INTERNET OF THINGS

Unit 1

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Introduction

- Internet Of Things is fully networked and connected devices sending analytics data back to cloud or data center.
- The definition of Internet of things :
- The network in which every object or thing is provided unique identifier and data is transferred through a network without any verbal communication.

- The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are 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 is actually a pretty simple concept. It means taking all the physical places and things in the world and connecting them to the internet
- To be smart, a thing doesn’t need to have super storage or a supercomputer inside of it.
- All a thing has to do is connect to super storage or to a super computer.
- In the Internet of Things, all the things that are being connected to the internet can be put into three categories:
  - *Things that collect information and then send it*
  - *Things that receive information and then act on it*
  - *Things that do both*

Introduction

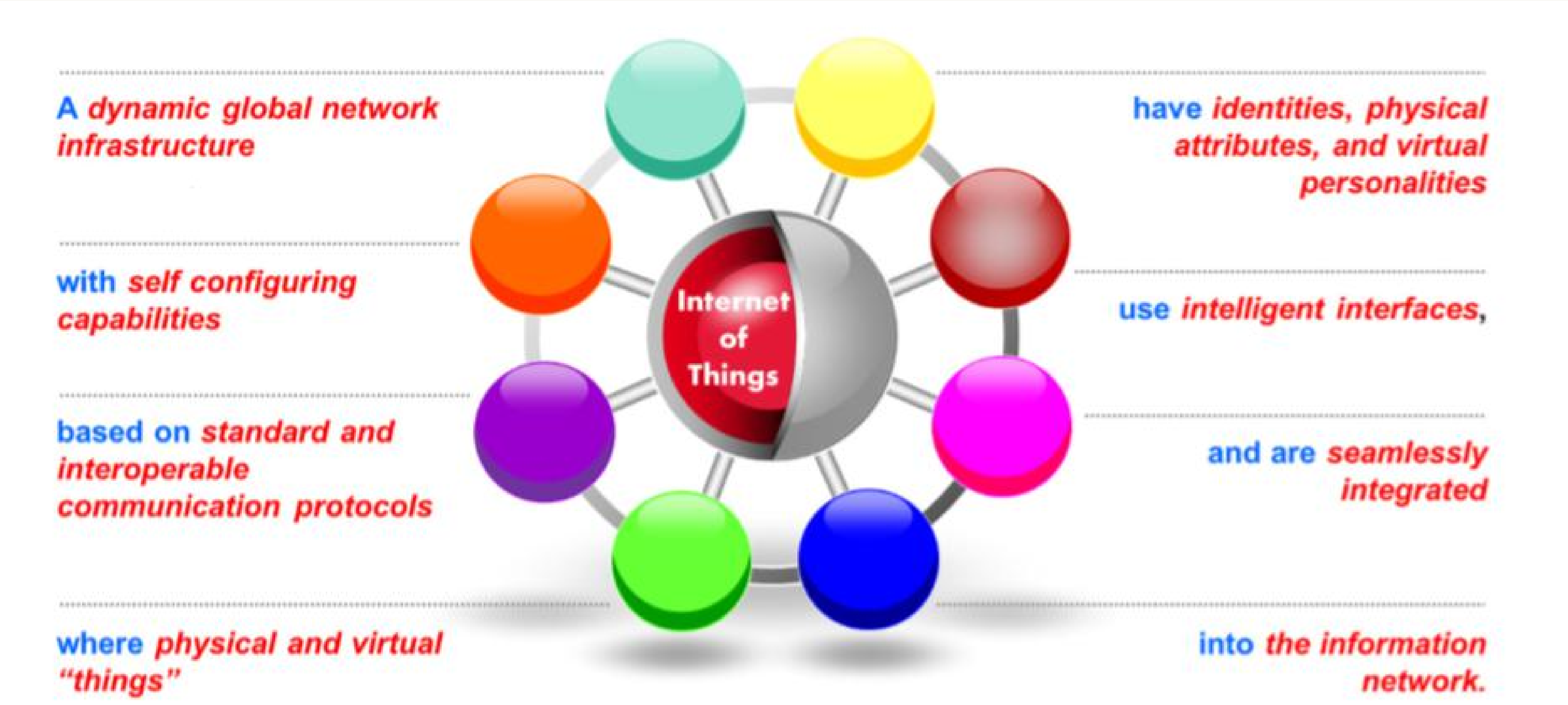
- The term Internet of Things was first coined by Kevin Ashton in 1999 in the context of supply chain management.
- Although the definition of ‘Things‘ has changed as technology evolved, the main goal of making computer sense information without the aid of human intervention remains the same.
- IoT technologies allow things, or devices that are not computers, to act smartly and make collaborative decisions that are beneficial to certain applications.
- They allow things to hear, see, think or act by allowing them to communicate and coordinate with others in order to make decisions that can be as critical as saving lives or buildings

Introduction

- In today’s emerging world of Internet, each and every thing is supposed to be in connected mode with the help of billions of smart devices.
- By connecting all the devices used in our day to day life, make our life trouble less.
- We are incorporated in a world where we are used to have smart phones, smart cars, smart gadgets, smart homes and smart cities.
- As the future internet will grow, it collaborates a huge number of objects which use standard protocols and architecture to provide services to end user.

Introduction

- It is envisioned to provide new interactions between physical world and Information and Communication Technology domain.
- This resulting networking paradigm is called Internet of Things.
- IoT provides unprecedented opportunities to users, manufacturers and service providers in a wide variety of sectors which are mentioned below.

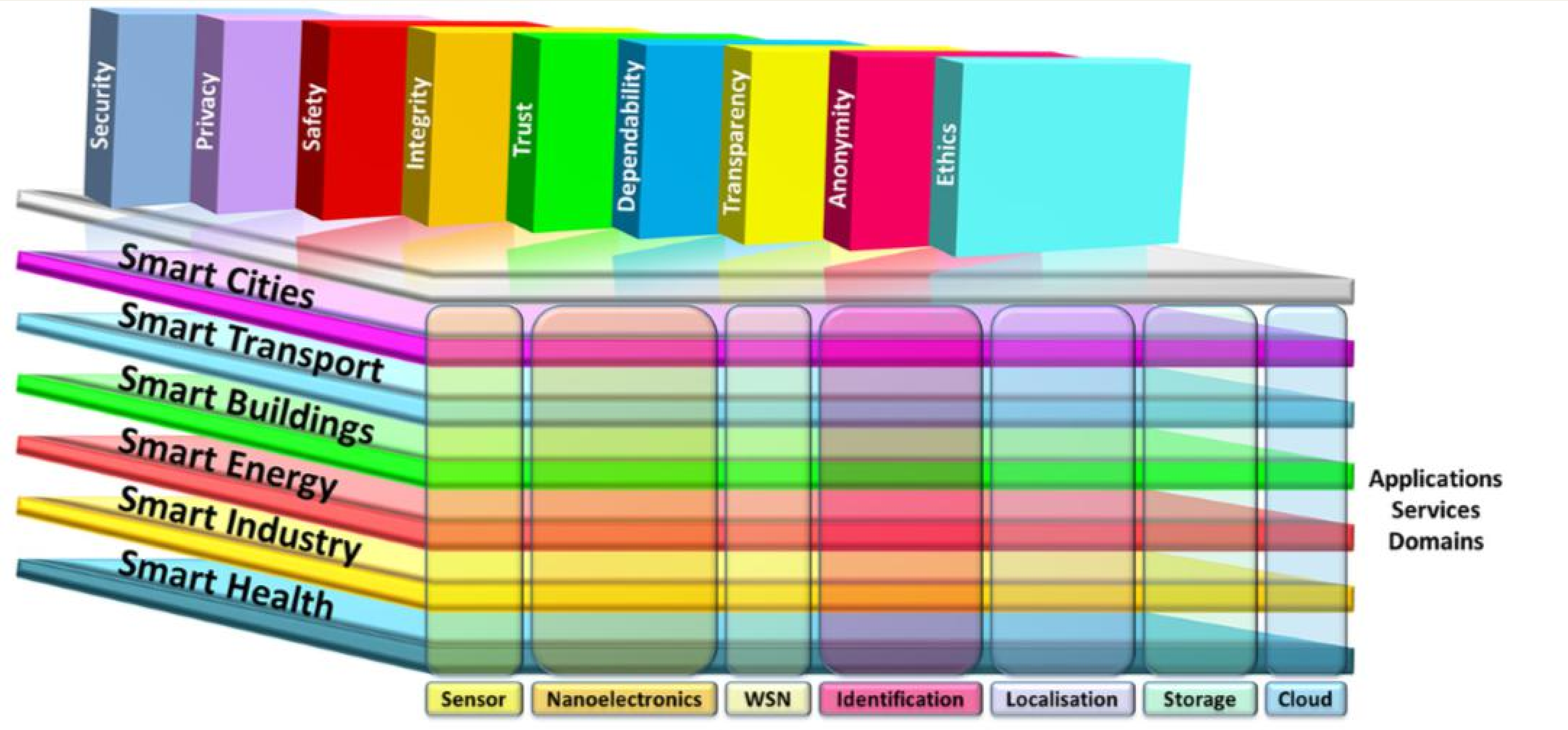

A dynamic global network infrastructure
with self configuring capabilities
based on standard and interoperable communication protocols
where physical and virtual "things"
Internet of Things
have identities, physical attributes, and virtual personalities
use intelligent interfaces,
and are seamlessly integrated
into the information network.

Introduction

- Scope of IoT is not just limited to just connecting things to the internet, but it allows these things to communicate and exchange data, process them as well as control them while executing applications.
- 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 use intelligent interfaces, and are seamlessly integrated into information network that communicate data with users and environments.

Introduction

- **Dynamic Global network & Self-Adapting** : Adapt the changes changing contexts
- **Self Configuring** : Eg. Fetching latest s/w updates without manual intervention.
- **Interoperable Communication Protocols** : Communicate through various protocols
- **Unique Identity** : Such as Unique IP Address or a URI
- **Integrated into Information Network** : This allows to communicate and exchange data with other devices to perform certain analysis.


Security
Privacy
Safety
Integrity
Trust
Dependability
Transparency
Anonymity
Ethics
Smart Cities
Smart Transport
Smart Buildings
Smart Energy
Smart Industry
Smart Health
Applications
Services
Domains
Sensor
Nanoelectronics
WSN
Identification
Localisation
Storage
Cloud

Introduction

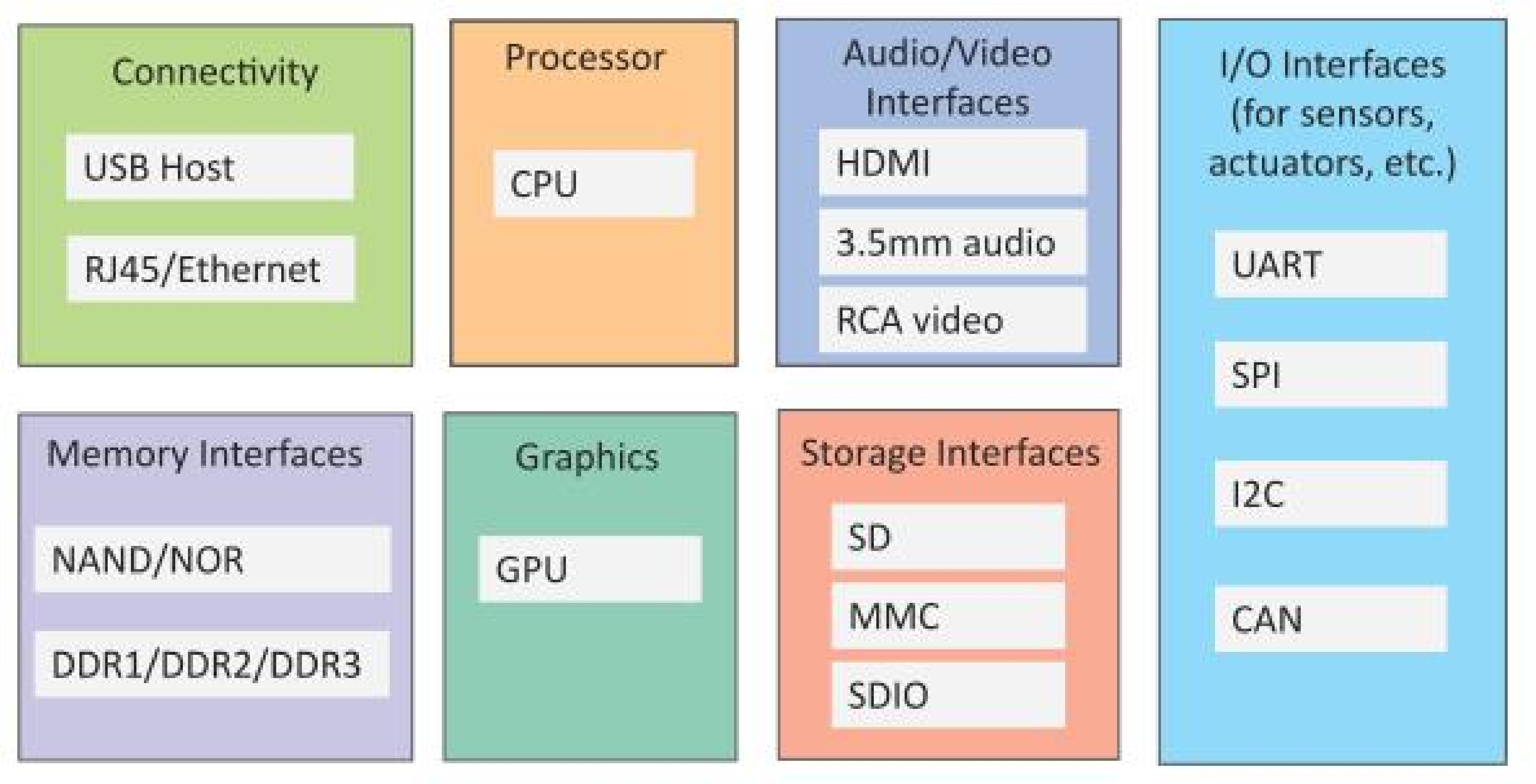
- Refers to IoT devices which have unique identities that can perform sensing, actuating and monitoring capabilities.
- IoT devices can exchange data with other connected devices or collect data from other devices and process the data either locally or send the data to centralized servers or cloud – based application back-ends for processing the data.

IoT Components

- There are three IoT components which enable seamless communication:
- a) Hardware - made up of sensors, actuators and embedded communication hardware
- b) Middleware - on demand storage and computing tools for data analytics
- c) Presentation - novel easy to understand visualization and interpretation tools which can be widely accessed on different platforms and which can be designed for different applications.

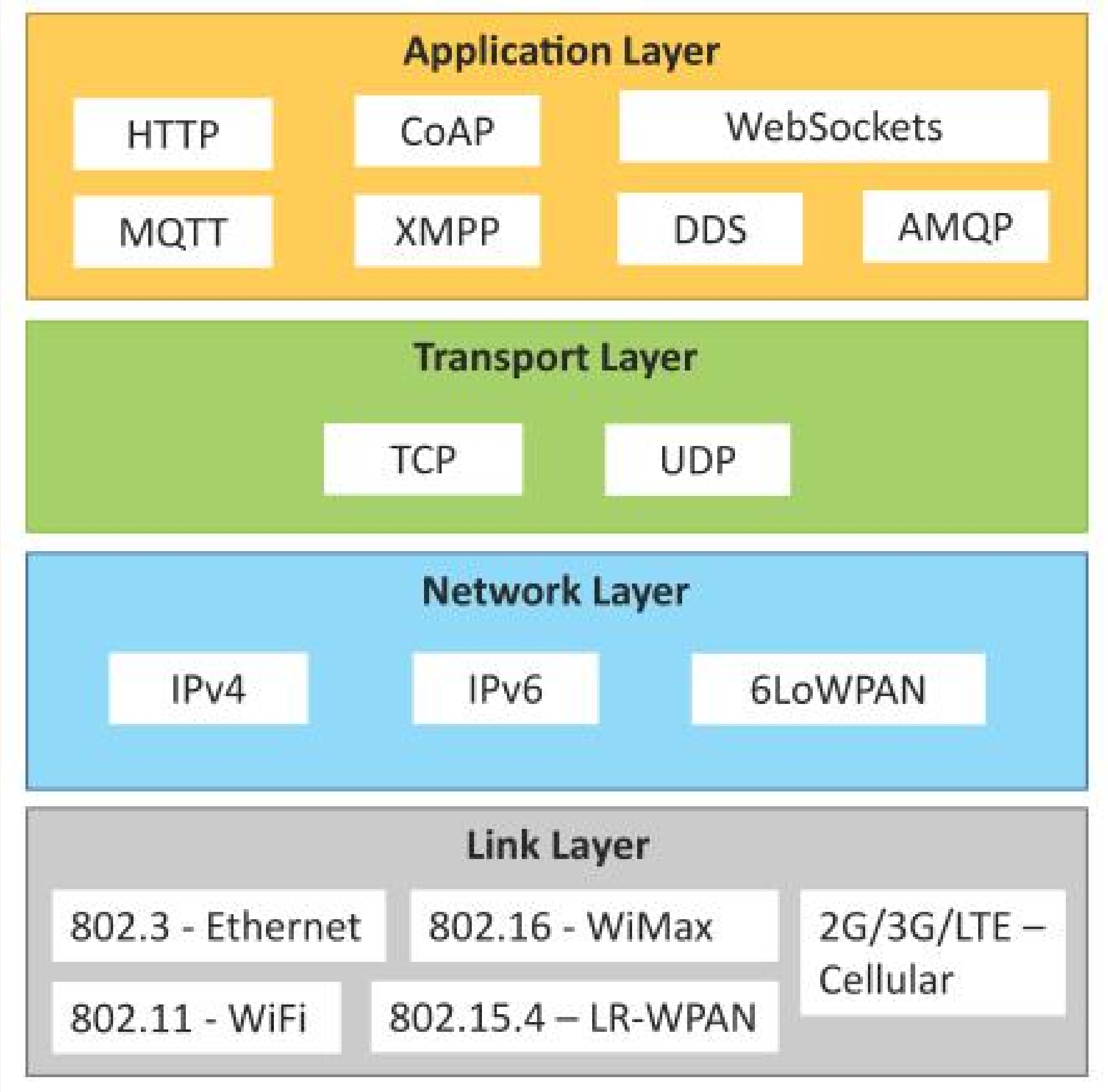
IoT connectivity

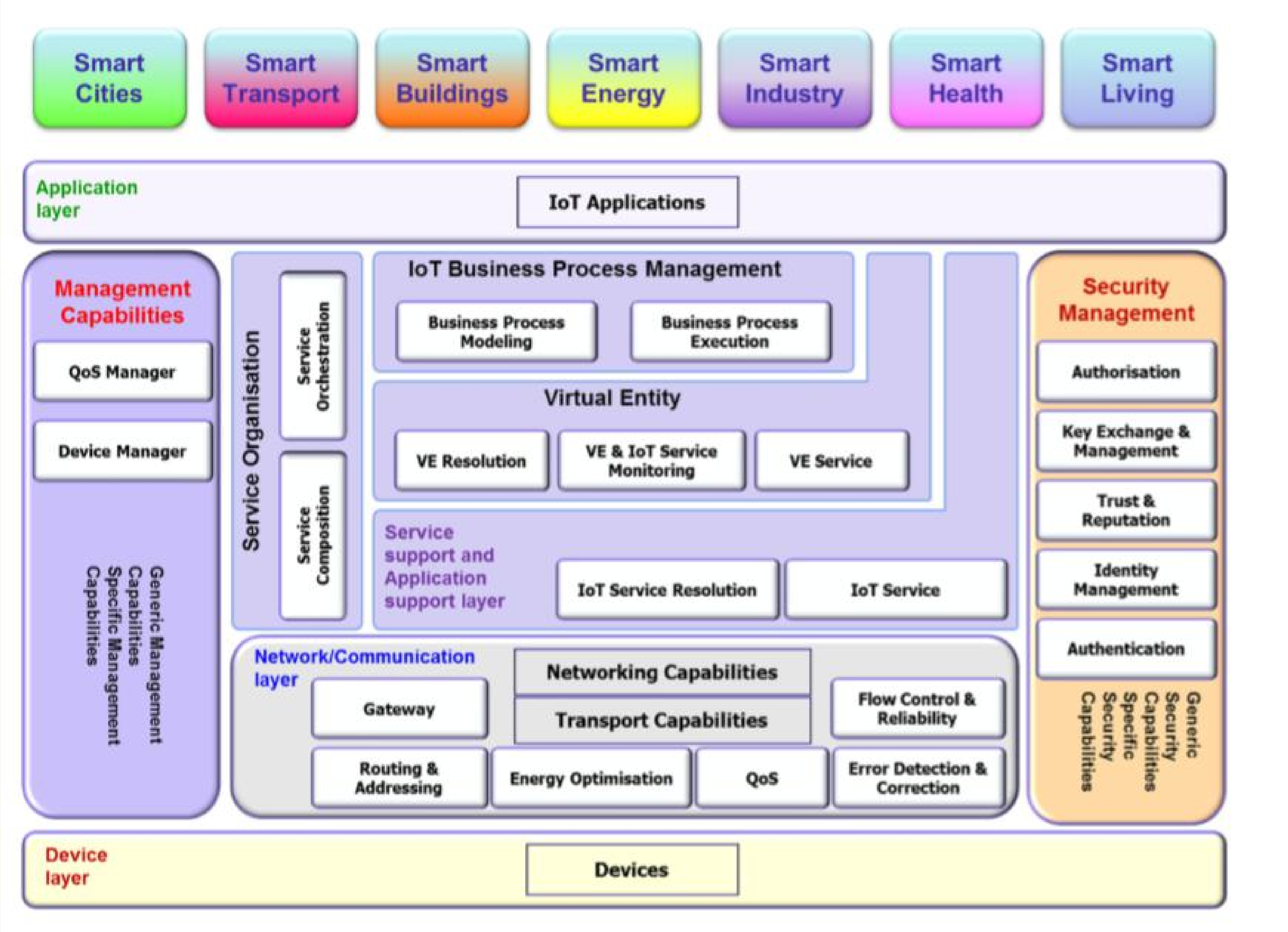
- An IoT device may consist of several interfaces for connections to other devices, both wired and wireless.
- I/O interfaces for sensors
- Interfaces for internet connectivity
- Memory and storage interfaces
- Audio/video interfaces


Connectivity
USB Host
RJ45/Ethernet
Processor
CPU
Audio/Video Interfaces
HDMI
3.5mm audio
RCA video
I/O Interfaces (for sensors, actuators, etc.)
UART
SPI
I2C
CAN
Memory Interfaces
NAND/NOR
DDR1/DDR2/DDR3
Graphics
GPU
Storage Interfaces
SD
MMC
SDIO

IoT Protocol

- Link Layer
  - *802.3 – Ethernet*
  - *802.11 – WiFi*
  - *802.16 – WiMax*
  - *802.15.4 – LR-WPAN*
  - *2G/3G/4G*
- Network/Internet Layer
  - *IPv4*
  - *IPv6*
  - *6LoWPAN*
- Transport Layer
  - *TCP*
  - *UDP*
- Application Layer
  - *HTTP*
  - *CoAP*
  - *WebSocket*
  - *MQTT*
  - *XMPP*
  - *DDS*
  - *AMQP*


Application Layer
HTTP
CoAP
WebSockets
MQTT
XMPP
DDS
AMQP
Transport Layer
TCP
UDP
Network Layer
IPv4
IPv6
6LoWPAN
Link Layer
802.3 - Ethernet
802.16 - WiMax
2G/3G/LTE – Cellular
802.11 - WiFi
802.15.4 – LR-WPAN



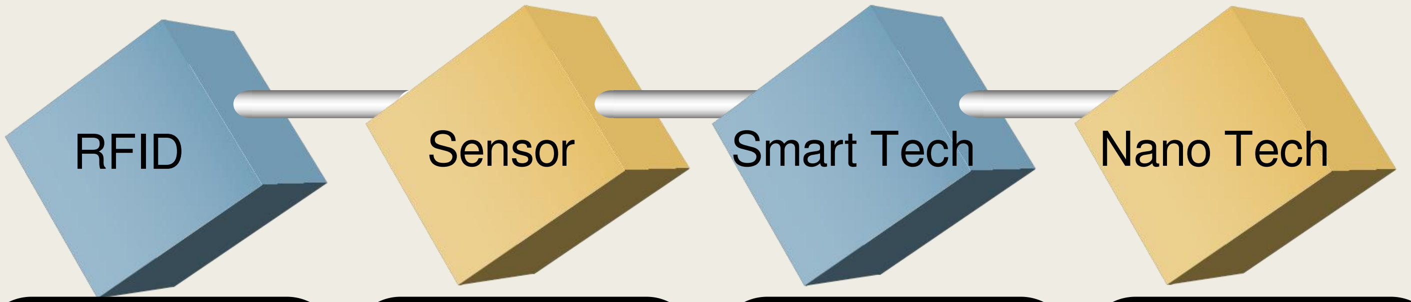
Smart Cities
Smart Transport
Smart Buildings
Smart Energy
Smart Industry
Smart Health
Smart Living
Application layer
IoT Applications
Management Capabilities
QoS Manager
Device Manager
Generic Management Capabilities
Specific Management Capabilities
Service Organisation
Service Orchestration
Service Composition
IoT Business Process Management
Business Process Modeling
Business Process Execution
Virtual Entity
VE Resolution
VE & IoT Service Monitoring
VE Service
Service support and Application support layer
IoT Service Resolution
IoT Service
Security Management
Authorisation
Key Exchange & Management
Trust & Reputation
Identity Management
Authentication
Generic Security Capabilities
Specific Security Capabilities
Network/Communication layer
Networking Capabilities
Transport Capabilities
Gateway
Flow Control & Reliability
Routing & Addressing
Energy Optimisation
QoS
Error Detection & Correction
Device layer
Devices

How IoT Works?

Internet of Things is not the result of a single novel technology; instead, several complementary technical developments provide capabilities that taken together help to bridge the gap between the virtual and physical world.

These capabilities include:

Communication and cooperation
Addressability
Identification
Sensing
Actuation
Embedded information processing
Localization
User interfaces



To identify and track the data of things

To collect and process the data to detect the changes in the physical status of things

To enhance the power of the network by devolving processing capabilities to different part of the network.

To make the smaller and smaller things have the ability to connect and interact.

Structure of IoT

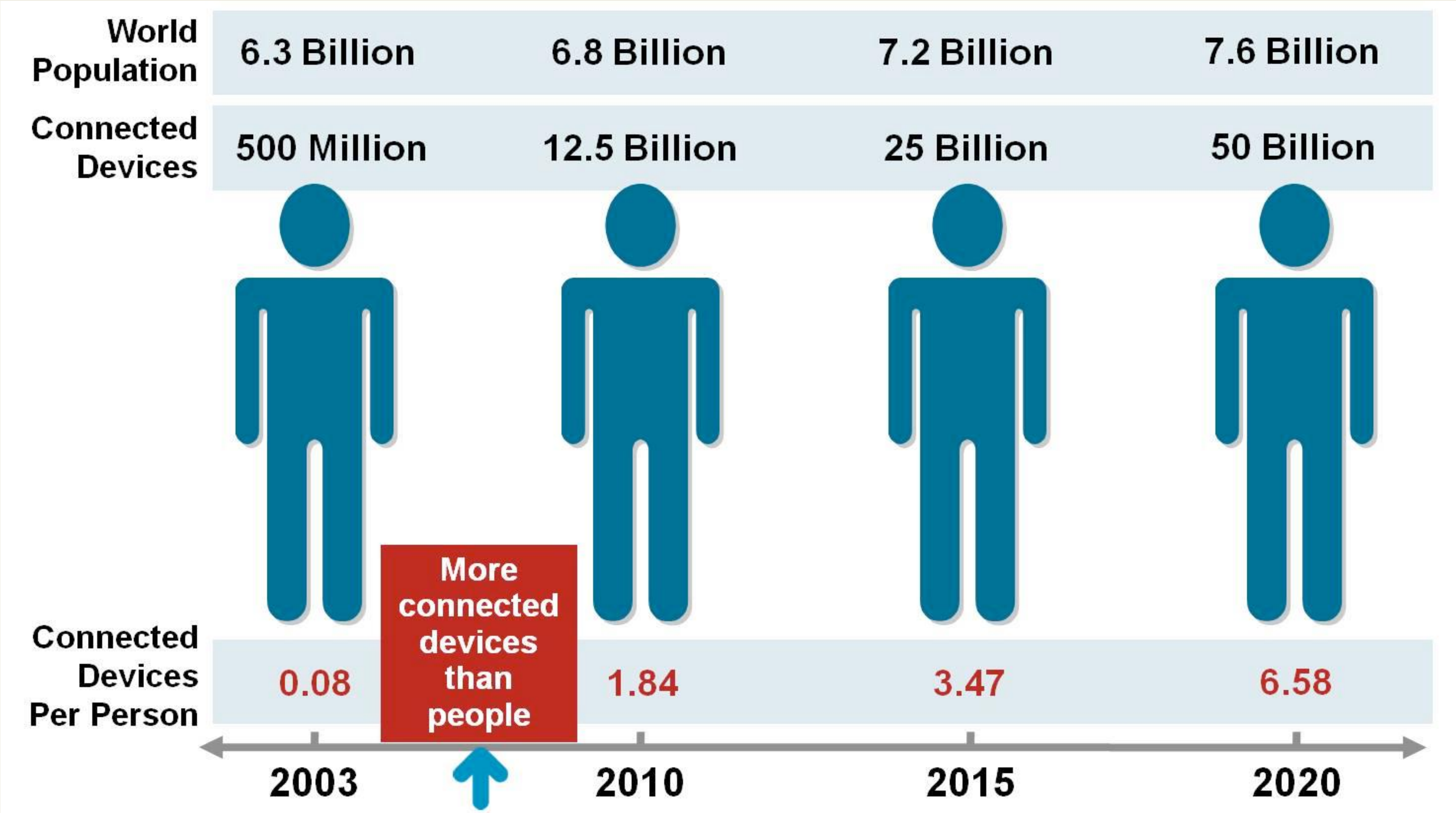
The IoT can be viewed as a gigantic network consisting of networks of devices and computers connected through a series of intermediate technologies where numerous technologies like RFIDs, wireless connections may act as enablers of this connectivity.

Tagging Things **:** Real-time item traceability and addressability by ***RFID***s.

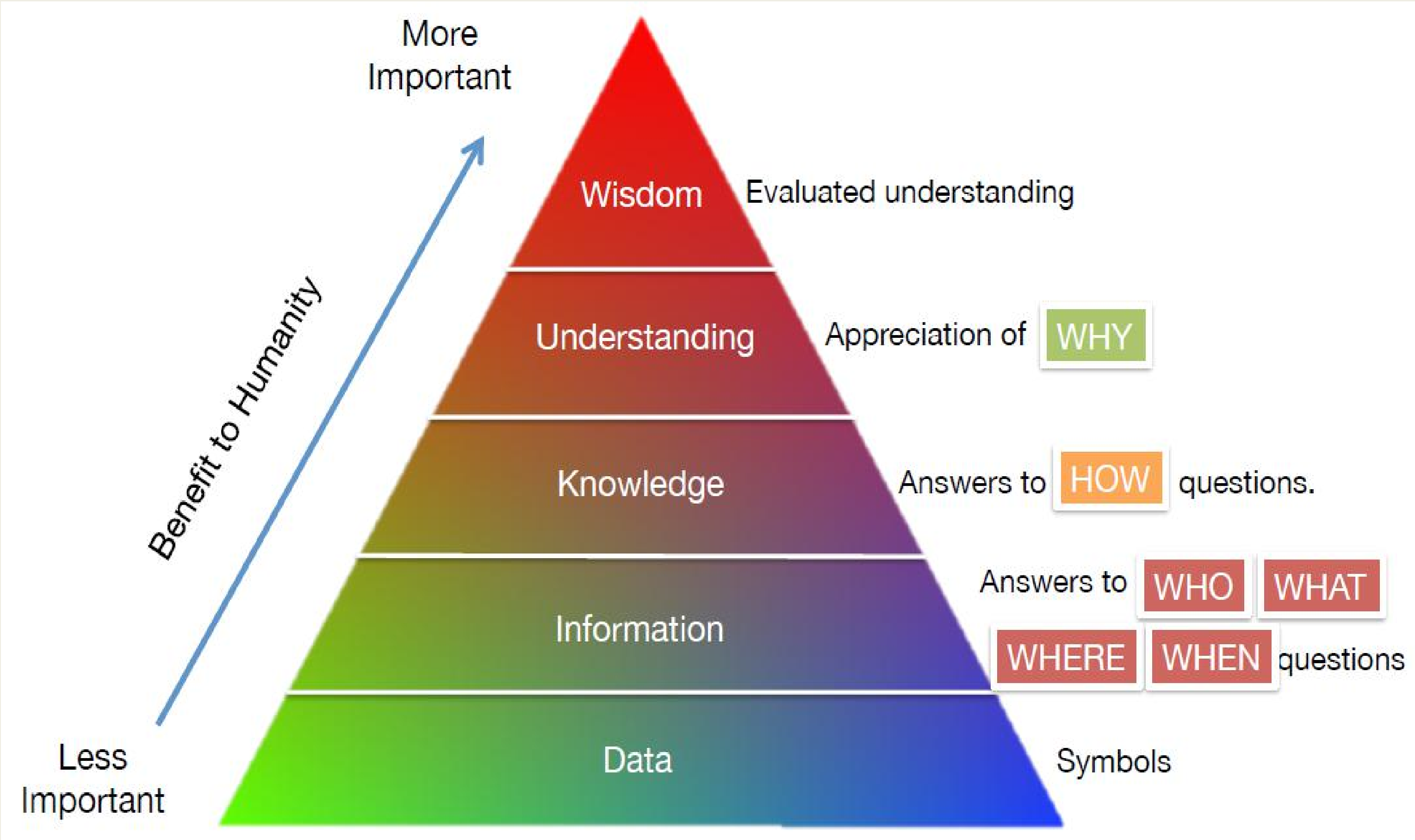
Feeling Things **:** ***Sensors*** act as primary devices to collect data from the environment.

Shrinking Things **:** *M*iniaturization and ***Nanotechnology*** has provoked the ability of smaller things to interact and connect within the "things" or "smart devices."

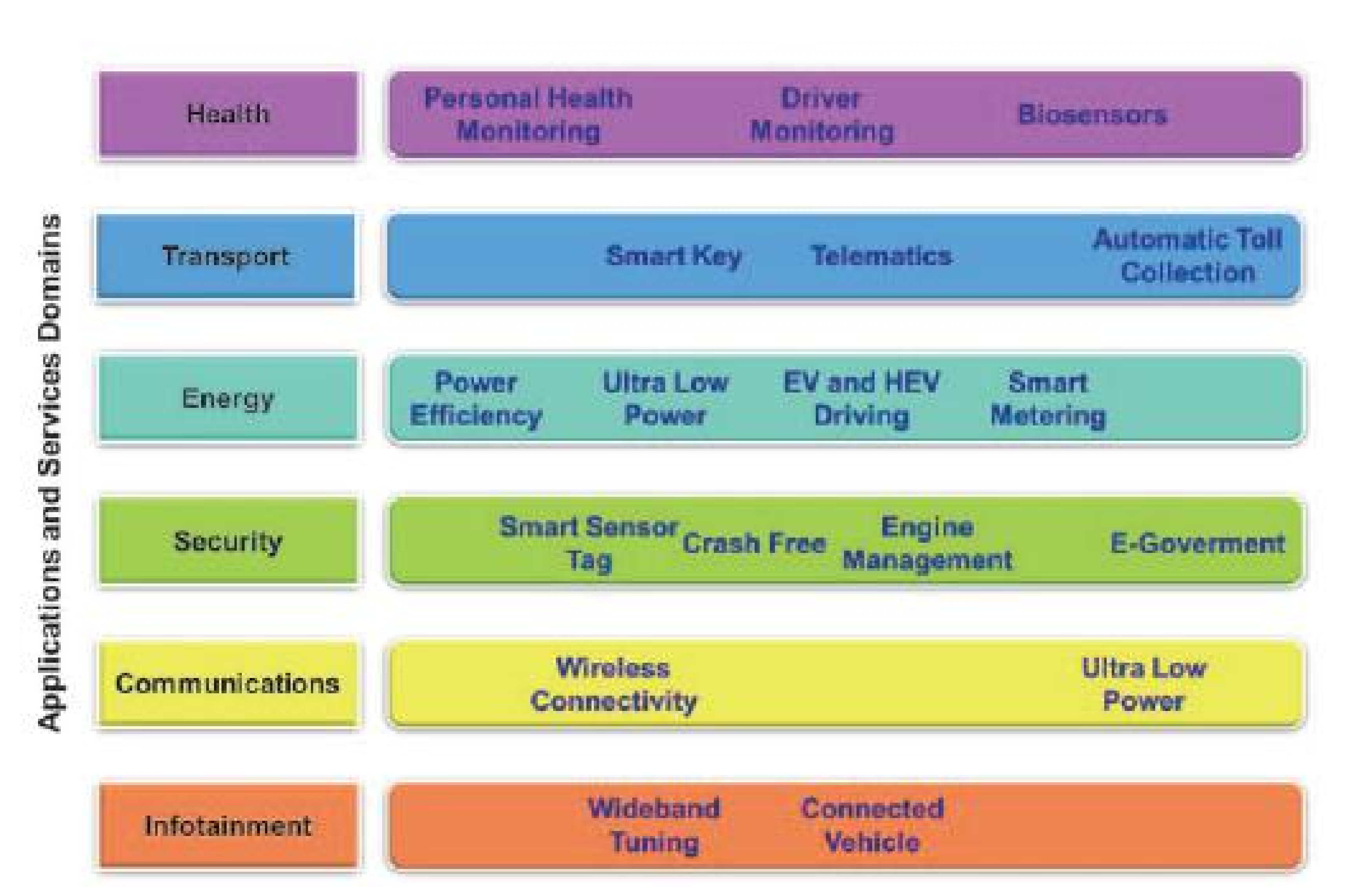
Thinking Things **:** ***Embedded intelligence*** in devices through sensors has formed the network connection to the Internet. It can make the "things" realizing the intelligent control.


World Population
6.3 Billion
6.8 Billion
7.2 Billion
7.6 Billion
Connected Devices
500 Million
12.5 Billion
25 Billion
50 Billion
Connected Devices Per Person
0.08
More connected devices than people
1.84
3.47
6.58
2003
2010
2015
2020

Knowledge Management



IoT Application Domain



Smart City

- **Smart Parking:** Monitoring of parking spaces availability in the city.
- **Structural health:** Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.
- **Noise Urban Maps:** Sound monitoring in bar areas and centric zones in real time.
- **Traffic Congestion:** Monitoring of vehicles and pedestrian levels to optimize driving and walking routes.
- **Smart Lightning:** Intelligent and weather adaptive lighting in street lights.
- **Waste Management:** Detection of rubbish levels in containers to optimize the trash collection routes.
- **Intelligent Transportation Systems:** Smart Roads and Intelligent Highways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.

Environment

- **Forest Fire Detection:** Monitoring of combustion gases and preemptive fire conditions to define alert zones.
- **Air Pollution:** Control of CO_2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.
- **Landslide and Avalanche Prevention:** Monitoring of soil moisture, vibrations and earth density to detect dangerous patterns in land conditions.
- **Earthquake Early Detection:** Distributed control in specific places of tremors.

Water

- **Water Quality:** Study of water suitability in rivers and the sea for fauna and eligibility for drinkable use.
- **Water Leakages:** Detection of liquid presence outside tanks and pressure variations along pipes.
- **River Floods:** Monitoring of water level variations in rivers, dams and reservoirs.

Energy Smart Grid, Smart Metering

- **Smart Grid:** Energy consumption monitoring and management.
- **Tank level:** Monitoring of water, oil and gas levels in storage tanks and cisterns.
- **Photovoltaic Installations:** Monitoring and optimization of performance in solar energy plants.
- **Water Flow:** Measurement of water pressure in water transportation systems.
- **Stock Calculation:** Measurement of emptiness level and weight of the goods.

Security & Emergencies

- **Perimeter Access Control:** Access control to restricted areas and detection of people in non-authorized areas.
- **Liquid Presence:** Liquid detection in data centres, warehouses and sensitive building grounds to prevent break downs and corrosion.
- **Radiation Levels:** Distributed measurement of radiation levels in nuclear power stations surroundings to generate leakage alerts.
- **Explosive and Hazardous Gases:** Detection of gas levels and leakages in industrial environments, surroundings of chemical factories and inside mines.

Retail

- **Supply Chain Control:** Monitoring of storage conditions along the supply chain and product tracking for traceability purposes.
- **NFC Payment:** Payment processing based in location or activity duration for public transport, gyms, theme parks, etc.
- **Intelligent ShoppingApplications:** Getting advice at the point of sale according to customer habits, preferences, presence of allergic components for them or expiring dates.
- **Smart Product Management:** Control of rotation of products in shelves and warehouses to automate restocking processes.

Logistics

- **Quality of Shipment Conditions:** Monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes.
- **Item Location:** Search of individual items in big surfaces like warehouses or harbors.
- **Storage Incompatibility Detection:** Warning emission on containers storing inflammable goods closed to others containing explosive material.
- **Fleet Tracking:** Control of routes followed for delicate goods like medical drugs, jewels or dangerous merchandises

Industrial Control

- **M2M Applications:** Machine auto-diagnosis and assets control.
- **Indoor Air Quality:** Monitoring of toxic gas and oxygen levels inside chemical plants to ensure workers and goods safety.
- **Temperature Monitoring:** Control of temperature inside industrial and medical fridges with sensitive merchandise.
- **Ozone Presence:** Monitoring of ozone levels during the drying meat process in food factories.
- **Indoor Location:** Asset indoor location by using active (ZigBee, UWB) and passive tags (RFID/NFC).
- **Vehicle Auto-diagnosis:** Information collection from CAN Bus to send real time alarms to emergencies or provide advice to drivers.

Agriculture

- **Wine Quality Enhancing:** Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.
- **Green Houses:** Control micro-climate conditions to maximize the production of fruits and vegetables and its quality.
- **Golf Courses:** Selective irrigation in dry zones to reduce the water resources required in the green.
- **Meteorological Station Network:** Study of weather conditions in fields to forecast ice formation, rain, drought, snow or wind changes.
- **Compost:** Control of humidity and temperature levels in alfalfa, hay, straw, etc. to prevent fungus and other microbial contaminants.

Animal Farming

- **Offspring Care:** Control of growing conditions of the offspring in animal farms to ensure its survival and health.
- **Animal Tracking:** Location and identification of animals grazing in open pastures or location in big stables.
- **Toxic Gas Levels:** Study of ventilation and air quality in farms and detection of harmful gases from excrements.

Domestic & Home Automation

- **Energy and Water Use:** Energy and water supply consumption monitoring to obtain advice on how to save cost and resources.
- **Remote Control Appliances:** Switching on and off remotely appliances to avoid accidents and save energy.
- **Intrusion Detection Systems:** Detection of window and door openings and violations to prevent intruders.
- **Art and Goods Preservation:** Monitoring of conditions inside museums and art warehouses.

eHealth

- **Fall Detection:** Assistance for elderly or disabled people living independent.
- **Medical Fridges:** Control of conditions inside freezers storing vaccines, medicines and organic elements.
- **Sportsmen Care:** Vital signs monitoring in high performance centers and fields.
- **Patients Surveillance:** Monitoring of conditions of patients inside hospitals and in old people's home.
- **Ultraviolet Radiation:** Measurement of UV sun rays to warn people not to be exposed in certain hours.

Properties of Autonomic IoT Systems

- **Self-adaptation**
- In the very dynamic context of the IoT, from the physical to the application layer, self-adaptation is an essential property that allows the communicating nodes, as well as services using them, to react in a timely manner to the continuously changing context in accordance with, for instance, business policies or performance objectives that are defined by humans.
- IoT systems should be able to reason autonomously and give self-adapting decisions. Cognitive radios at physical and link layers, self-organising network protocols, automatic service discovery and (re-)bindings at the application layer are important enablers for the self-adapting IoT.

- **Self-organization**
- In IoT systems — and especially in WS&ANs — it is very common to have nodes that join and leave the network spontaneously.
- The network should therefore be able to re-organize itself against this evolving topology. Self organizing, energy efficient routing protocols have a considerable importance in the IoT applications in order to provide seamless data exchange throughout the highly heterogeneous networks.
- Due to the large number of nodes, it is preferable to consider solutions without a central control point like for instance clustering approaches.
- When working on self-organization, it is also very crucial to consider the energy consumption of nodes and to come up with solutions that maximize the IoT system lifespan and the communication efficiency within that system.

- **Self-optimisation**
- Optimal usage of the constrained resources (such as memory, bandwidth, processor, and most importantly, power) of IoT devices is necessary for sustainable and long-living IoT deployments.
- Given some high-level optimization goals in terms of performance, energy consumption or quality of service, the system itself should perform necessary actions to attain its objectives.

- **Self-configuration**
- IoT systems are potentially made of thousands of nodes and devices such as sensors and actuators. Configuration of the system is therefore very complex and difficult to handle by hand.
- The IoT system should provide remote configuration facilities so that self-management applications automatically configure necessary parameters based on the needs of the applications and users.
- It consists of configuring for instance device and network parameters, installing/uninstalling/upgrading software, or tuning performance parameters.

- **Self-protection**
- Due to its wireless and ubiquitous nature, IoT will be vulnerable to numerous malicious attacks.
- As IoT is closely related to the physical world, the attacks will for instance aim at controlling the physical environments or obtaining private data.
- The IoT should autonomously tune itself to different levels of security and privacy, while not affecting the quality of service and quality of experience.

- **Self-healing**
- The objective of this property is to detect and diagnose problems as they occur and to immediately attempt to fix them in an autonomous way.
- IoT systems should monitor continuously the state of its different nodes and detect whenever they behave differently than expected.
- It can then perform actions to fix the problems encountered. Encounters could include re-configuration parameters or installing a software update.

- **Self-description**
- Things and resources (sensors and actuators) should be able to describe their characteristics and capabilities in an expressive manner in order to allow other communicating objects to interact with them.
- Adequate device and service description formats and languages should be defined, possibly at the semantic level.
- The existing languages should be re-adapted in order to find a trade-off between the expressiveness, the conformity and the size of the descriptions.
- Self-description is a fundamental property for implementing plug and play resources and devices.

- **Self-discovery**
- Together with the self-description, the self-discovery feature plays an essential role for successful IoT deployments. IoT devices/services should be dynamically discovered and used by the others in a seamless and transparent way.
- Only powerful and expressive device and service discovery protocols (together with description protocols) would allow an IoT system to be fully dynamic (topology-wise).

- **Self-matchmaking**
- To fully unlock the IoT potential, virtual objects will have to:
  - Be reusable outside the context for which they were originally deployed and
  - Be reliable in the service they provide.
- On the one hand, IoT services will be able to exploit enriched availability of underlying objects. They will also have to cope with their unreliable nature and be able to find suitable “equivalent object” alternatives in case of failure, unreachability etc.
- Such envisaged dynamic service-enhancement environments will require self-matchmaking features (between services and objects and vice versa) that will prevent users of IoT future services from having to (re-)configure objects themselves.

- **Self-energy-supplying**
- And finally, self-energy-supplying is a tremendously important (and very IoT specific) feature to realize and deploy sustainable IoT solutions.
- Energy harvesting techniques (solar, thermal, vibration, etc.) should be preferred as a main power supply, rather than batteries that need to be replaced regularly, and that have a negative effect on the environment.