLEWARE

- As IoT grows and billions of devices need to connect to the world, one of the most critical components of future Internet of Things systems may be a device known as an "**IoT gateway**."
- An IoT gateway aggregates sensor data, **translates between sensor protocols**, processes sensor data before sending it onward and more.

IOT CLOUD PLATFORMS

- IoT Cloud platform that is designed to store and process Internet of Things (IoT) data. The platform is built to take in the massive volumes of data generated by devices, sensors, websites, applications, customers and partners and initiate actions for real-time responses.
- Some popular IoT cloud Platforms are listed in next slide.

IOT CLOUD PLATFORM CONT.....

- ThingsBoard
- Thinger.io
- ThingWorx
- IBM Watson
- AWS IoT
- Microsoft Azure

ThingsPeak

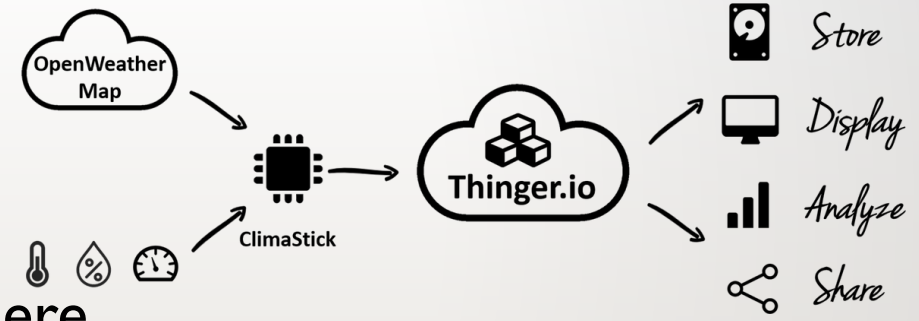
Xively

Kaa

SiteWhere

Carriots

Cayenne



ThingsBoard

IBM Bluemix™

IOT DATA COMMUNICATION PROTOCOLS

- MQTT - ***MQ Telemetry Transport (MQTT)***
- CoAP - Constrained Application Protocol
- AMQP - Advanced Message Queuing Protocol
- XMPP - Extensible Messaging and Presence Protocol
- OPA-UA - **OPC** Unified Architecture(**UA**)

OPERATING SYSTEM FOR IOT APPLICATIONS

- Contiki
- RIOT
- Ubuntu core
- TinyOS

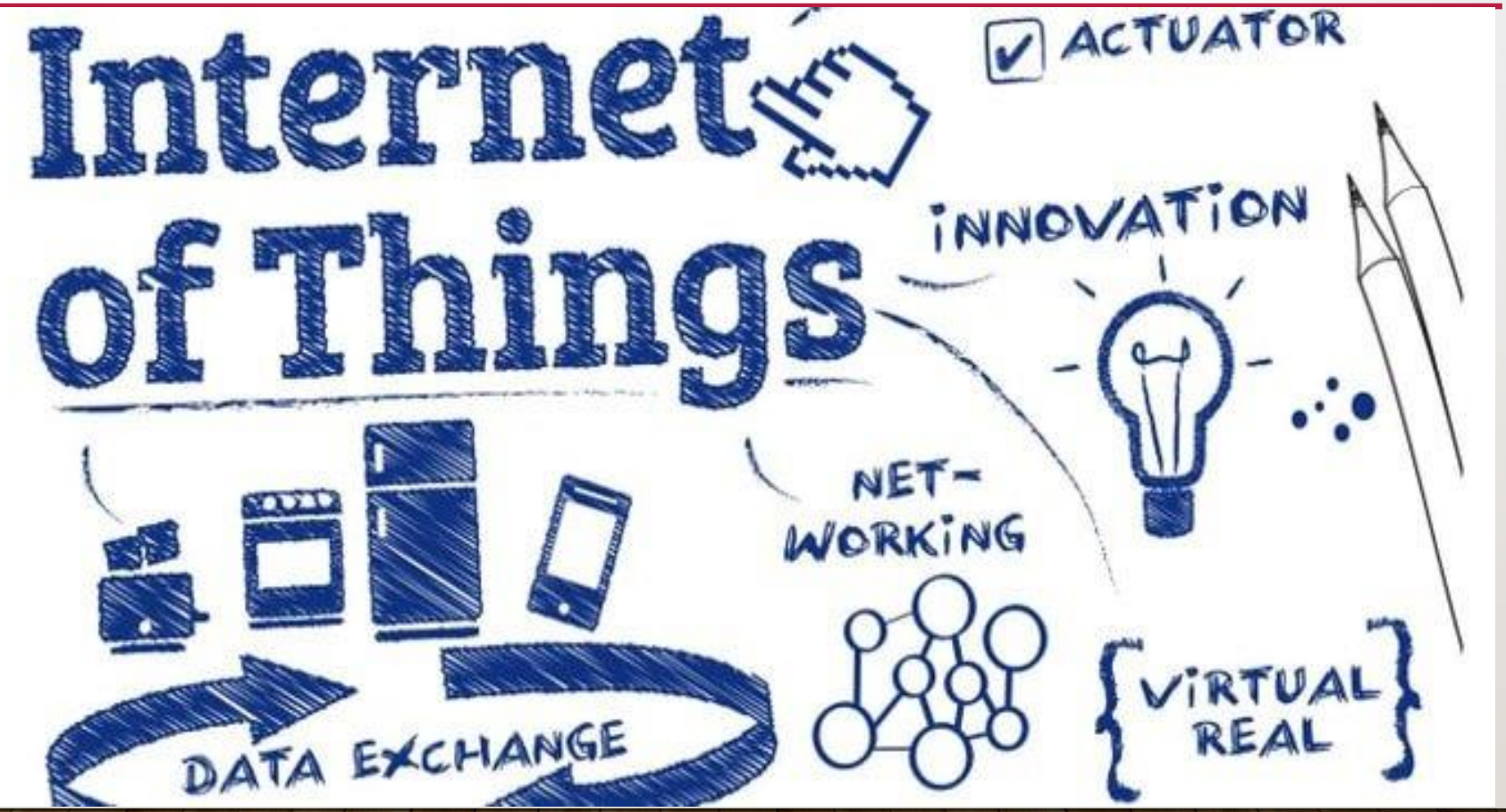
Additional OS with minimal foot prints

- Fuchsia OS
- Windows 10 IoT
- WindRiver VxWorks
- balenaOS
- Nano-RK
- Nucleus RTOS
- Particle Device OS

Detailed study- https://www.fossmint.com/operating-systems-for-the-internet-of-things/
https://www.g2.com/categories/iot-operating-systems

WSN TECHNOLOGIES

- Wi-Fi
- BLE
- ZigBee
- Thread
- Mi-Wi
- LoRA
- 6LowPAN
- 3G/4G/5G
- NB-IoT
- SigFox



DATABASES SUITED FOR IOT APPLICATIONS

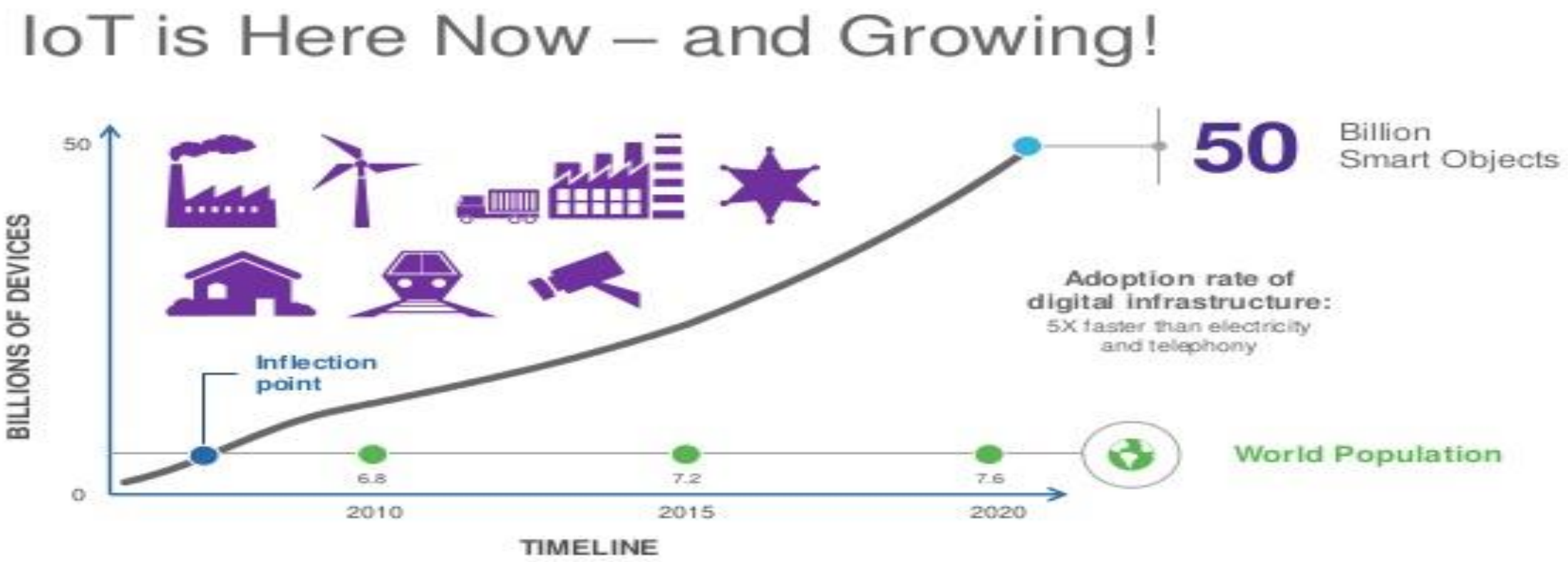
- InfluxDB – Time Series Database (Retention Policy)
- CreateDB - distributed SQL database management system
- MongoDB - document-oriented database program
- RethinkDB - Scalable JSON database for the real-time We
- SQLite - serverless (self-contained) transactional SQL database engine
- Apache Cassandra - distributed, wide column store, NoSQL, DBMS

Ref: https://opensourceforu.com/2018/05/open-source-databases-that-work-best-for-iot/

CHALLENGES IN IOT

- Signaling
- Security
- Presence
- Power Consumption
- Bandwidth
- Heterogeneous Network -
  - Cell Tower, Slow Connectivity, Fast Connectivity, Firewalls, Proxy Server, Tunnels

BUSINESS TRENDS (FACTS AND FIGURES)



SOME INTERESTING FACTS

- If you did a google search for "IoT" in 2012, the top results would have included "Illuminates of Thanateros" and "International Oceanic Travel Organization".
- A search for **"Internet of Things"** would have produced a result page with a list of academic papers at the top, but with no advertisements – A **strong indicator that in 2012, few people spent marketing dollars on the IoT.**

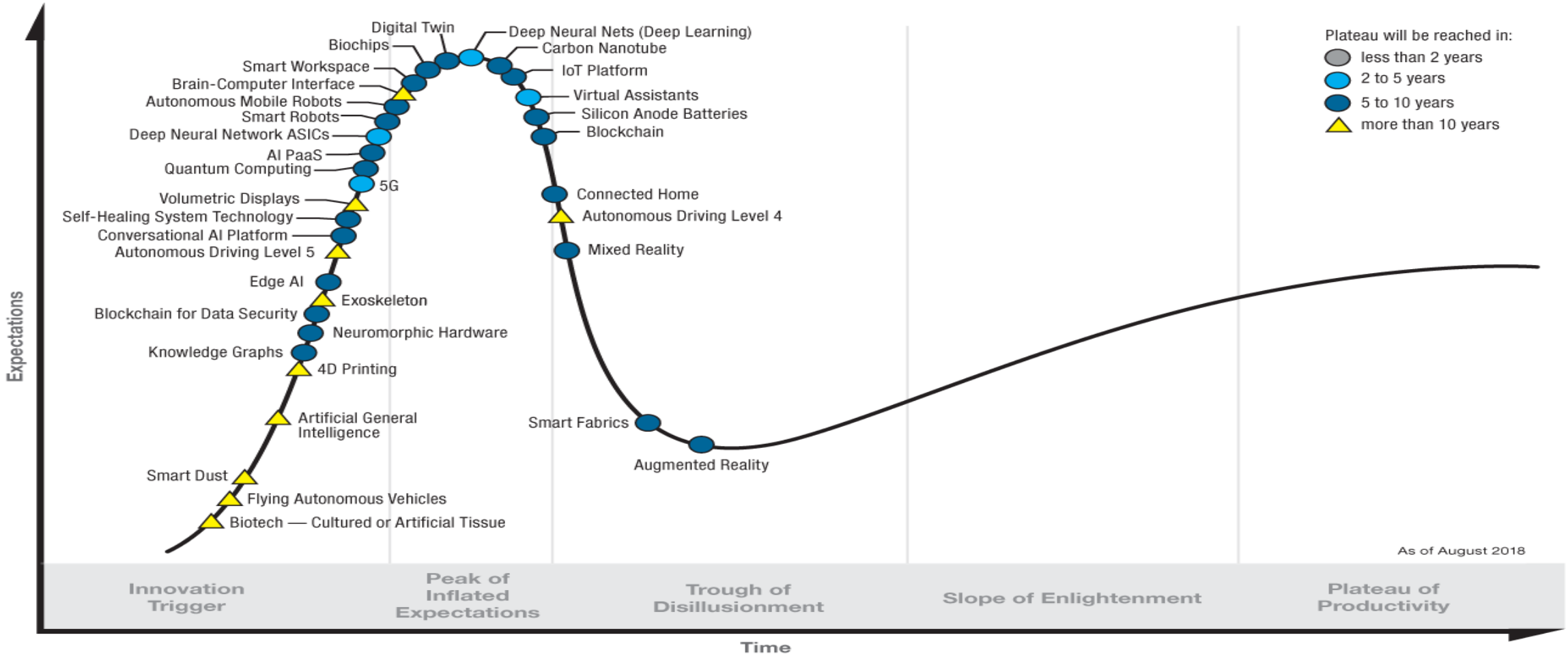
SOME INTERESTING FACTS CONT..

- Two years on, and this had changed dramatically, **In 2014, the IoT was one of the most hyped buzzwords** in the buzzwords in the IT industry.
- IT analysts everywhere tried to outdo each other's growth projections for 2020, from **CISCO's 50 billion connected devices to Gartner's economic value add of 1.9 trillion dollars**.

HYPE - CYCLE

No.	Phase	Description
1	Technology 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.
2	Peak of Inflated Expectations	Early publicity produces a number of success stories—often accompanied by scores of failures. Some companies take action; most don't.
3	Trough of Disillusionment	Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investment continues only if the surviving providers improve their products to the satisfaction of early adopters.
4	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.
5	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. If the technology has more than a niche market then it will continue to grow.[1]

Hype Cycle for Emerging Technologies, 2018



gartner.com/SmarterWithGartner

Source: Gartner (August 2018)

Gartner

Gartner Hype Cycle for Emerging Technologies, 2019

Plateau will be reached:

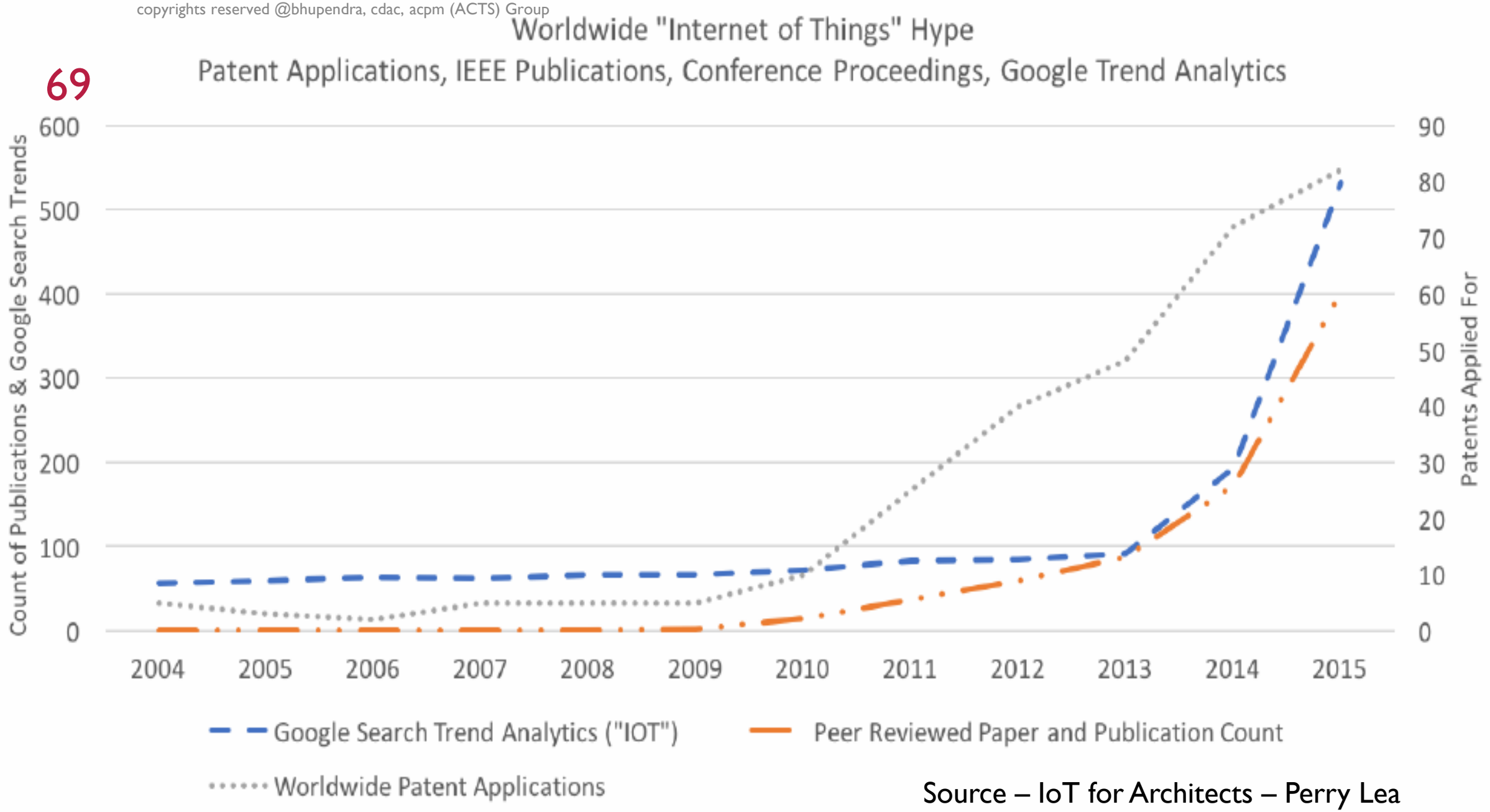
○ less than 2 years ● 2 to 5 years ● 5 to 10 years ○ more than 10 years ● obsolete before plateau

As of August 2019

gartner.com/SmarterWithGartner

Source: Gartner

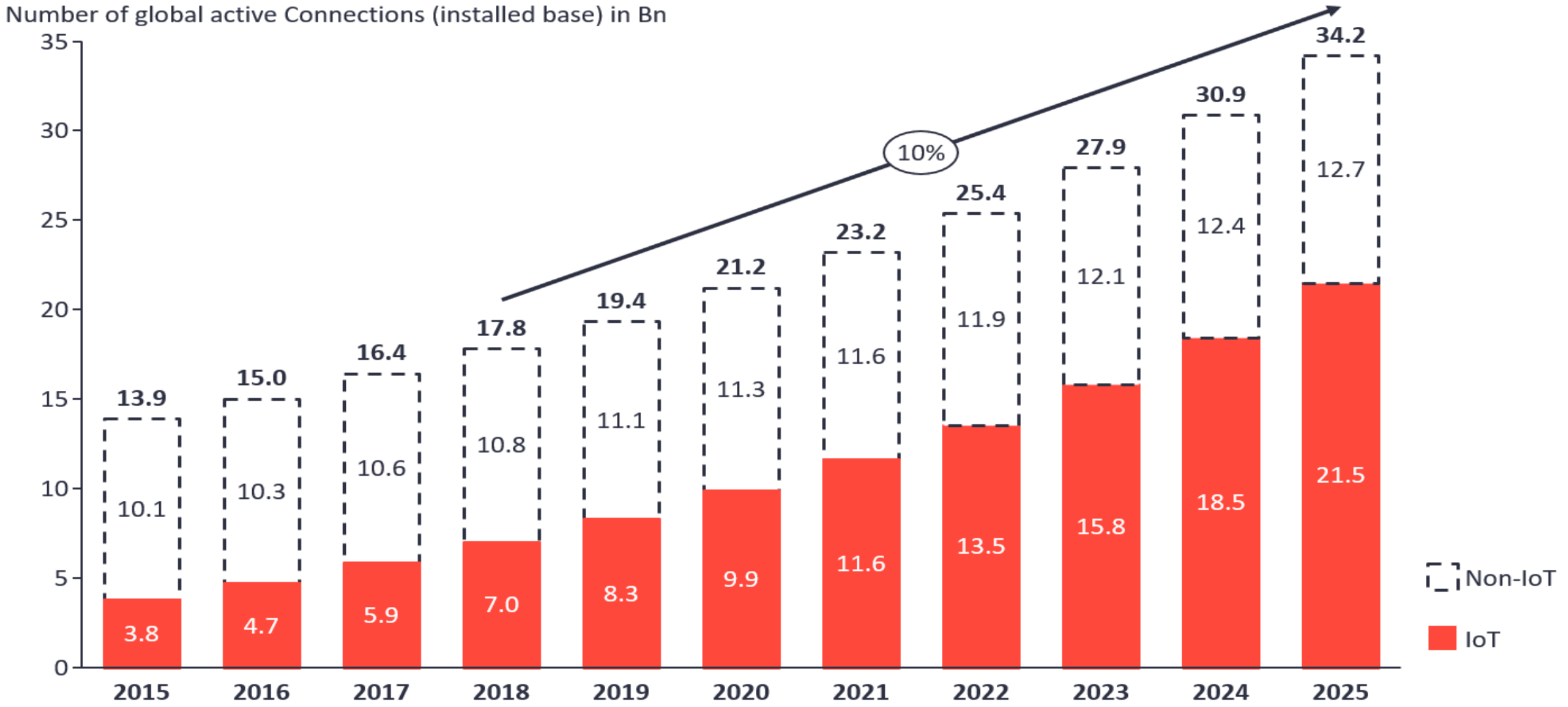
Gartner



Source – IoT for Architects – Perry Lea

Total number of active device connections worldwide

70

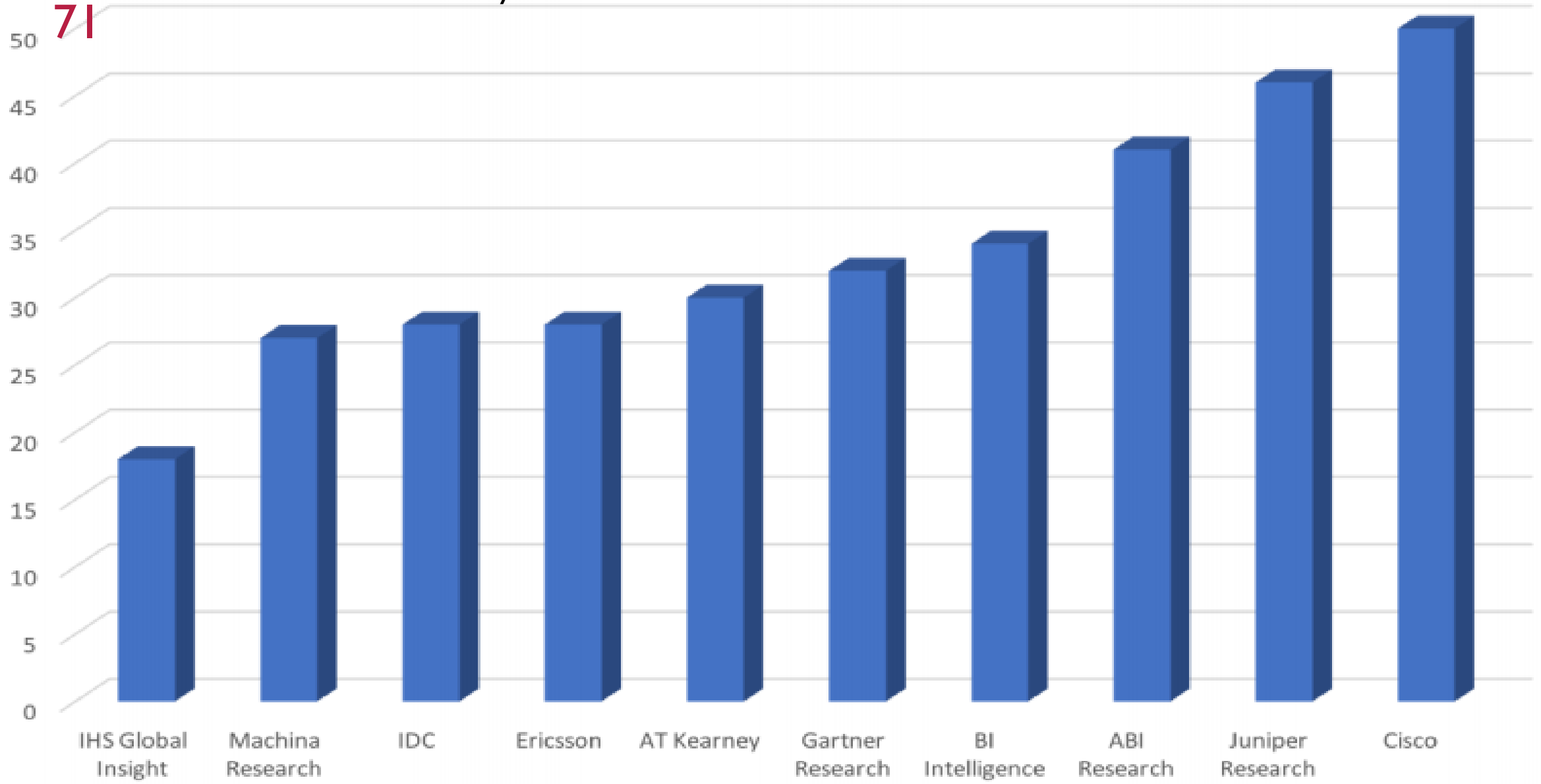


Note: Non-IoT includes all mobile phones, tablets, PCs, laptops, and fixed line phones. IoT includes all consumer and B2B devices connected – see IoT break-down for further details
Source: IoT Analytics Research 2018

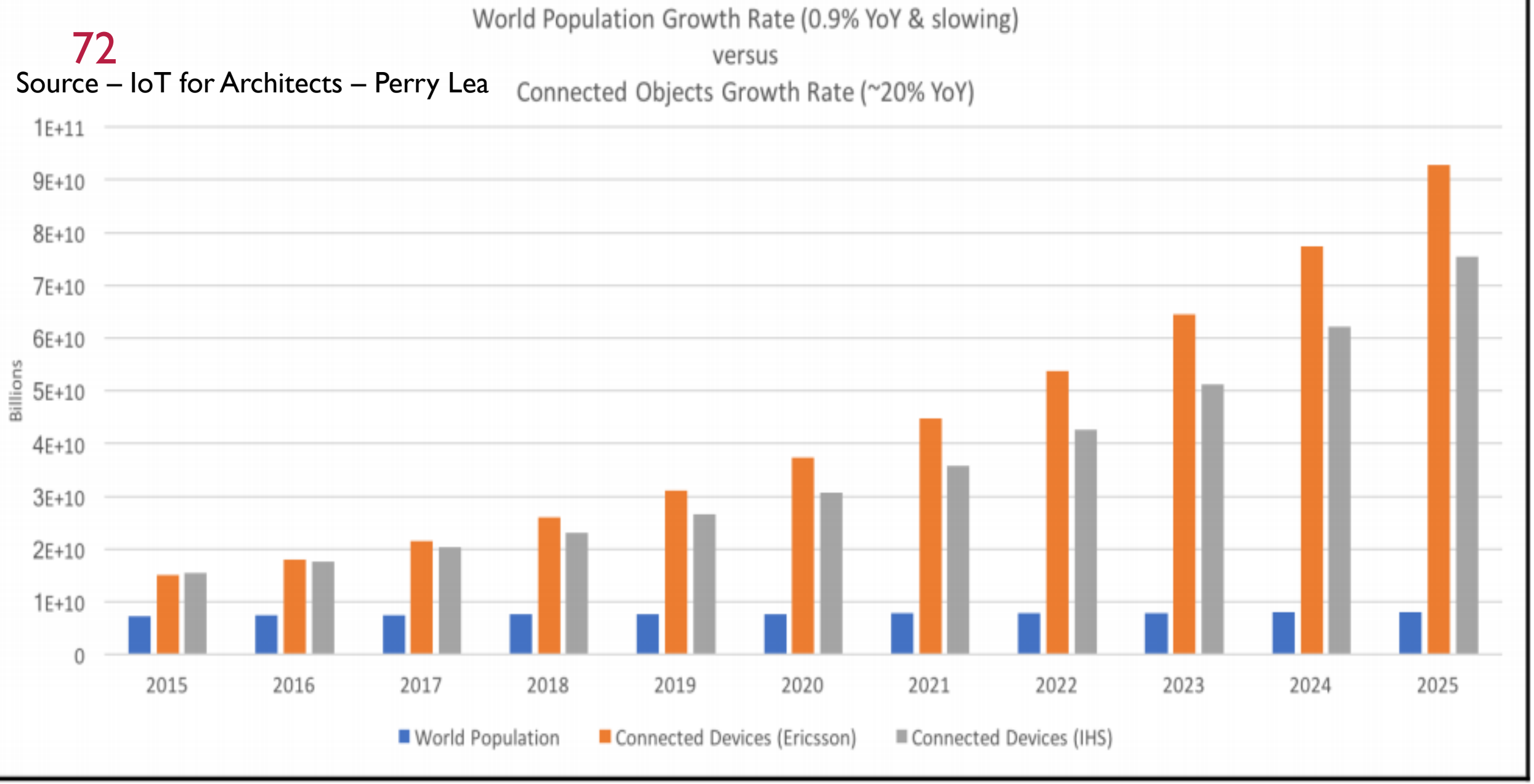
Source – IoT-Analytics

Billion IOT Connected Objects by 2020

Source – IoT for Architects – Perry Lea



Source – IoT for Architects – Perry Lea



ETHICAL CHALLENGES IN IOT

- Enforce the property rights on information.
- Ensure the access to information.
- Ensure the integrity of the information.
- Enforce the right to private life.

Source: Valacich, J., Schneider, C., Information Systems Today. Managing in the Digital World, 4th Edition, Pearson Publishing House, Boston, 2010, p. 484

ECONOMIC IMPACT -

- **It should be noted that economic impact is not solely revenue generation. This impact from IoT comes in form of –**
  - **New revenue streams (Green Energy solutions) -** reduce energy consumption, CO2 emission and pollution, exploit environmental conservation, and minimizing power consumption.
  - **Reducing costs (in-home patient healthcare)**
  - **Reducing time to market (factory automation)**
  - **Improving supply chain logistics(Asset tracking) – BLE Beacons**
  - **Reducing production loss (theft, spoilage of perishable)**
  - **Increasing productivity (Machine Learning and data analytics)**
  - **Cannibalization (Nest replacing traditional thermostats) -** slashing the price of a product or introducing a new product into a market of established product categories

THEMATIC AREAS

- Agriculture
- Home Automation
- Smart City
- Industrial IoT
- Smart Retail
- Defense

USE CASES

INDUSTRIAL AND MANUFACTURING

- Preventive maintenance on pre-existing factory machinery
- Throughput increase through real time demand
- Energy saving
- Safety systems such as thermal sensing, pressure sensing and gas leaks
- Factory floor expert systems

CONSUMER IOT

- Smart home gadgetry – Smart irrigation, smart garage doors, smart locks, smart lights, smart thermostats and smart security.
- Wearables – Health and Movement Trackers, smart clothing/wearables.
- Pets – Pet location systems

RETAIL

- Targeted advertising, such as locating known or potential customers by proximity and providing sales information.
- Asset Tracking – inventory control, loss control and supply chain optimizations.
- Cold storage monitoring – Analyzing cold storage of perishable inventory.
- Beaconing system within entertainment venues, conferences, concerts, amusements parks and museums.

HEALTHCARE

- In-Home patient care
- Learning models of predictive and preventative healthcare
- Hospital equipment and supply asset tracking
- Remote field medicine
- Patient fall indicators

AGRICULTURAL AND ENVIRONMENTAL

- Smart irrigation and fertilization techniques to improve yields
- Livestock health and asset tracking.
- Drone based land surveys
- Volcanic and fault line monitoring for predictive disasters

SMART CITY

- Pollution control
- Microclimate weather predictions using city wide sensor networks
- Waste management service on demand
- Smart irrigation of parks and public spaces depending on weather and current usages
- Improved traffic flow and fuel economy through smart traffic light control and patterning.
- Smart cameras to watch for crime and real time automated alerts
- Smart parking

GOVERNMENT AND MILITARY

- Sensor bombs deployed on battlefield to form sensor networks to monitor threats
- Government asset tracking systems
- Real time military personal tracking and location services.
- Synthetic sensors to monitor hostile environments
- Water level monitoring to measure dam and flood containment.

84 REFERENCES

- Internet of Things – From Research and Innovation to Market Deployment
- Internet of Things for architects – Perry Lea
- Wikipedia
- Internet of Things: A Hands-On Approach - Arshdeep Bahga, Vijay Medisetti