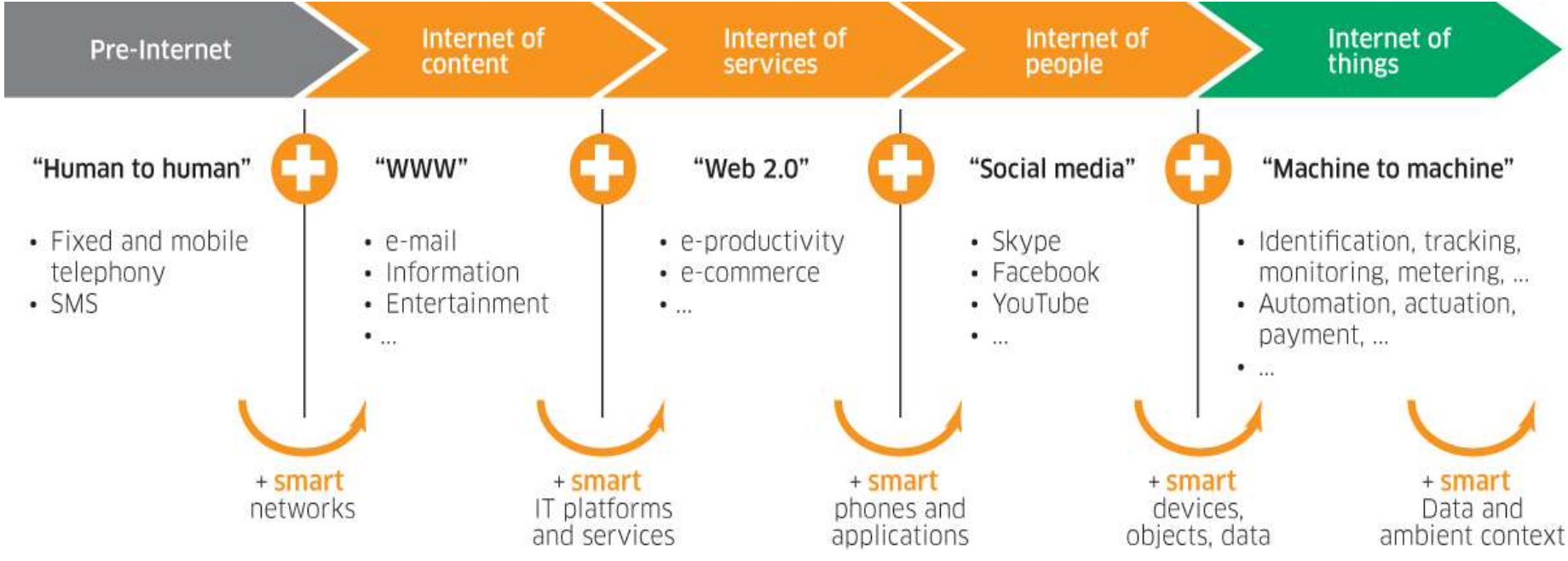
INTERNET OF THINGS (IOT)

CONTENTS

- What is the Internet of Things (IoT)?
- History of IoT?
- Trends in the Adoption of IoT
- Modern IoT Applications
- Building Blocks of IoT
- IoT Verticals
- Challenges

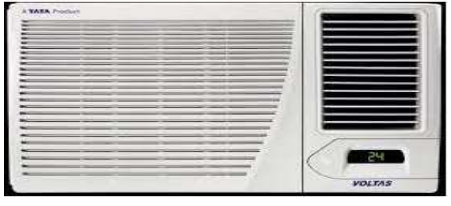
WHAT IS THE INTERNET OF THINGS?

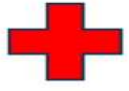


WHAT IS INTERNET OF THING

Start with a device (a thing) – anything besides a traditional computer

Add computational intelligence to improve the functionality of device





Add a network connection to further enhance its function

WHAT IS THE INTERNET OF THINGS?....CONTD

- Smart phone-(example)
  - Sense the location,
  - knows how it is being held,
  - knows how much light is there in the room,
  - how close it is to your face,
  - knows what you are saying to it,
  - even has an eye so that it can see its surroundings and
  - Above all it has an ability to communicate over a wireless network.

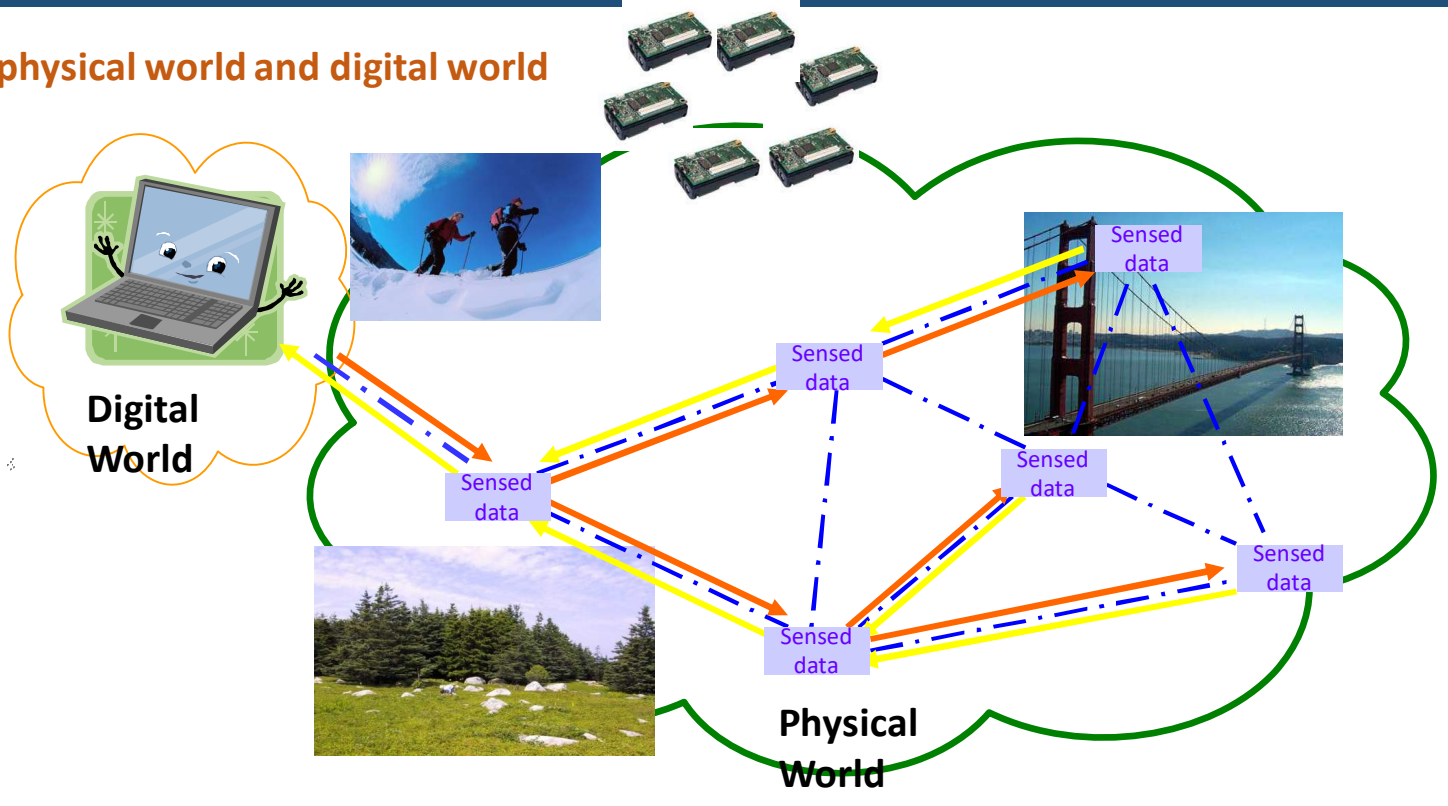
WHAT IS THE INTERNET OF THINGS?....CONTD

- *"The term Internet of Things generally refers to the interconnectivity of physical devices and digital world using a plethora of sensing and actuating modules capable of sending/receiving data via cloud either directly or through a gateway using a communication protocol."*

- *In IoT, "Things" refers to all real world entities which have computational intelligence and are capable of connecting to internet while being aware of their environment and are globally reachable at any time.*

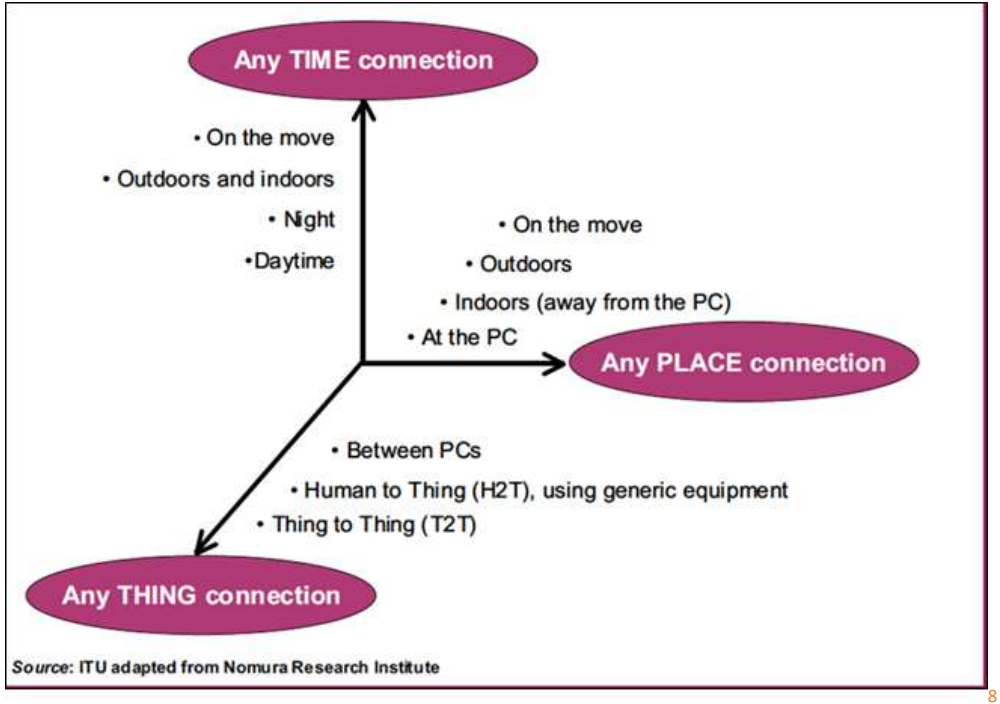
WHAT IS THE INTERNET OF THINGS?....CONTD

To Connect physical world and digital world



WHAT IS THE INTERNET OF THINGS?....CONTD

From any time, any place, connectivity for anyone, we will now have connectivity for anything



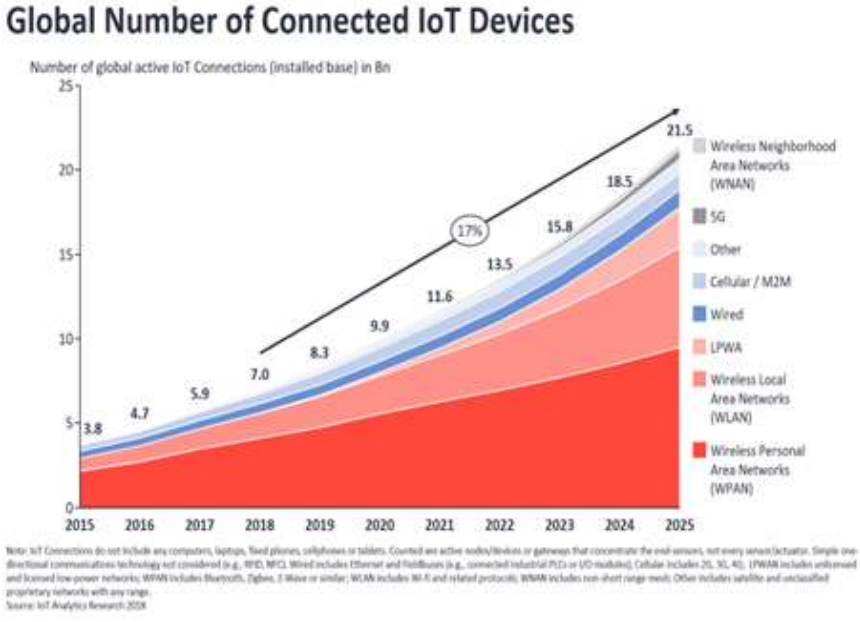
HISTORY OF IOT

- "Internet of Things" was first introduced by Kevin Ashton in 1999
  - at Procter & Gamble (P&G) while optimizing an inventory system of supply chain based on RFID technology
- During that period, conceiving IoT was not possible as
  - wireless communication was not matured, and cellular technology did not fully embrace the IP based configuration
- IoT devices mainly depend on IP networking to transmit and receive data as compared to RFID technology
  - As RFID did not require IP addresses or direct internet access, so it turned out to be a more convenient and less costly option for connecting things

Kevin Ashton is the co-founder of the Auto-ID Center at MIT and currently President & CEO at Onnit, Inc and a Columnist @ RFID Journal

HISTORY OF IOT ….CONTD

- In June 2000, LG introduced first refrigerator comprising a LAN port for IP networking
- In 2008, collaboration of industry partners appreciated the concept of deploying IoT in manufacturing industries
- In 2010, Chinese government declared to include IoT in their upcoming strategic plan
- Gartner, invented the famous "hype cycle for emerging technologies" and included IoT in their list in 2011
- In 2010, Ericsson predicted that 50 billion devices would be connected by 2020, a prediction echoed by Cisco in 2011
- According to survey by IoT Analytics Research, global number of connected IoT devices will ramp up to 21.5 billion by 2025



HISTORY OF IOT ….CONTD

In 2012, LeWeb which is one of the biggest Europe's technology conference was also organized on Internet of things

International Data Corporation (IDC) published a report stating that IoT is projected to increase from $656 billion in 2014 to $ 1.7 trillion in 2020

In 2013 IDC revised their predictions and stated that IoT has the potential to generate returns up to $8.9 trillion by 2020

In 2014, the technology magazine, Wired, reported that Google declared to purchase Nest, a company for manufacturing smoke detectors and thermostats, for $ 3.2 billion

HISTORY OF IOT ….CONTD

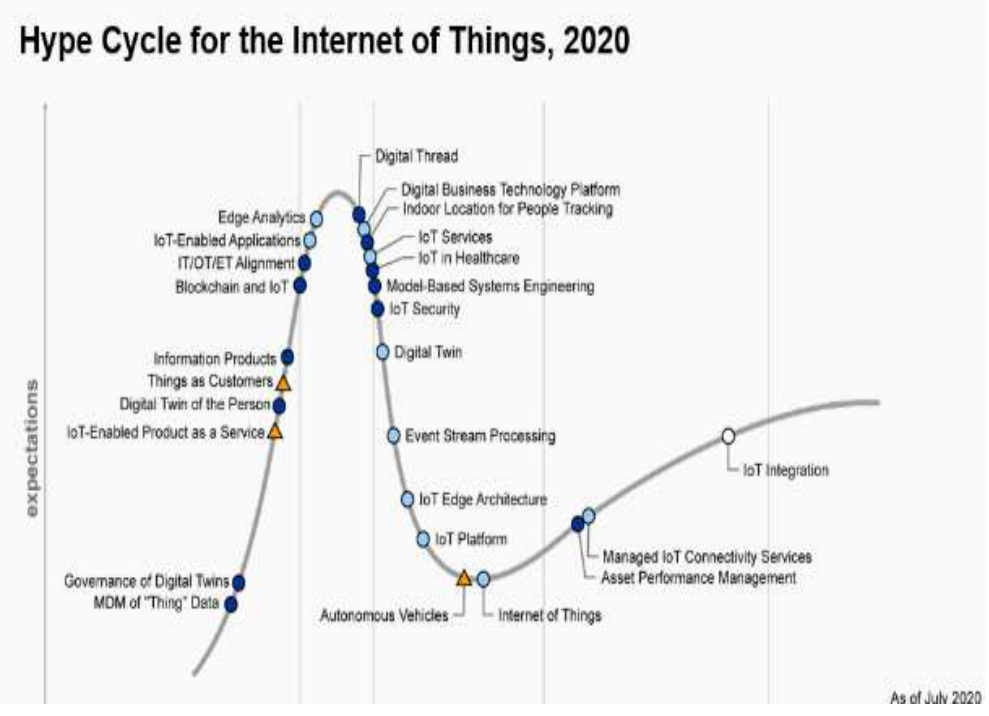
In 2015, IoT became the theme for a conference organized by Salesforce in San Francisco

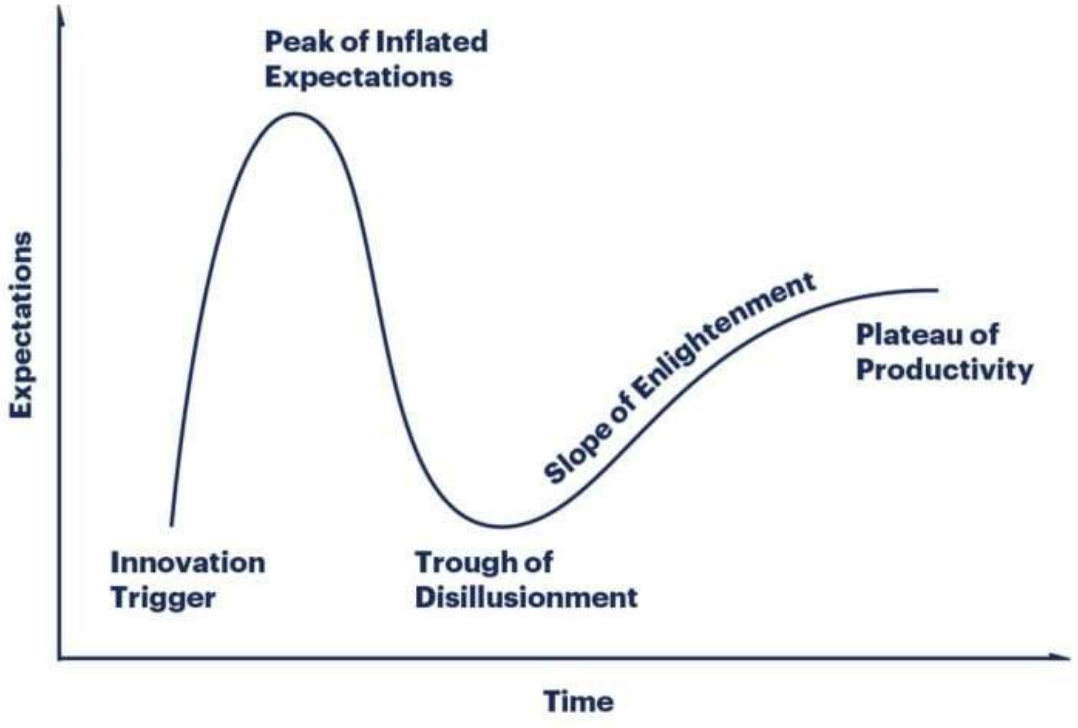
In 2016 and 2017, Gartner presented three trends in their hype cycle for emerging technologies, where IoT platforms were placed under the trend of "Digital Platforms"

In 2018 IoT Analytics Research forecasted the global market share of IoT to be $1,567 billion by 2025

Microsoft Azure and Amazon AWS grew 93% and 49% respectively (within the last couple of years)

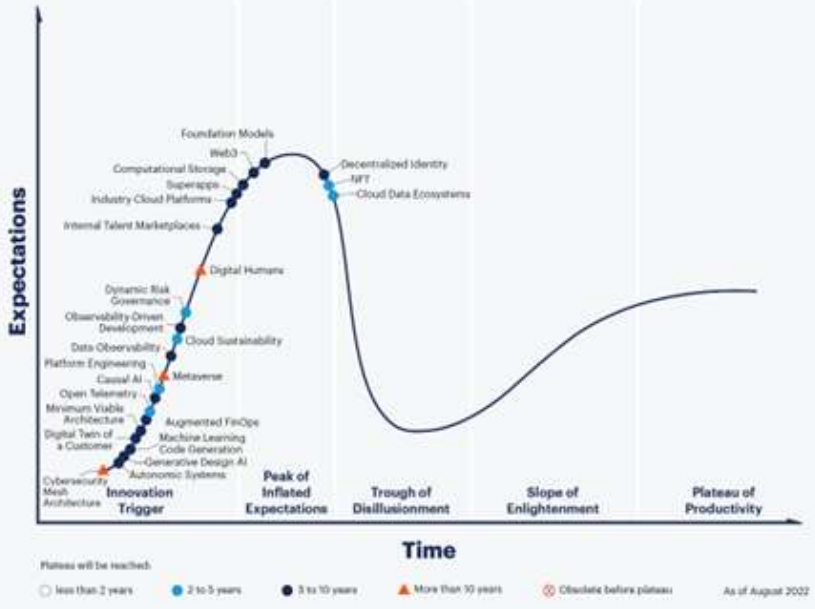
In 2021, Gartner predicted that the number of IoT device will approach to 30.9 billion by 2025 leading to billions of dollar of economic growth and utilities in all facets of life





Understanding Hype Cycle

Hype Cycle for Emerging Tech, 2022



gartner.com

Gartner

Hype Cycle for Emerging Technologies, 2023

gartner.com

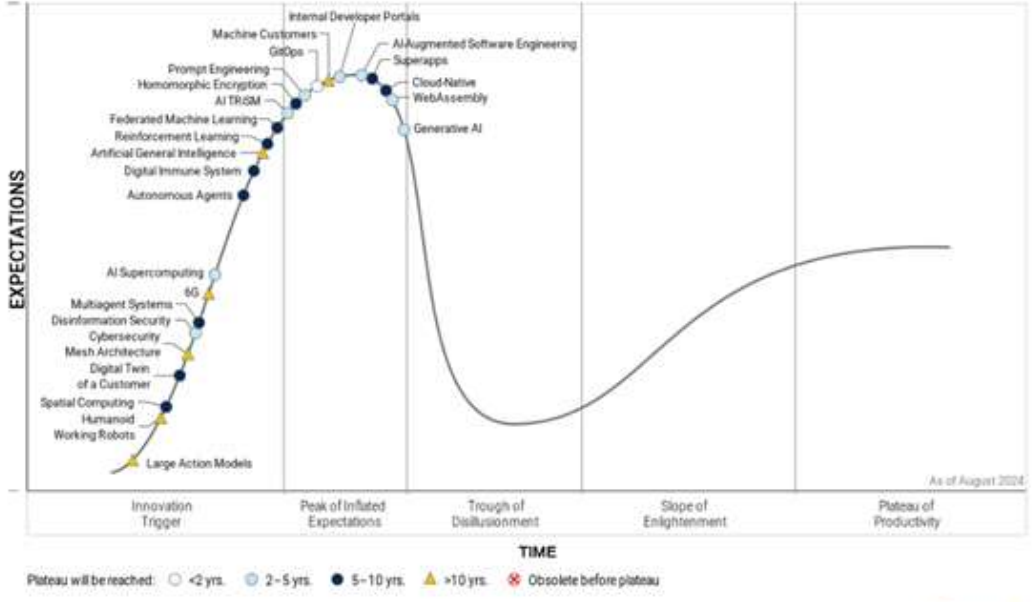
Gartner

Hype Cycle for Emerging Technologies, 2023

gartner.com

Gartner

Hype Cycle for Emerging Technologies, 2024



Gartner

TRENDS IN THE ADOPTION OF IOT

Cost

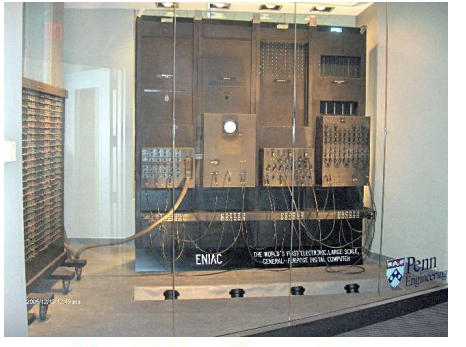
- Cost of hardware has decreased
  - ENIAC 1945: $500,000
  - Generic Laptop Computer today : $500

Hardware Size

- Smaller size and less weight needed to incorporate computation into devices
  - ENIAC 1945, 1800 sq ft, 27 tons
  - Laptop computer today: 0.05 sq ft, under 3 pounds

Computational Ability

- Many IoT devices need significant computation and speed
  - Speech to text, audio processing, network communication
  - ENIAC, 1945: instruction per second ->5000
  - Laptop today: instruction per second ->18 billion



ENIAC (Electronic Numerical Integrator and Computer)

Laptop Computer

TRENDS IN THE ADOPTION OF IOT

Internet Access

- **Internet is available almost everywhere** in the developed world
  - Some parts of the world still lack access, but this is being addressed
- **Wireless access** (cell phone, Wi-Fi) enables networking with cheap infrastructure
  - Less need to install physical cables
- **Data costs are fairly low**
  - This point is arguable, but many can afford it
- **Data bandwidth is high**
  - Can stream multiple movies in real time

IOT IS POWERFUL AND PERVASIVE

IoT is pervasive

Cloud is big **powerful compute servers** that are accessed through the internet

- IoT devices are **windows or interface** to the cloud
  - Example
    - Siri – you ask questions from siri, it searches big data servers to fetch the right answer
      - Window to massive computational resource
- IoT devices **act as an access point** to the large databases and large computational service in the cloud
- Example
  - Streaming Netflix videos

IOT IS POWERFUL AND PERVASIVE

IoT is pervasive

Networking is pervasive, **IoT is pervasive**, which means it is **everywhere**

It is **embedded** in devices and you're not necessarily aware of that, but they're are all over the place

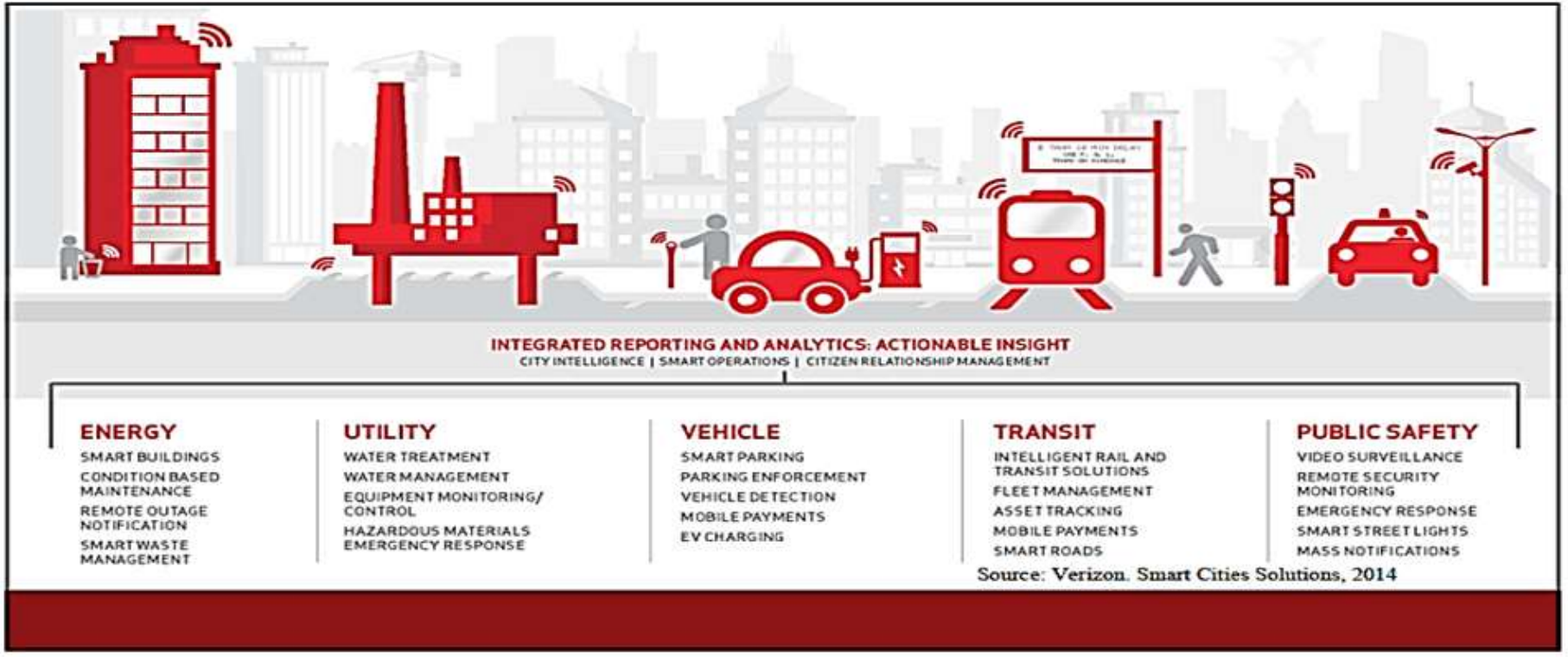
At home	TV/game machine can listen to your commands	Home automation system can control your appliances
At work	Motion sensors detect your presence	RFID readers detect entry/exit
On your person	Cell phones	Insulin pumps Health trackers, pacemaker

MODERN IOT APPLICATIONS

MODERN IOT APPLICATIONS

- Smart Cities
- Healthcare
- Agriculture
- Manufacturing and Logistics

SMART CITIES



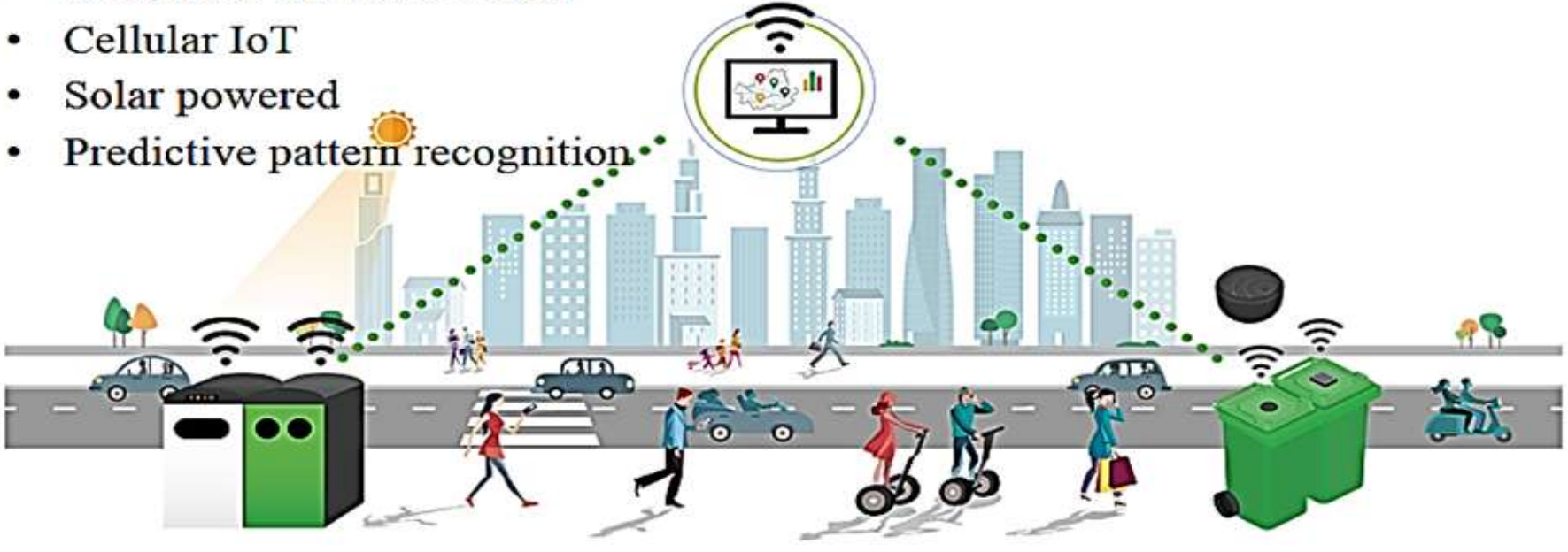
SMART WASTE MANAGEMENT

http://ecubelabs.com/

http://bigbelly.com/

SMART WASTE MANAGEMENT

- Ultrasonic fill-level sensor
- Cellular IoT
- Solar powered
- Predictive pattern recognition



http://ecubelabs.com/integrated-waste-management/

SMART WASTE MANAGEMENT

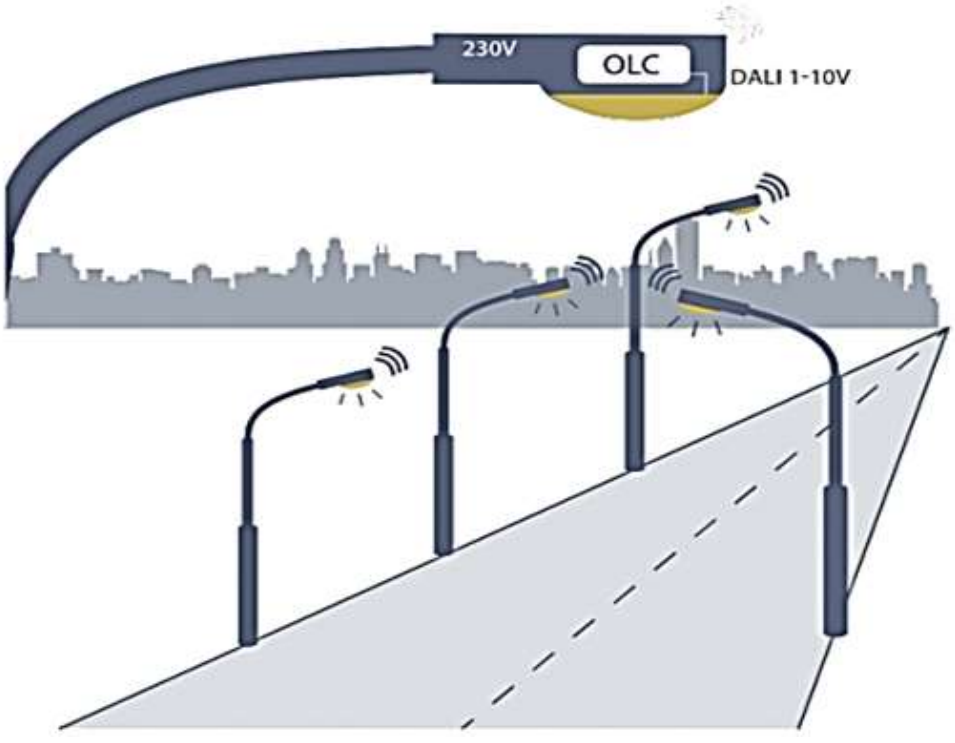
http://ecubelabs.com/

- Go from collecting 840 containers 4 times a day to collecting 80 containers a day
- Increase waste collection by 90%

SMART STREET LIGHTS

http://tvlight.com/

SMART STREET LIGHTS



- Light sensor, motion sensor
- Cellular IoT
- Real-time mesh network

Street Lighting System (SaaS)

https://tvlight.com/

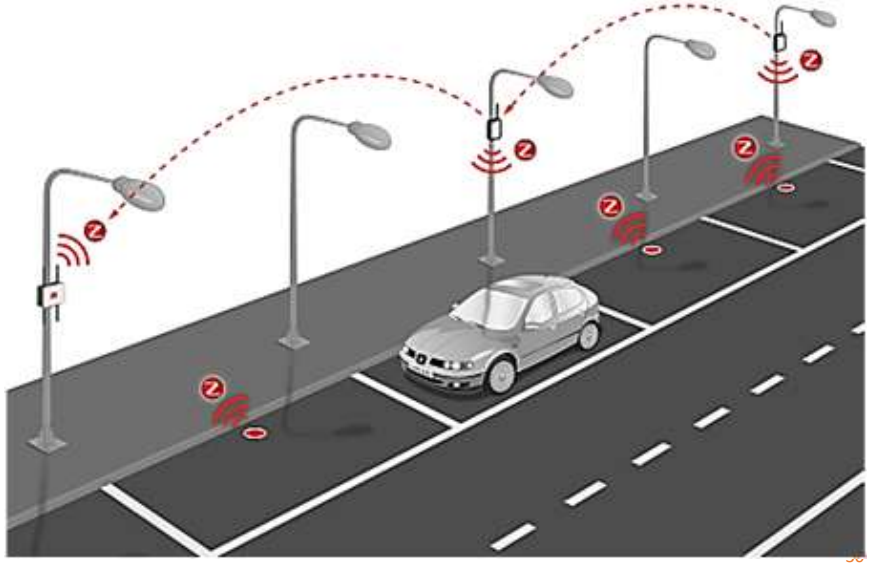
SMART STREET PARKING

- In the past year, **how many times did you give up when looking for a parking space in cities? How many times did you argue with someone about a parking spot? On average, how long did you take to look for a parking spot?**
- More than 30% of a city's traffic is caused by drivers searching for a parking spot
- In New York City, 29% of commuters said that they spent 20 minutes on average looking for a parking spot and 10% spent more than 40 minutes

SMART STREET PARKING

SMART STREET PARKING

- Infrared- and magnetic-based vehicle detection sensor mounted on the road surface
- Zigbee, LoRaWAN wireless connections
- Mesh networks are implemented with in streetlights.
- Apps to direct drivers to empty spaces
- Dynamic parking prices



http://www.libelium.com/smart_parking/

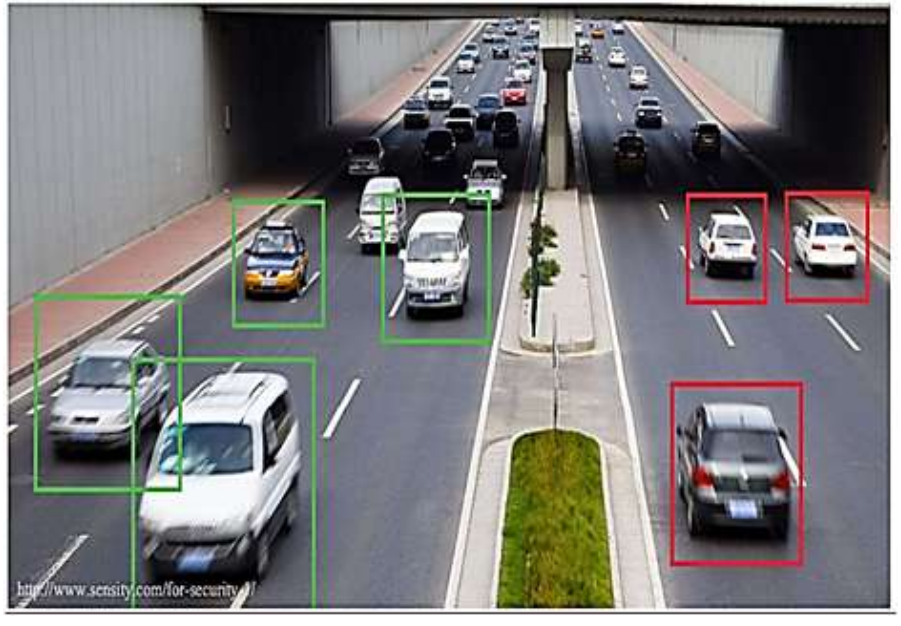
SMART STREET PARKING IN POLAND

http://www.worldsensing.com/success-story/gliwice-smart-parking-solution/#


Kraft Creation

SECURITY WITHOUT SURVEILLANCE

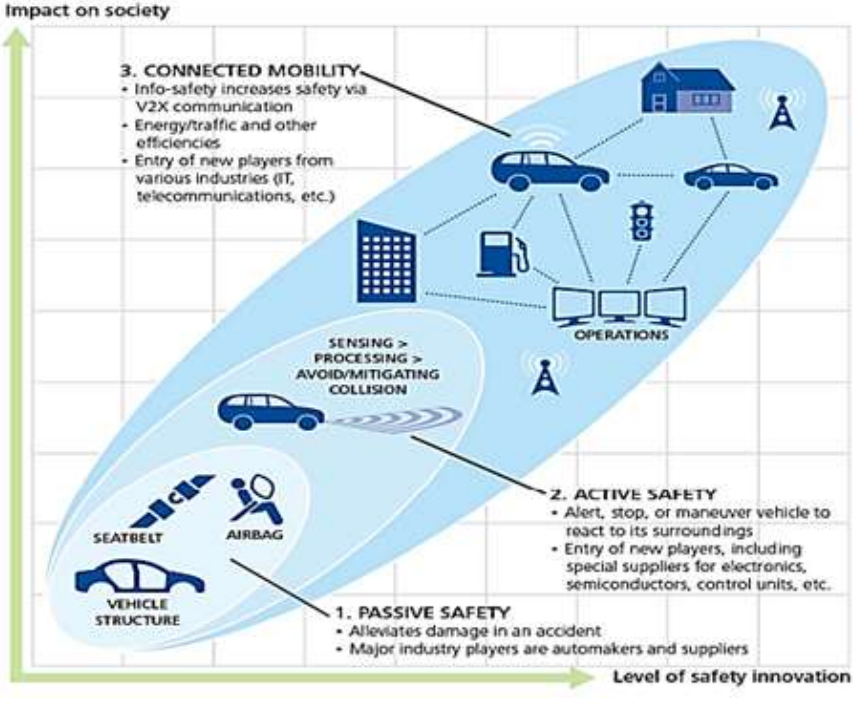
- Real-time analytics rather than human-monitored surveillance
- Edge-based analytics rather than cloud-based analytics
  - All videos are stored locally.
  - This also reduces the requirement on data rate.
- Resultant analytics sent to central cloud database for issuing alerts



CONNECTED VEHICLES

http://government-2020.dupress.com/trend/connected-vehicles/

CONNECTED VEHICLES – STAGES OF SAFETY INNOVATION



- Passive vehicle safety uses sensors to take the vehicle's immediate surroundings into consideration.
- Recent efforts enable the sharing of information gathered by the sensors between vehicles, and between vehicles and their surroundings to increase safety further.
  - V2X (vehicle-to-X, where X represents other vehicles, infrastructure, roads, and so on)
- A step towards autonomous driving

https://dupress.deloitte.com/dup-us-en/deloitte-review/issue-12/the-rise-of-safety-innovations-in-intelligent-mobility.html

- V2X encompasses several communication types, each focused on a specific aspect of the vehicle ecosystem:
  - **V2V (Vehicle-to-Vehicle):** Vehicles communicate directly with each other to exchange information such as speed, position, and direction. This can help prevent accidents by alerting drivers (or autonomous systems) to potential hazards.
  - **V2I (Vehicle-to-Infrastructure):** Vehicles communicate with roadside infrastructure, such as traffic lights, road signs, or toll booths. This allows for improved traffic management, optimized routing, and real-time updates on road conditions.
  - **V2P (Vehicle-to-Pedestrian):** Vehicles communicate with pedestrians' devices (e.g., smartphones) to enhance pedestrian safety. Pedestrians can be alerted to oncoming vehicles, or vehicles can adjust their behavior based on pedestrian activity.
  - **V2N (Vehicle-to-Network):** Vehicles connect to cellular networks to access cloud services, download maps, receive updates, or communicate with other vehicles via a central server.
  - **V2G (Vehicle-to-Grid):** Electric vehicles (EVs) communicate with the power grid to optimize energy consumption and assist with grid balancing by feeding energy back into the grid.

- 🚙 **Car is V2X enabled**
- 🔸 **V2V (other car)** → *Collision warnings / sudden braking*.
- 🔹 **V2I (traffic light / infrastructure)** → *Signal timing / emergency vehicle priority*.
- 🔻 **V2P (pedestrian with smartphone)** → *Crosswalk alert / safety message*.
- ☁️ **V2N (cloud/network)** → *Navigation, congestion info, OTA updates*.

MODERN IOT APPLICATIONS

HEALTHCARE

HEALTHCARE APPLICATIONS OUTLINE

- Baby Monitoring
- Elderly Monitoring
- Mood Enhancement
- Disease treatment and progression monitoring
- Enhance Adherence

BABY MONITORING – ACTIVITY TRACKING

- Body position
- Breathing
- Oxygen level
- Skin temp
- Wake/sleep pattern
- ECG

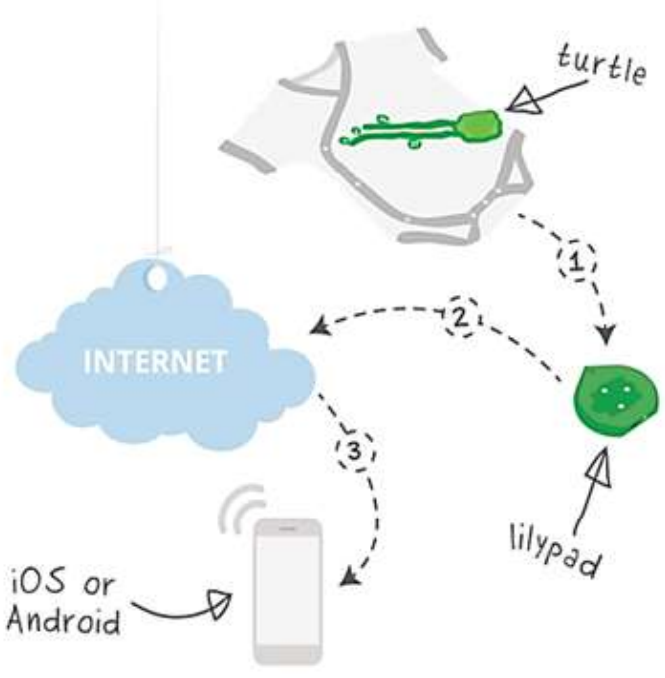
Can be integrated with other IoT devices such as thermostat and camera to “close the loop”. For example, if the baby is too warm, the thermostat will automatically adjust

BABY MONITORING – ACTIVITY TRACKING

http://mimobaby.com/

http://www.owletcare.com/smart-sock-2/

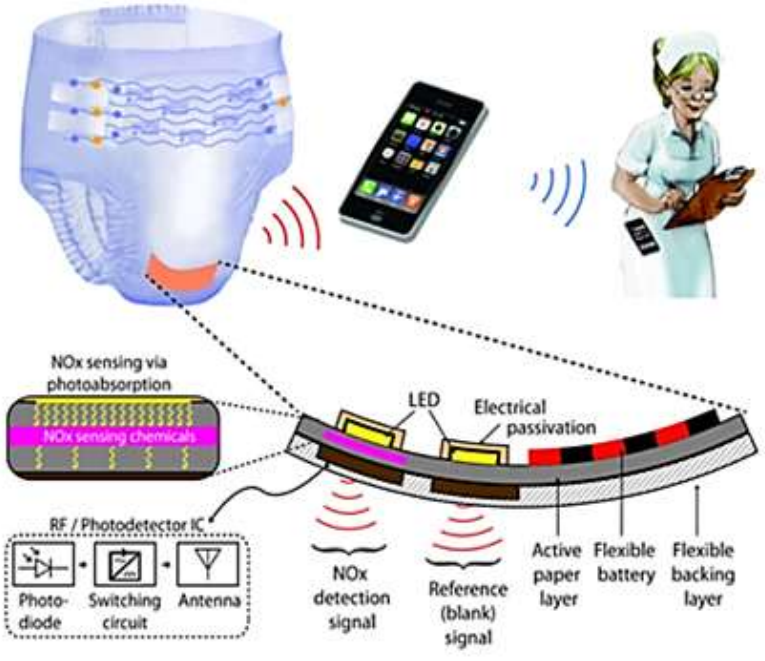
BABY MONITORING – ACTIVITY TRACKING



1. The turtle sends information about the baby's breathing, body position, sleep activity, and skin temp to the Lilypad via Bluetooth LE.
2. The Lilypad streams data and live audio to the cloud via WiFi.
3. Parents receive real-time insight about their baby on their smartphone.

http://mimobaby.com/

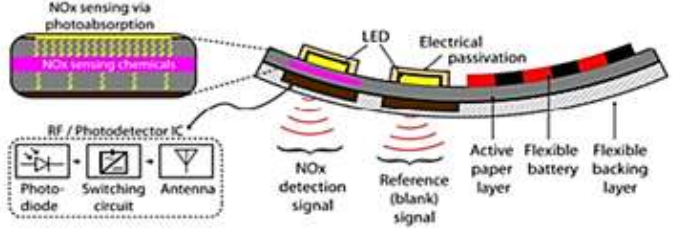
BABY MONITORING – URINARY TRACT INFECTION MONITORING



- Urinary tract infection (UTI) is the second most common infection in the US accounting for 7M hospital visits and 100,000 hospitalization per year.
- It is easy to cure if detected and treated in early stage.
- Urine culture test is accurate but time consuming.
- Dip stick test is fast but high false alarm rate.

https://sites.google.com/site/jagpurdue/projects/catalyst

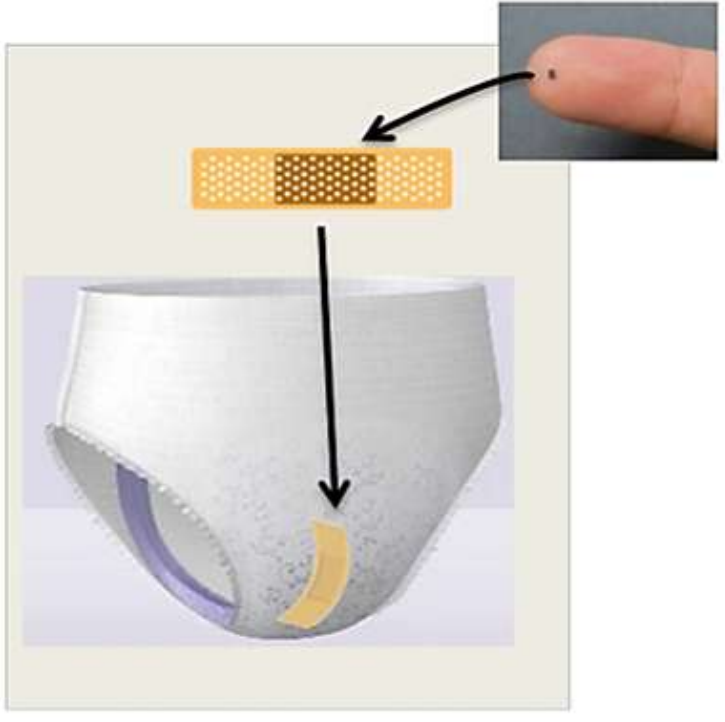
BABY MONITORING – URINARY TRACT INFECTION MONITORING



- Urine-activated paper battery (self-powered)
- Paper-based colorimetric nitrite sensor consisting of an LED, a urine-absorbing strip, a reagent strip, an active photodiode, and a reference photodiode.
- Sensor signal is converted into a PWM waveform.
- BLE module transmits the PWM signal to the caregiver.

https://sites.google.com/site/jagpurdue/projects/catalyst

ELDERLY MONITORING – INCONTINENCE MANAGEMENT



- In most nursing homes, between 40% and 60% of residents suffer from urinary incontinence
- Smart diaper allows caregivers to remotely detect if an incontinence event has occurred
- Improved quality and dignity of care by not having to disturb the elderly

http://rfmicron.com/health-care/

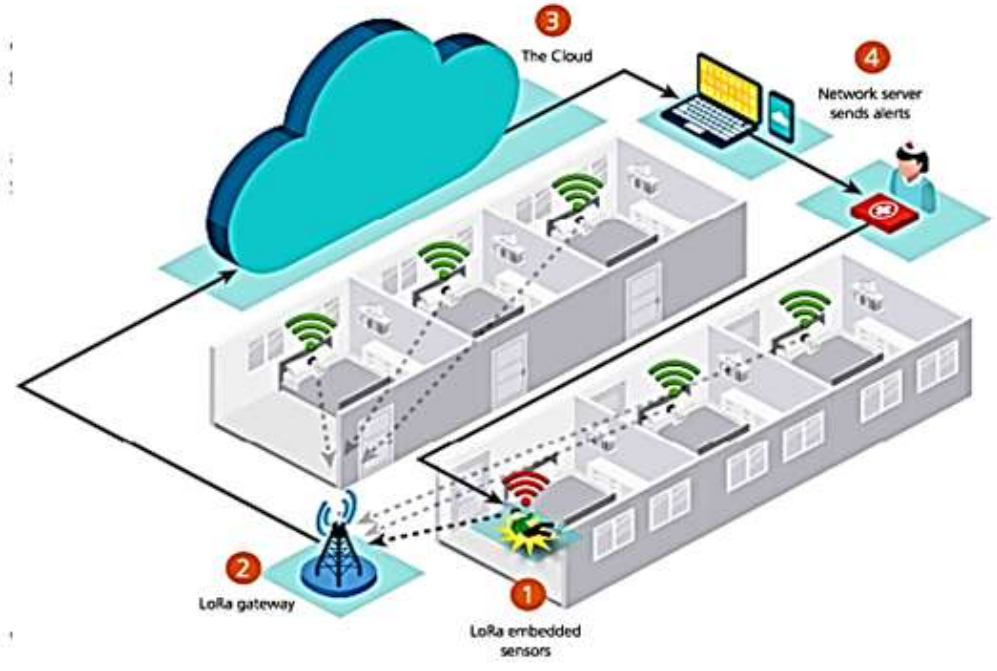
http://www.medisens.com/news/press-release-1

ELDERLY MONITORING – FALL DETECTION

- One-fourth of Americans aged 65+ falls each year
- Every 11 seconds, an older adult is treated in the emergency room for a fall; every 19 minutes, an older adult dies from a fall
- Falls are the leading cause of fatal injury and the most common cause of nonfatal trauma-related hospital admissions among older adults
- Falls result in more than 2.8 million injuries treated in emergency departments annually, including over 800,000 hospitalizations and more than 27,000 deaths
- In 2013, the total cost of fall injuries was $34 billion
- The financial toll for older adult falls is expected to increase as the population ages and may reach $67.7 billion by 2020. (The medicare budget is $584 billion in 2016.)

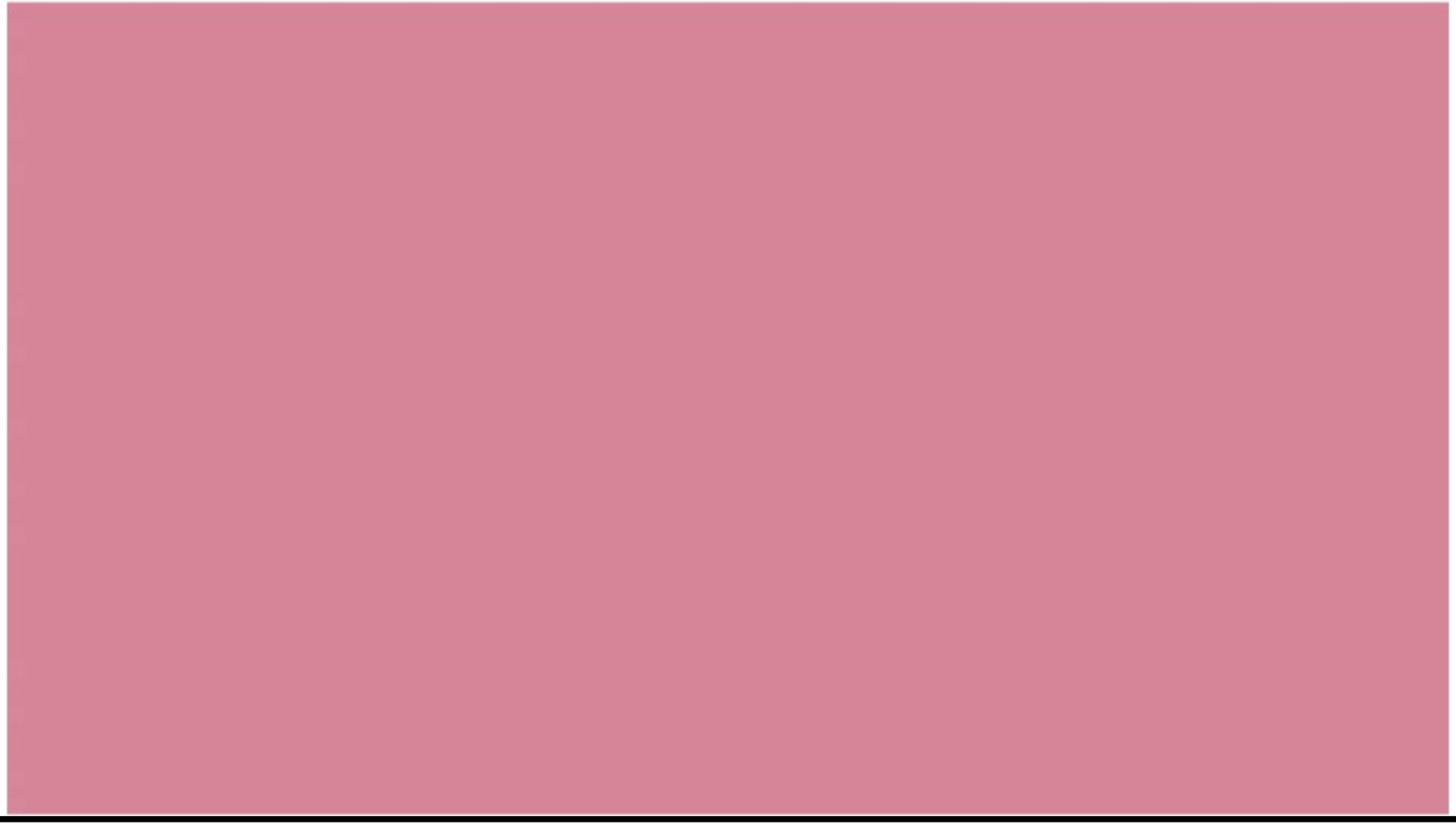
https://www.ncoa.org/news/resources-for-reporters/get-the-facts/falls-prevention-facts/

ELDERLY MONITORING – FALL DETECTION



1. Fall/movement data collected by sensors embedded with LoRa Technology
2. Data from all sensors is sent to a LoRa gateway as person moves
3. Gateway sends information to the Cloud where the data is analyzed by an application to determine what is normal and what is a fall
4. Application server sends reports and alerts on the fall and location of the person to a computer or mobile device

http://www.semtech.com/wireless-rf/internet-of-things/downloads/Semtech_Health_FallDetection_AppBrief-FINAL.pdf



MOOD ENHANCEMENT

- Relaxing music could be cued to ease stress
- Window shades could be programmed to let in the maximum amount of natural light
- Use IoT to encourage healthy behaviours
- Automatically dim the lights in the home at a recommended bedtime.
- Automatically turn off the TV to encourage exercise

MOOD ENHANCING – SLEEP MONITORING

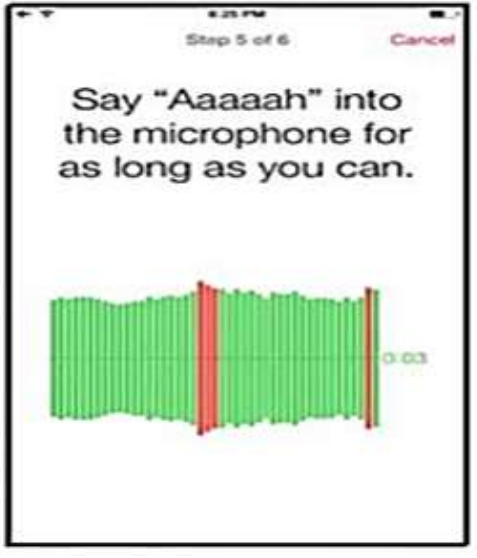
https://www.beddit.com/

DISEASE TREATMENT AND PROGRESSION MONITORING – PARKINSON'S

Patients with Parkinson's disease must be continually assessed in order to keep up with their symptoms. This becomes potentially problematic as symptoms fluctuate on a constant basis, and a monthly check in with their doctor may not be representative of their experience.

https://www.slideshare.net/rcnossen/healthcare-iot-and-analytics-to-treat-parkinsons

DISEASE TREATMENT AND PROGRESSION MONITORING – PARKINSON'S



Instead of patients actively performing certain tasks, could we monitor disease progression passively in the background?

http://parkinsonmpower.org/

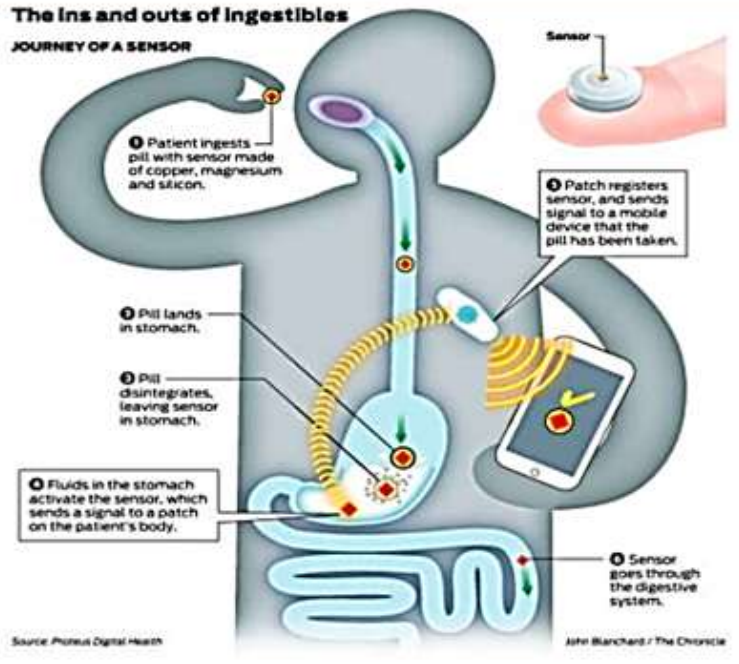
DISEASE TREATMENT AND PROGRESSION MONITORING – PARKINSON'S

- Using sensors, mobile devices, and advanced machine learning capabilities, a patient could keep track of a host of valuable data from mobility to sleep patterns all in real time
- Practitioners get a more complete look into the progression of their patient's disease states
- Intel and Michael J. Fox Foundation for Parkinson's Research, and Pfizer and IBM are individually collaborating on this idea
  - The collaboration involves planned clinical trial

ENHANCE ADHERENCE

- 84% of U.S. healthcare spending is on patients with chronic conditions.
- More than 50% of prescribed medications are not taken as directed.
- Reasons why people are not able to take their medication as directed:
- They may forget.
- They may not be convinced of the medication's effectiveness or be unsure that it is working.
- They may fear the side effects or have difficulty taking the medication.
- The rising cost of prescription medications is a barrier for many

ENHANCE ADHERENCE – INGESTIBLE SENSORS



https://www.youtube.com/watch?v=7jPrJdpGB74

https://www.youtube.com/watch?v=5LQ-edGTQdk

http://www.sfchronicle.com/business/article/Did-you-take-your-pill-Ingestible-sensors-can-11206980.php

ENHANCE ADHERENCE - CHALLENGES

- A lack of Electronic Health Record (EHR) integration and concerns about data security may prevent healthcare from fully adopting the IoT technology.
- The need to adopt an integration-first mindset instead of keep building interesting/fun gadgets. Sometimes, a dump gadget can be as useful if it could integrate seamlessly with the EHR.

MODERN IOT APPLICATIONS

AGRICULTURE

AGRICULTURE APPLICATIONS – OUTLINE

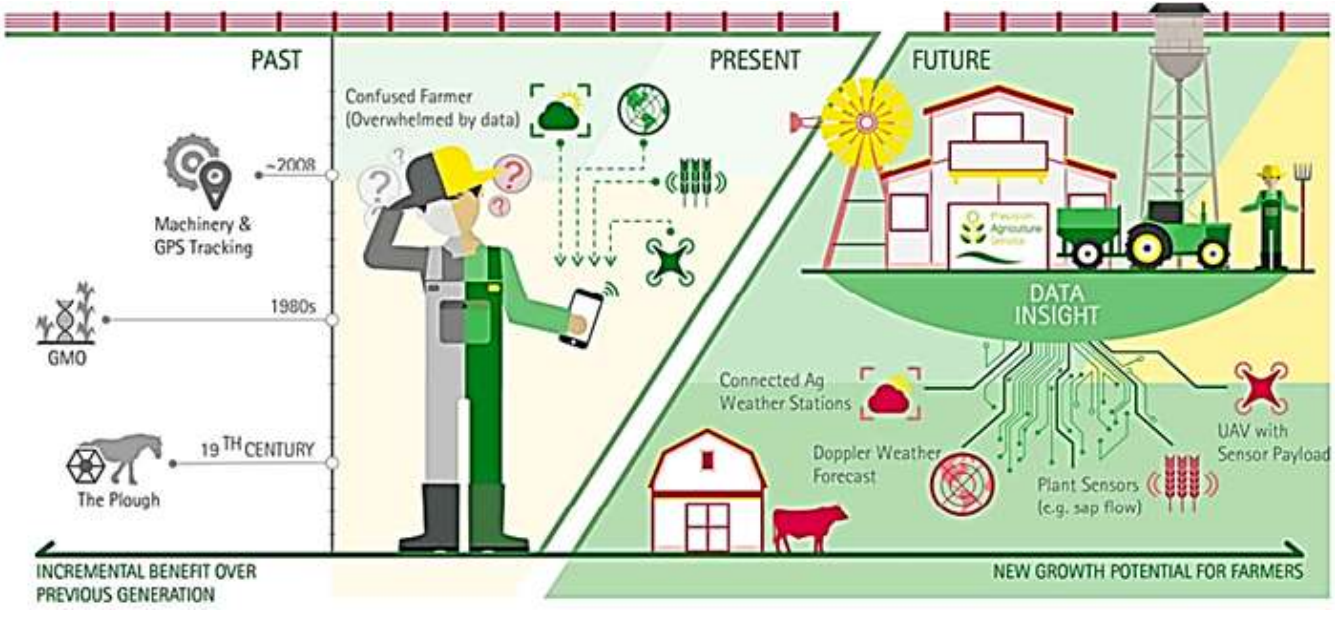
- Precision agriculture
- Connected livestock
- Food safety

PRECISION AGRICULTURE

- A farming management concept based on observing, measuring and responding to inter and intra-field variability in crops
- In the past, precision agriculture technology was implemented by big agribusinesses due to high costs
- IoT technologies – which include everything from GPS services, sensors, and big data calculation – have made precision agriculture affordable by many farmers
- Farmers don't have to rely as much on their gut. Instead, they can make decisions based on detailed information about water, climate changes, soil quality, the health of their crops and livestock, and the conditions of their machinery

https://flex.com/intelligence/iot/old-macdonalds-new-connected-farm

PRECISION AGRICULTURE



https://www.accenture.com/cn-en/insight-accenture-digital-agriculture-solutions

PRECISION AGRICULTURE

Opportunities for vertical integration

https://www.cbinsights.com/research/agriculture-tech-market-map-company-list/

CONNECTED LIVESTOCK

- Around 1.4 billion cattle around the world
- Animals can't tell you when they first get sick. It can be hard for humans to tell a cow is ill until there are visible signs of sickness.
- IoT sensors cannot diagnose an illness but it will let the farmer know when something needs attention.

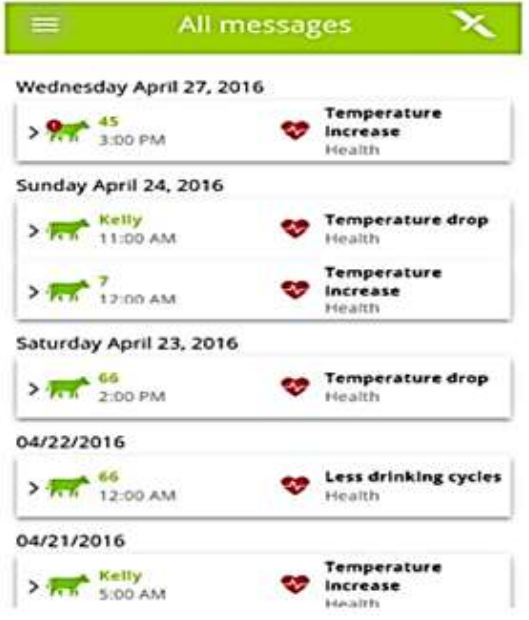
https://www.smaxtec.com/en/

CONNECTED LIVESTOCK

- pH measurement
  - Early detection of fermentation disorders
- Activity level measurement
  - Early, automatic oestrus detection
  - Onset illness
- Temperature measurement
  - Early detection of onset of diseases such as feverish disorders, metabolic disorders, post-calving disorders
  - Early detection of start of calving

https://www.smaxtec.com/en/

CONNECTED LIVESTOCK



http://uk.smaxtec.com/smaxtec-system/

FOOD SAFETY

- Wi-Fi or cellular connectivity
- When a produce recall is initiated, the juice machine will check the packs and prevent the machine from pressing affected packs.

https://www.juicero.com/

MODERN IOT APPLICATIONS

MANUFACTURING AND LOGISTICS

MANUFACTURING AND LOGISTICS APPLICATIONS OUTLINE

- Smart manufacturing
- Smart packaging

SMART MANUFACTURING

- The use of IoT devices to improve **efficiency** and **productivity** of manufacturing operations. Typically, it involves **retrofitting** sensors to existing manufacturing equipment. But new manufacturing equipment often comes with **IoT sensors pre-installed.**
- According to IDC data, published early 2017, the manufacturing industry was good for a total IoT spending of $178 billion in 2016, which is more than twice as much the second largest vertical market, transportation.
- Manufacturing operations accounts for 57.5% of the total IoT spending on manufacturing.

http://www.businesswire.com/news/home/20170104005270/en/Internet-Spending-Forecast-Grow-17.9-2016-Led

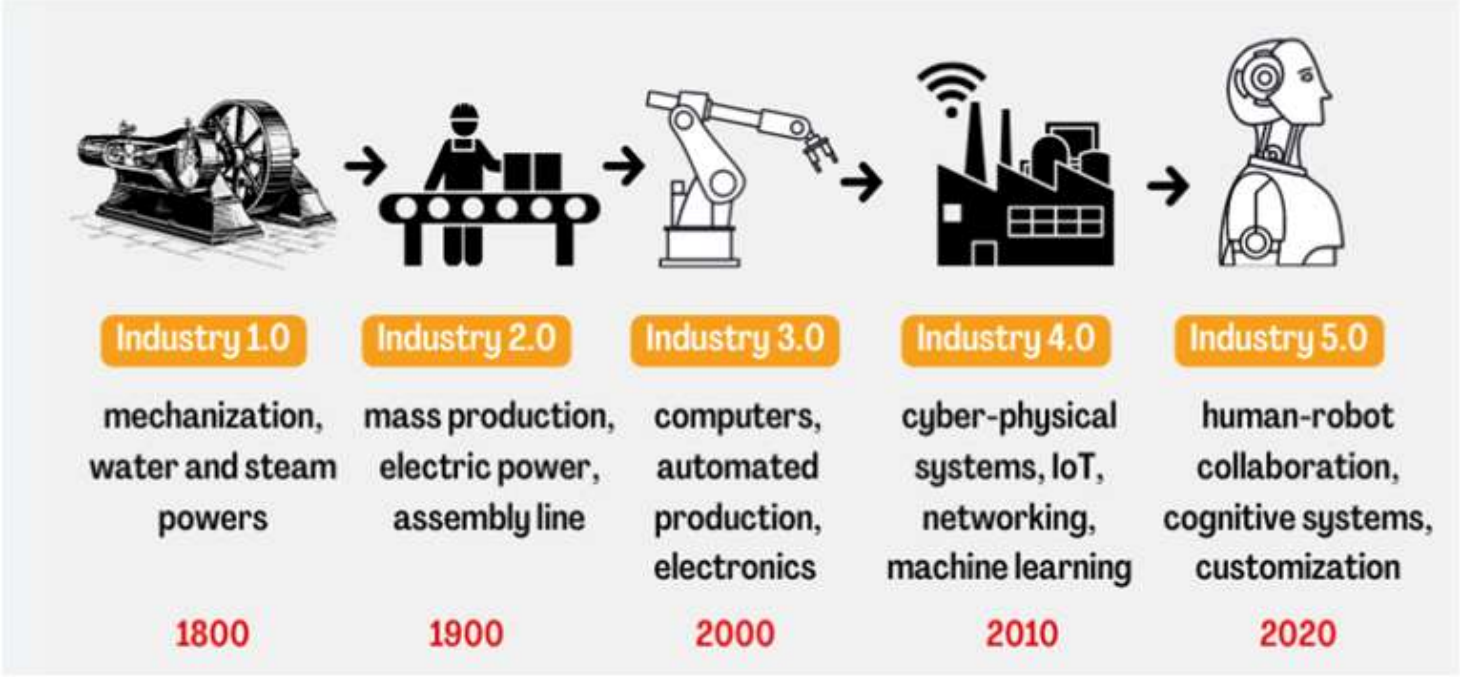
SMART PACKAGING

- Packaging systems used with food and pharmaceutical that **help extend shelf life, monitor freshness, display information on quality, improve safety, and improve convenience**
- Usually involve **active functions beyond the inert passive containment**, for example, the ability to **sense or measure an attribute of the product**, **the inner atmosphere of the package, or the shipping environment**
- This information can be **communicated** to users or can **trigger** other active packaging functions

INDUSTRIAL REVOLUTION

INDUSTRY 1.0	INDUSTRY 2.0	INDUSTRY 3.0	INDUSTRY 4.0
18th century	19th century	Mid 20th century	Today
Steam power	Electricity	ICTs Electronics	Advanced robotics 3D printing Internet of Things Artificial Intelligence Big data
Mechanical production, moving away from cottage industry	Mass production and assembly line	Automated and networked production	Intelligent, flexible and distributed production

INDUSTRIAL REVOLUTION



https://www.coretigo.com/industrial-revolution-from-industry-1-0-to-industry-5-0/

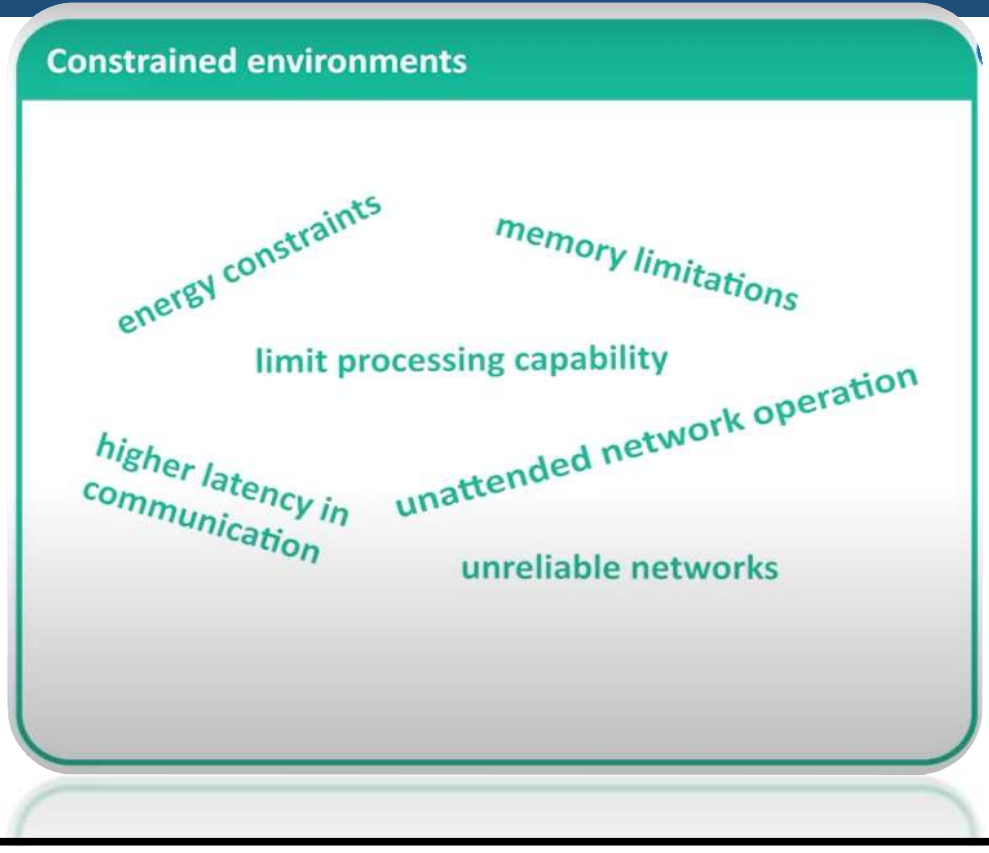
https://www.linkedin.com/pulse/industry-50-next-industrial-revolution-around-corner-shirish-kulkarni/

CHARACTERISTICS OF IOT

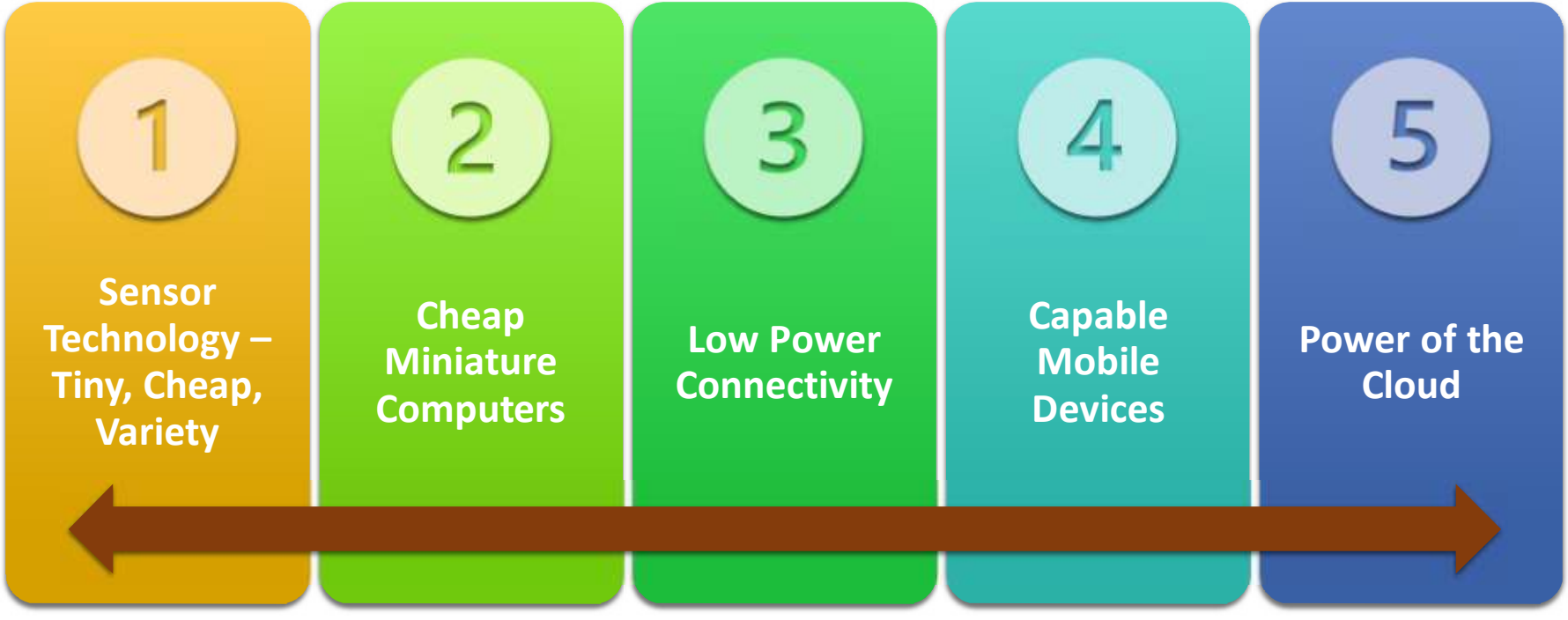
IDEAL IOT

Smart	Agile	On demand	Secure	Low Maintenance
Fast	Upgradable	Adaptable	Ubiquitous	Growing

CONSTRAINED ENVIRONMENT



DRIVING FORCES FOR IOT



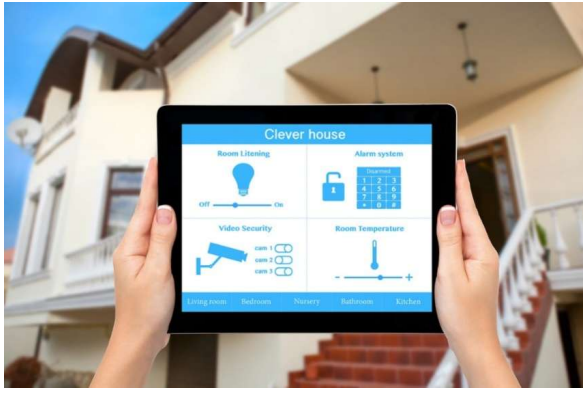
IOT EVOLUTION

Product

Smart Product

Smart & Connected Product

Product System



System of Systems

EVOLUTION OF CONNECTED DEVICES

SMART HEALTHCARE

- Devices connect to hospitals, doctors and relatives to alert them of medical emergencies and take preventive measures.

SMART VEHICLES

- Vehicles self-diagnose themselves and alert owners about system failures.

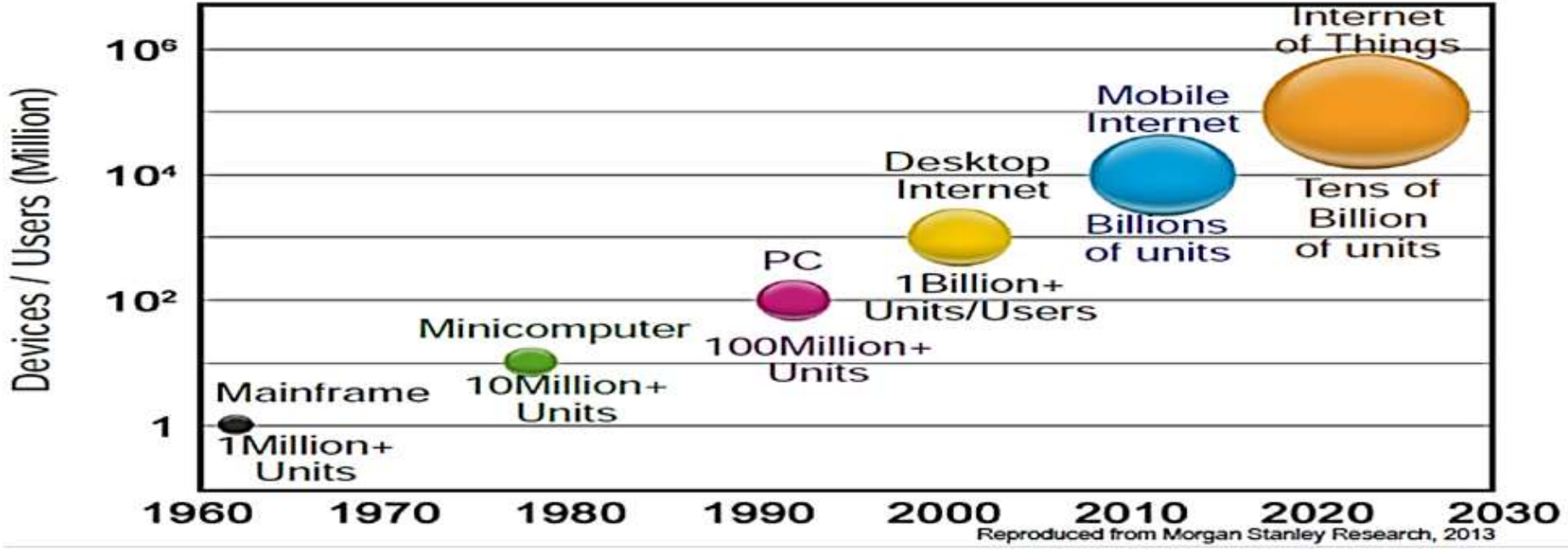
SMART CITIES

- City-wide infrastructure communicating amongst themselves for unified and synchronized operations and information dissemination.

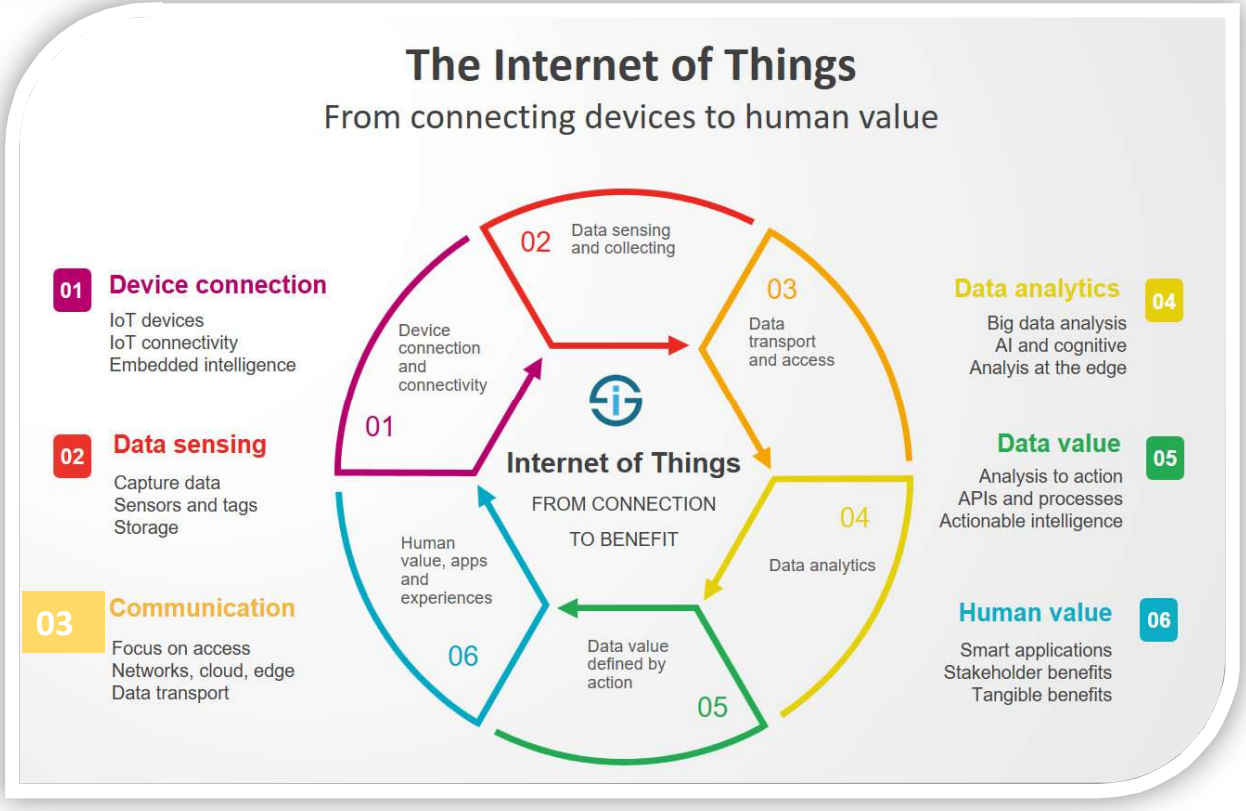
SMART DUST

- Computers smaller than a grain of sand can be sprayed or injected almost anywhere to measure chemicals in the soil or to diagnose problems in the human body.

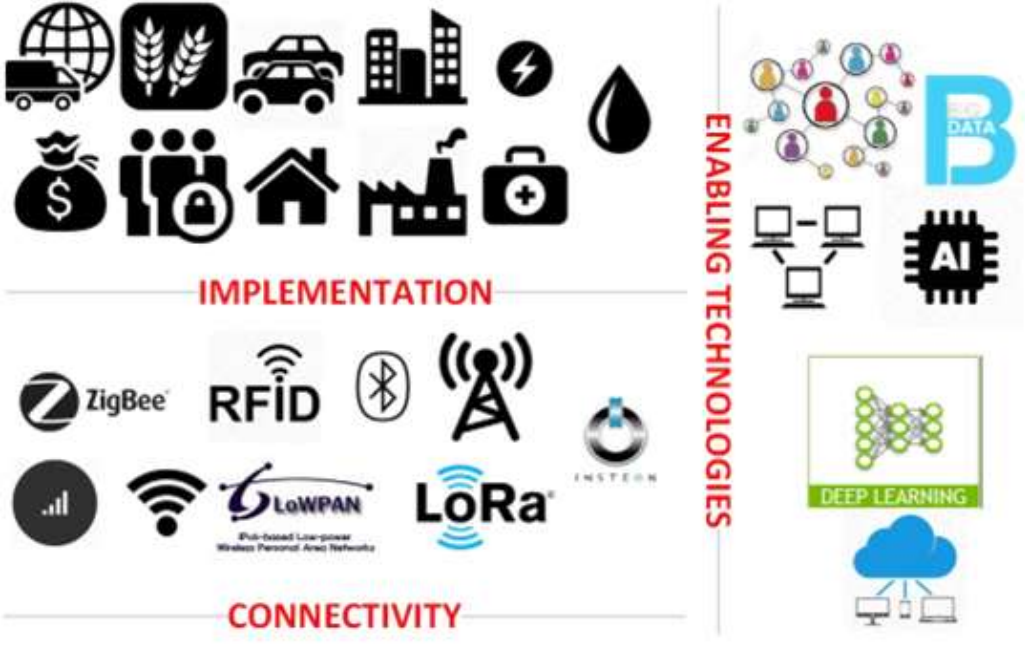
IOT WILL BE THE NEXT BIG THING

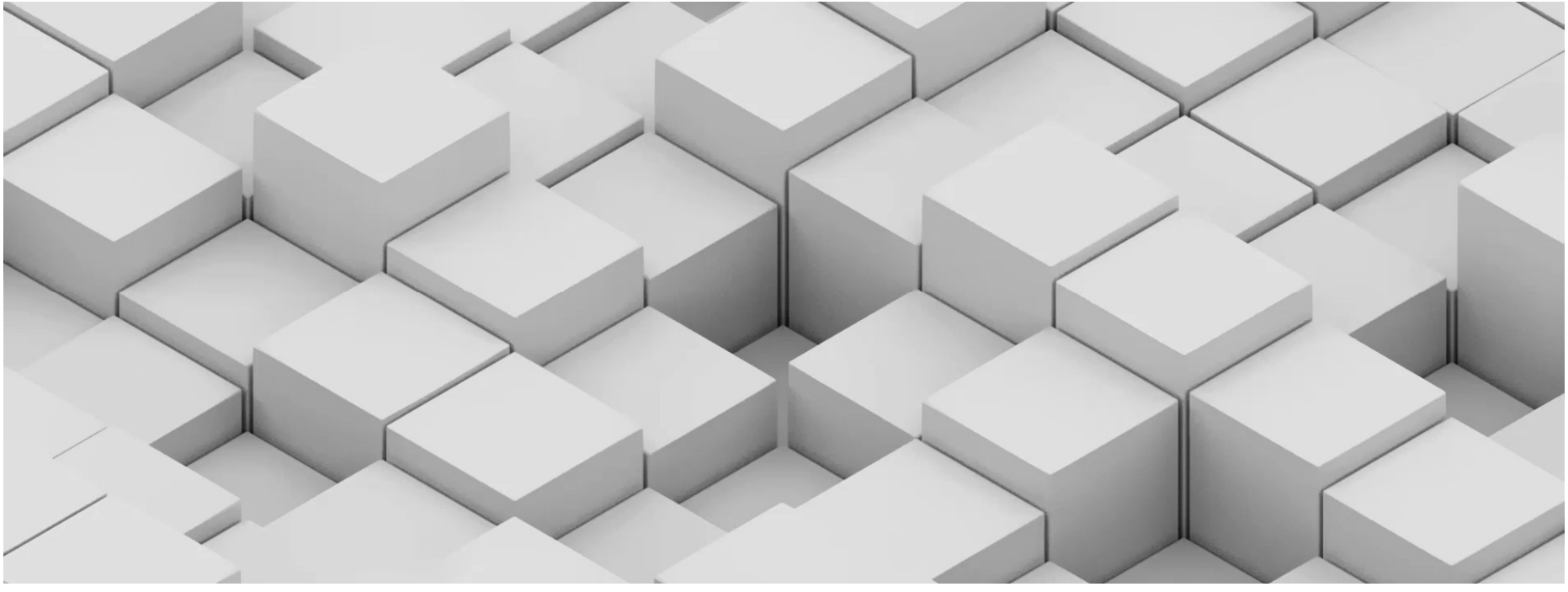


COMPLETE IOT CYCLE



IOT ENABLERS

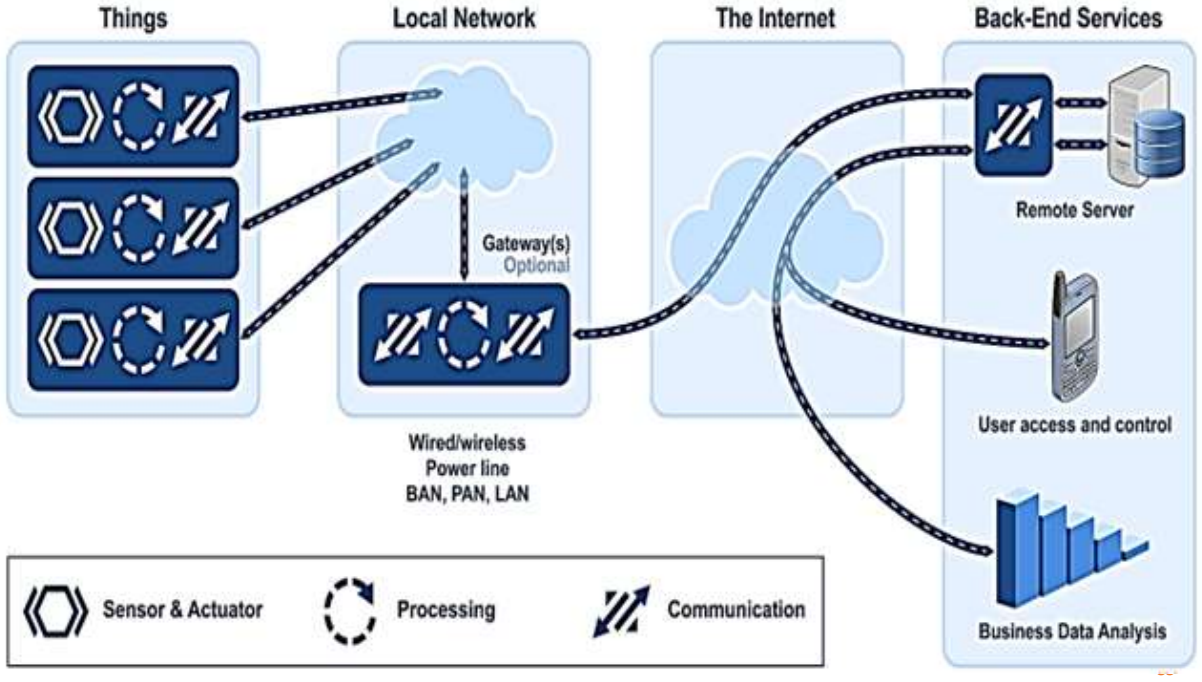




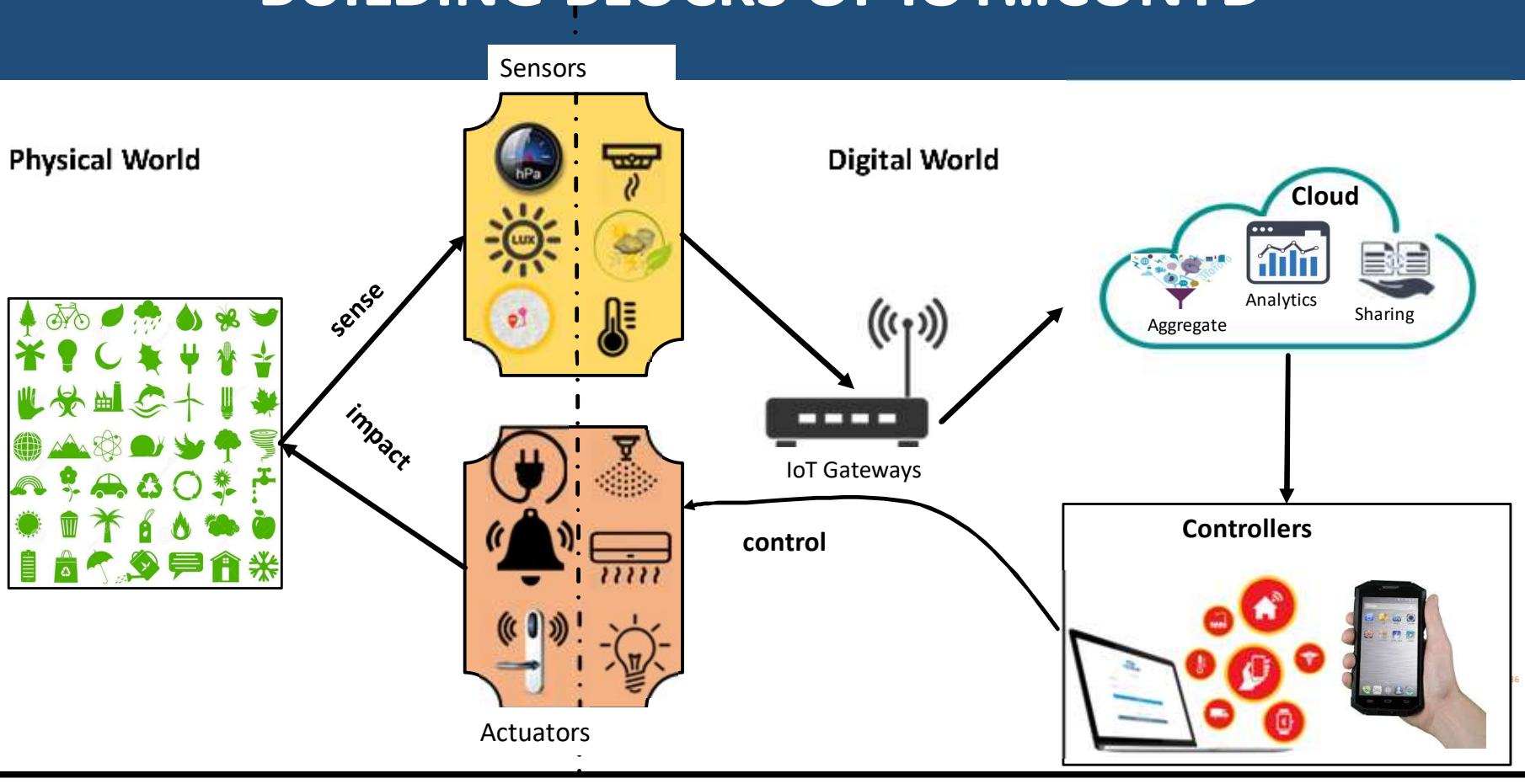
BUILDING BLOCKS OF IOT

BUILDING BLOCKS OF IOT

- Sensors and Actuators
- Communication Technologies
- Gateway/Edge devices
- Data storage
- Edge/Fog computing
- Data Analytics
- Data Visualization
- Power Management



BUILDING BLOCKS OF IOT…CONTD



BUILDING BLOCKS OF IOT CONTD…

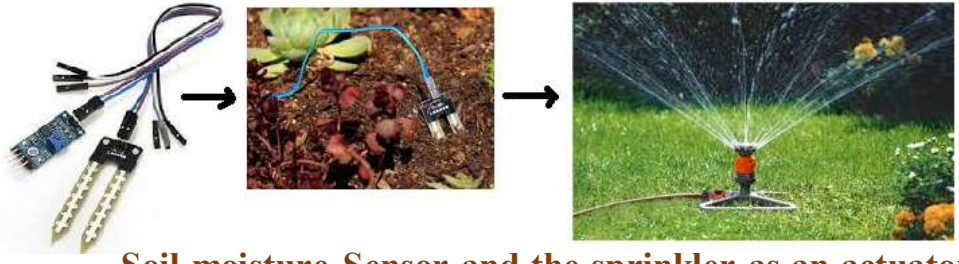
Sensors

- They are mainly input components
- Sense and collect data from their environment and act as a data source
- Convert the sensed energy (such as light, heat, sound, motion, etc) into electrical signals
- Data collected can be processed, stored and used in various context to derive useful inferences from it
- Commonly used sensors are temperature sensors, motion sensors, smoke sensors, blood glucose & pressure sensor, heart rate sensor, voltage sensor and acoustic sensors to name a few

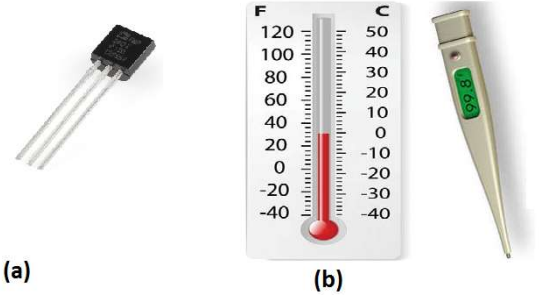
Actuators

- They are mainly output components
- In contrast to the sensor, the actuator behaves in an inverse fashion
- Takes electrical data as input and transform it into mechanical energy or motion
- They alter the surrounding. Some examples:
- Adding lighting, heat, sound, etc.
- Controlling motors to move objects
- Displaying messages
- and others…

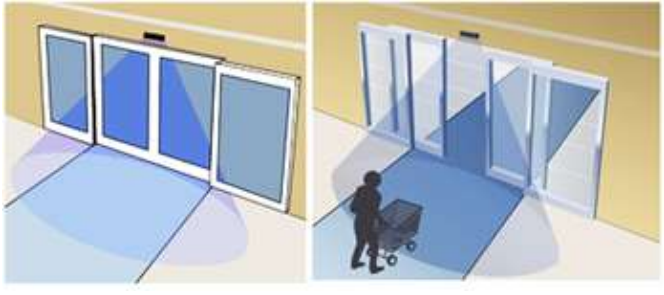
BUILDING BLOCKS OF IOT CONTD…



Soil moisture Sensor and the sprinkler as an actuator

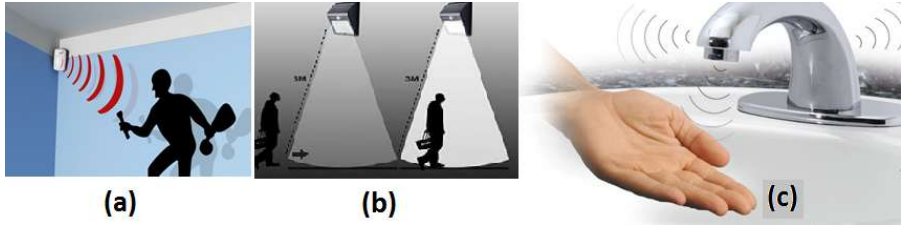


(a) Temperature Sensor (b) Temperature measuring devices



Radar operated doors

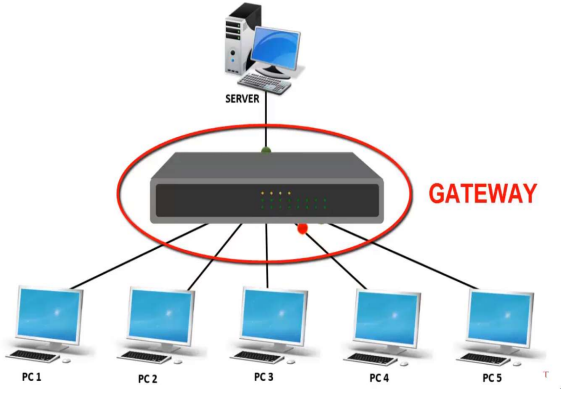
Applications of Motion Sensor



(a) Burglar Alarm, (b) Smart Lights, (C) Infrared based water taps

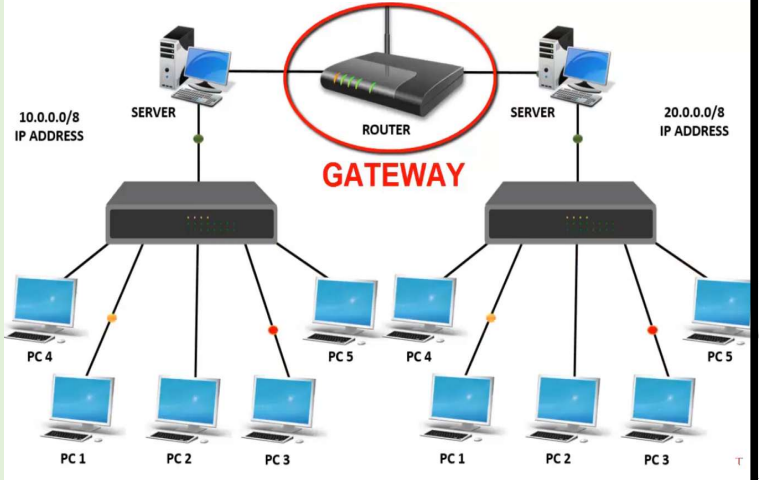
BUILDING BLOCKS OF IOT CONTD…

- **Gateway-(Switch)**
  - A networking device used to connect two or more networks
  - It may be a router, firewall, server or any other device that enable traffic to flow in and out of the network
  - If devices are connected within the same network then a switch is used as a gateway, regulating the network traffic
  - Operates at data link layer of OSI model and uses MAC address of devices to transfer data



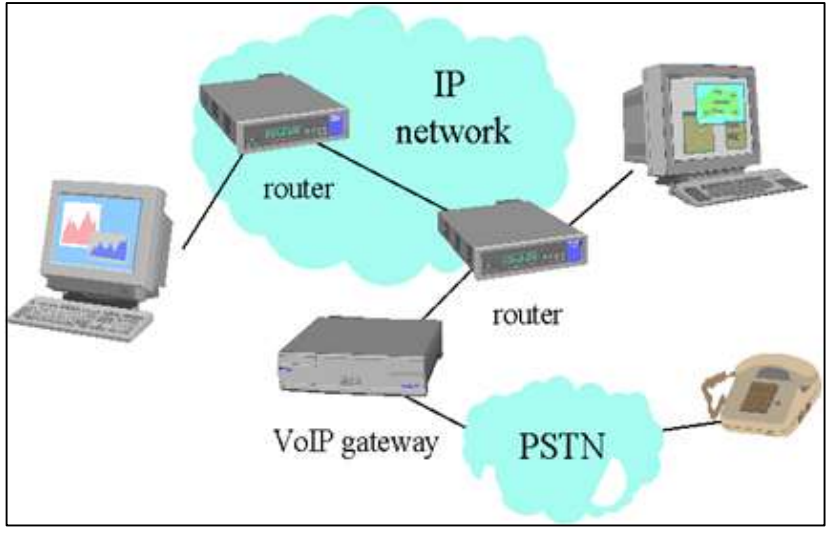
BUILDING BLOCKS OF IOT CONTD…

- **Gateway-(Router)**
  - Devices working in two different networks cannot directly communicate with each other
  - For such type of communication, centralized device known as router is used to enter into different networks
  - Router will play the role of gateway and is the main access point to move into different network
  - Router operates at network layer of OSI model and uses IP addresses to transfer data



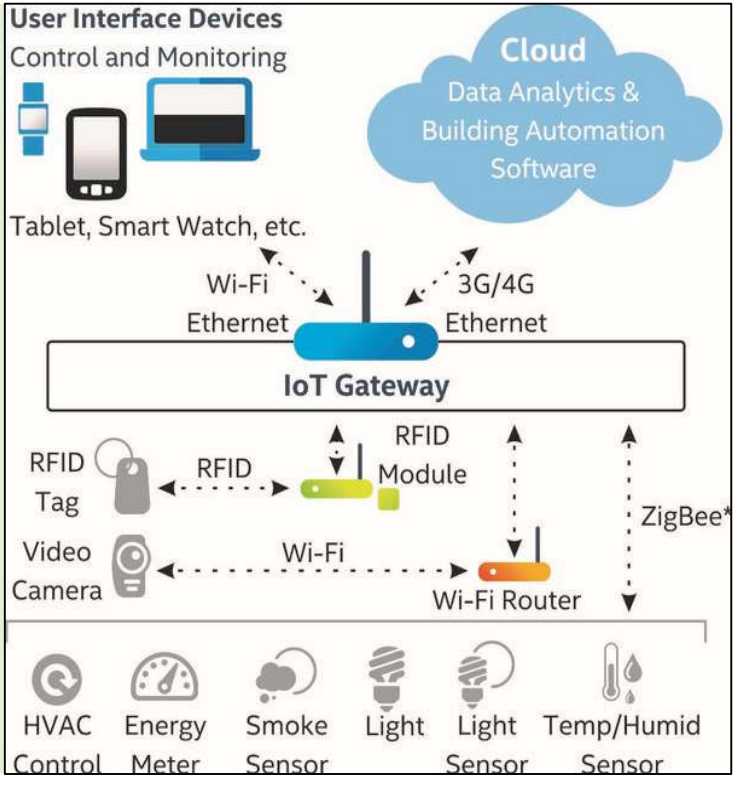
BUILDING BLOCKS OF IOT CONTD…

- **Gateway**
  - Router can link two different networks running on same protocol
  - Gateway device connects two different networks running on two different protocols and
    - For this reason, the gateway is also called a protocol converter such as VOIP to PSTN or network access control



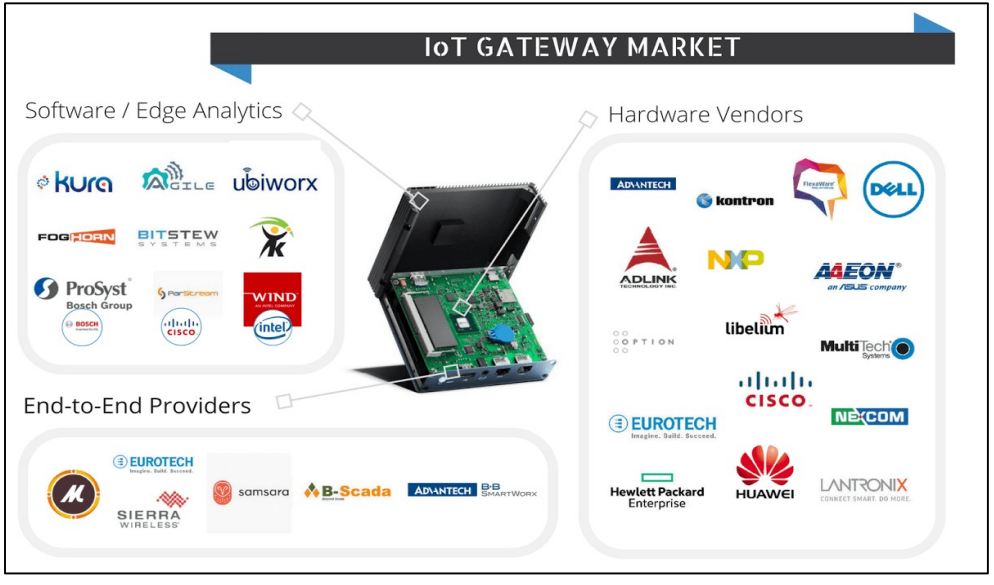
BUILDING BLOCKS OF IOT CONTD…

- **IoT Gateway**
  - Differs from traditional gateway in terms of
    - Degree of intelligence and the number of functions it performs other than protocol conversion and translation
  - It is a physical device or a software program that connects the IoT devices such as sensors, actuators to a cloud, a network computer or an intelligent device
  - Single point of connection for IoT devices
  - No need to connect individual devices to application software
  - The functions performed by IoT gateway include
    - Device management and configuration, gathering data from the sensors, send it to the cloud for storage, processing or performing analytics to make smart decisions , provide security

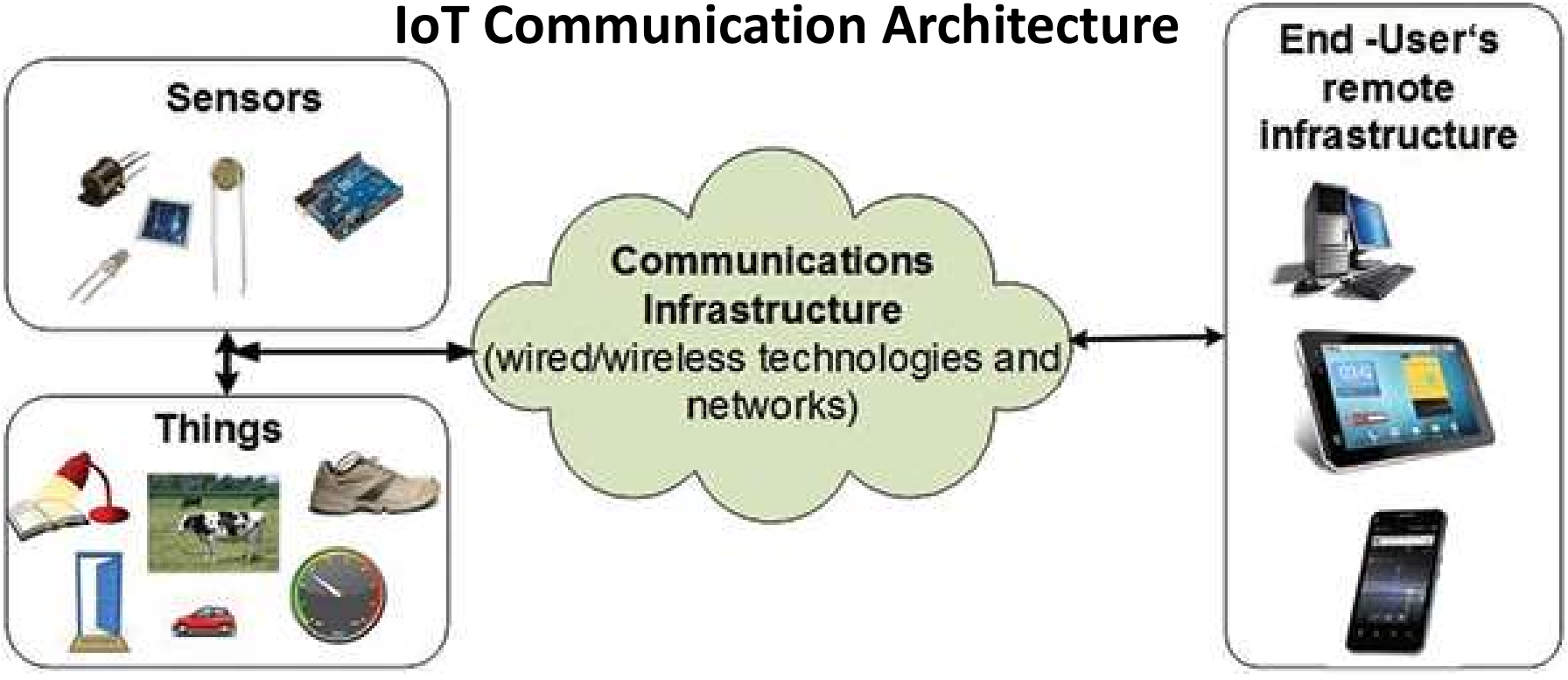


BUILDING BLOCKS OF IOT CONTD…

- IoT Gateway
  - Some of the off the shelf IoT gateways available in market
  - Although these solutions are commercially available but some degree of customizations is required to meet real business needs



BUILDING BLOCKS OF IOT CONTD…



BUILDING BLOCKS OF IOT CONTD…

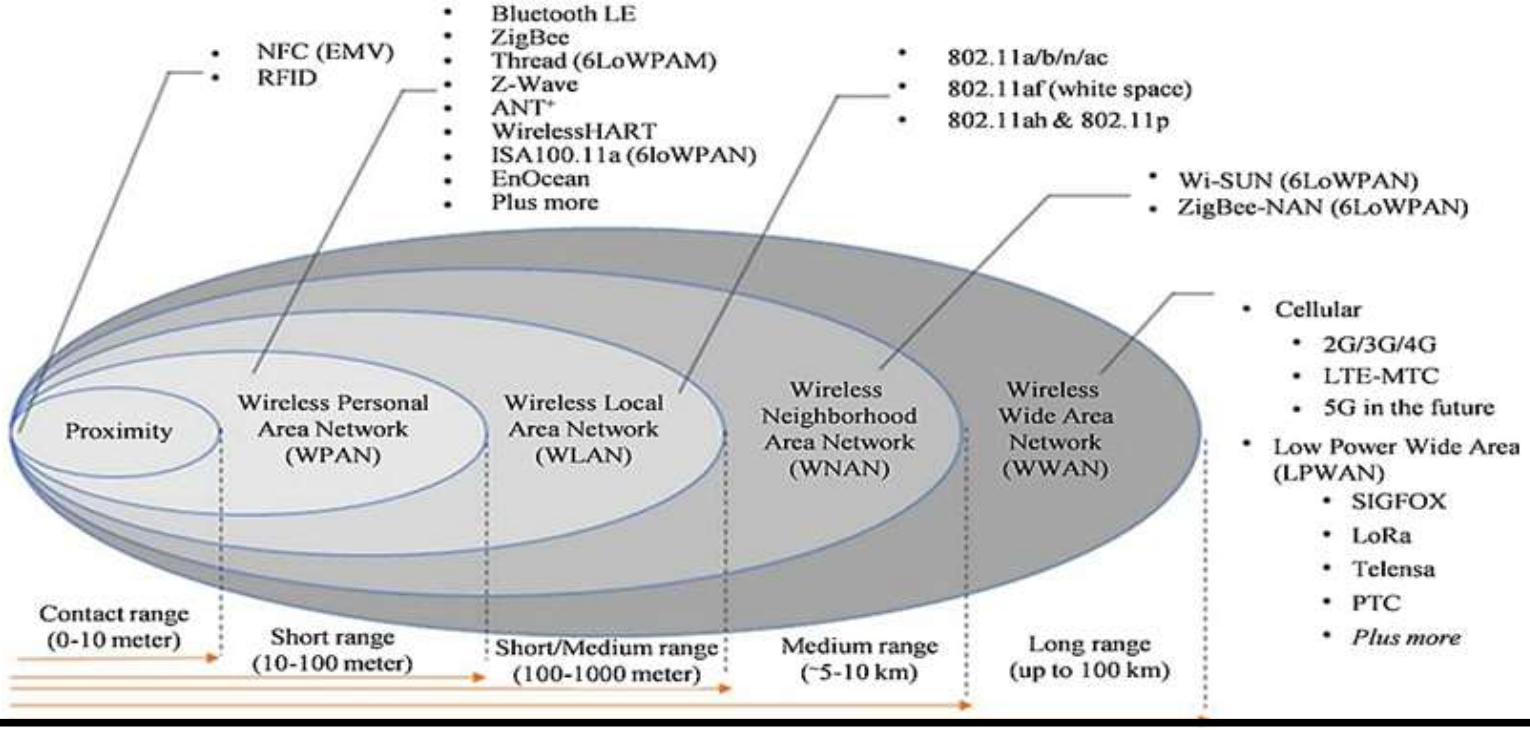
- **IoT Communication Protocols**
  - CoAP (Constrained Application Protocol)
  - MQTT (Message Queue Telemetry Transport)
  - XMPP (Extensible Messaging and Presence Protocol)
  - HTTP (Hyper Text Transfer protocol)

- Used for M2M communication
- Less secure

- Used for web communication
- More Secure

BUILDING BLOCKS OF IOT CONTD…

- **Communication Technologies**



BUILDING BLOCKS OF IOT CONTD…

- **Communication Technologies**

	SIGFOX	LoRa	clean slate cIoT	NB LTE-M Rel. 13	LTE-M Rel. 12/13	EC-GSM Rel. 13	5G (targets)
Range (outdoor) MCL	<13km 160 dB	<11km 157 dB	<15km 164 dB	<15km 164 dB	<11km 156 dB	<15km 164 dB	<15km 164 dB
Spectrum Bandwidth	Unlicensed 900MHz 100Hz	Unlicensed 900MHz <500kHz	Licensed 7-900MHz 200kHz or dedicated	Licensed 7-900MHz 200kHz or shared	Licensed 7-900MHz 1.4 MHz or shared	Licensed 8-900MHz 2.4 MHz or shared	Licensed 7-900MHz shared
Data rate	<100bps	<10 kbps	<50kbps	<150kbps	<1 Mbps	10kbps	<1 Mbps
Battery life	>10 years	>10 years	>10 years	>10 years	>10 years	>10 years	>10 years
Availability	Today	Today	2016	2016	2016	2016	beyond 2020

CONNECTIVITY LAYERS

SERVICES

LOCAL CONNECTIVITY

SERVICE PROVIDERS

GLOBAL CONNECTIVITY

IOT MANAGEMENT

BUILDING BLOCKS OF IOT CONTD…

- **Data storage (Cloud or Server)**
  - Collected data needs to be stored and processed somewhere known as IoT platforms, these are typically cloud-based infrastructures which:
    - receive and send data via standardized interfaces, known as API (Application Programming Interface)
    - Store, process and analyse data.
  - Many commercial platforms are available today e.g, Microsoft Azure, Amazon AWS, IBM cloud, google cloud, salesforce.com etc

BUILDING BLOCKS OF IOT CONTD…

- **Data storage (Cloud or server)**
- **Google Cloud IoT, Amazon Web Services (AWS) IoT and Microsoft Azure IoT** Suite provide intelligent IoT solutions
  - Services include secure and reliable connection and data management services such as storing, updating, processing, analyzing and visualizing data in real time.
- **Saleforce.com IoT Cloud is driven by Thunder,**
  - Handle large volumes of events occurring at real time
  - Data can be from sensors, websites, mobile apps, device etc. and user can specify conditions for these events to take appropriate actions
- **IBM Watson IoT cloud platform is an Artificial Intelligence based cloud platform**
  - Offer machine learning services on its Bluemix Platform as a service (Paas)
  - Provides solutions such as sentiment analysis, weather prediction, image and text recognition and so on

BUILDING BLOCKS OF IOT CONTD…

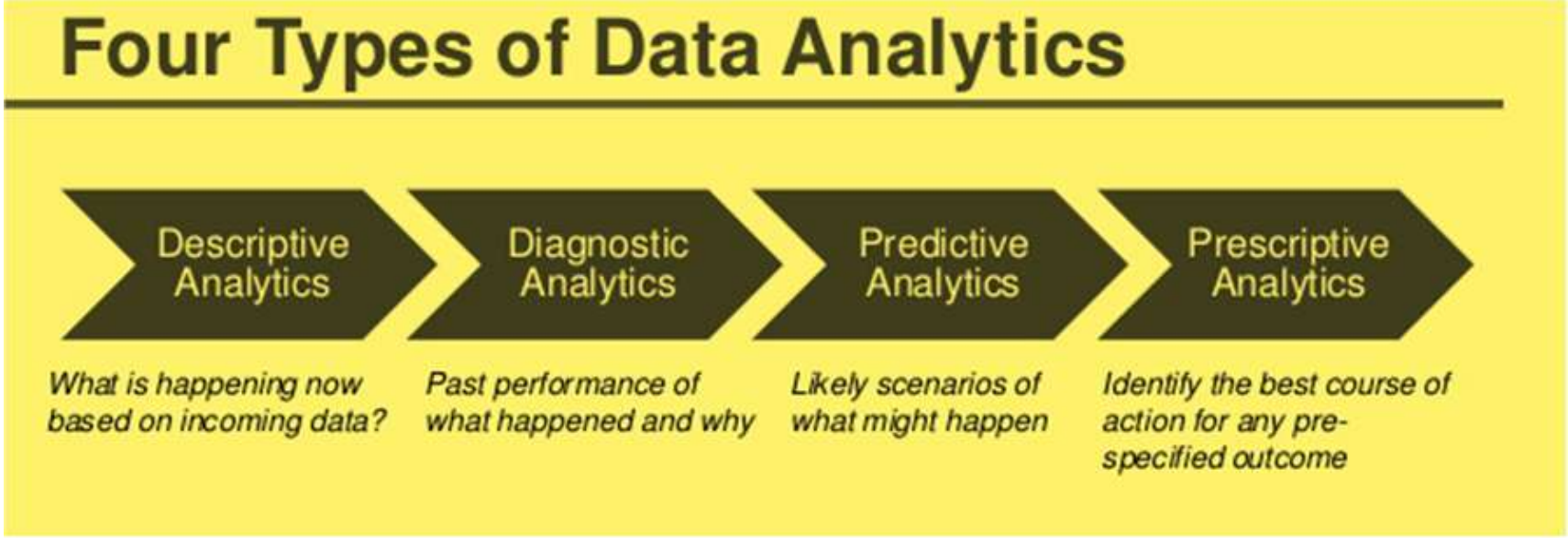
- **Data Analytics**
  - Internet of things (IoT) generate large amount of data which is typically stored on cloud
  - Large chunks of data is of no value without analytics
  - Analytics add power and context to the data so that useful inferences can be drawn and a deeper insight can be gained to drive actionable outcomes for improving business
  - Primary objective of running analytics on big data is to support and enable organizations to have enriched knowledge of data for improved decision making

BUILDING BLOCKS OF IOT CONTD…

- **Data Analytics**
  - Traditional data analytic tools have limited
    - Storing, processing and analytic capabilities and thus cannot handle large bulk of data whereas big data analytics empower data scientists to analyze large volume and variety of data which is generated at a high velocity
  - Big data analytics tools are generally available today, which stretch from simple statistical tools to more sophisticated machine learning approaches, with deep learning being the latest trend
  - Data analytics has also revolutionized health care, agriculture, automotive, military, aerospace and manufacturing industry

BUILDING BLOCKS OF IOT CONTD…

- **Types of Data Analytics**



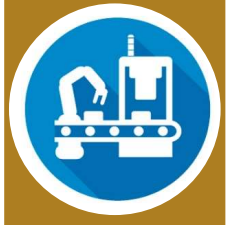
BUILDING BLOCKS OF IOT CONTD…

- **User Interface**
  - User Interface is the component that how the data is presented to the final users.
  - IoT product needs to have a very appealing user interface, both web based as well as smart phone or tablet based
  - Multiple users capable

IOT VERTICALS

Smart Homes

Smart Healthcare



Smart Industry

Smart Cities

Smart Vehicles

Smart Farming

Smart Aviation

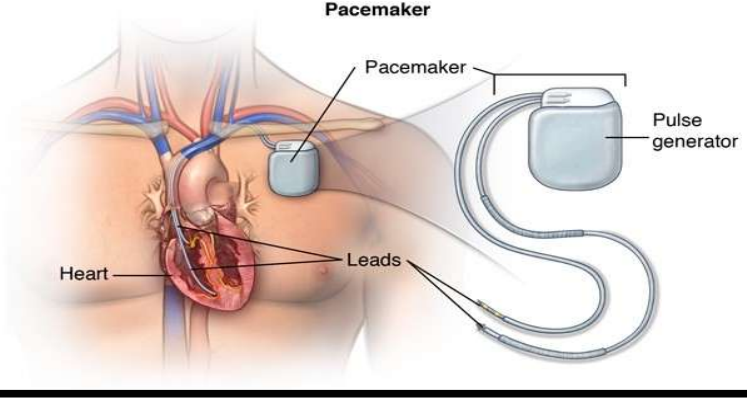
Smart Military

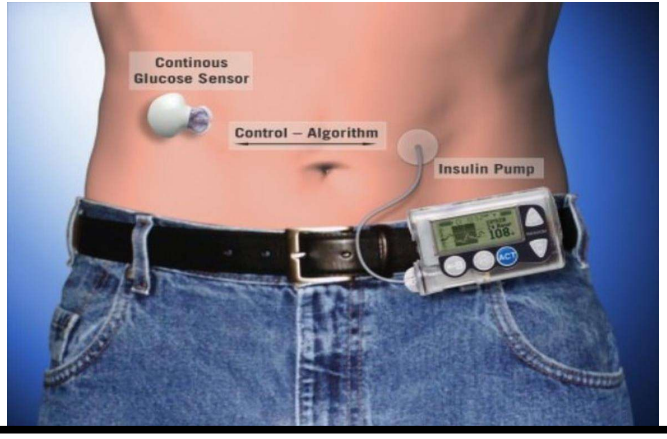
CHALLENGES

- Estimated 20-50 billion devices by 2030
- Reason is the integration of existing devices, smart devices as well as constrained nodes in a singular framework.
- Integration of various connectivity features such as cellular, Wi-Fi, ethernet with upcoming ones such as Bluetooth Low Energy (BLE), DASH7, Insteon, IEEE 802.15.4, etc.
- The ITU vision is approaching reality as the present day networked devices have outnumbered humans on earth.

CHALLENGES

- **Privacy and Security**
  - One of the most important and addressable issues of IoT systems
  - IoT devices not only gather personal data but also monitor and track your location and activities
  - Users are skeptical of storing personal information in public or private clouds
  - Pacemakers and Insulin Pumps can be hacked to cause lethal attacks, killing the victim





CHALLENGES

- Ever increasing growth of IoT sensors
  - Adding more variety and complexity to data
  - Integration of data from multiple sources in variable formats make IoT big data analytics more complex
  - Drawing inferences and other contextual information to discover patterns and correlations in real-time is a challenge

CHALLENGES CONTD..

- Power management
  - IoT devices must be fed with constant power to perform their operations without interruption in real time
  - Conventional communication network have permanent power source for the connected devices
  - However, IoT devices are based on small data transfer & low power devices which are typically battery operated or powered by solar cells
  - To fully realize the potential of IoT, an indefinite power supply is required but technology for doing that is not yet arrived

ACKNOWLEDGEMENT

- Various contents in this presentation have been taken from different books, lecture notes and the web. These solely belong to their owners and are here used only for clarifying various educational concepts. Any copyright infringement is *not* intended.

Project-Based Assignment

Project-Based Assignment

Prepare a **High-Level Design** for transforming Islamabad into a smart city or design of a smart campus using ICT, ensuring that all critical aspects are considered for a comprehensive approach

---

Submit a **Proposal** to Nominate your Group Leader

Number of Members per **Group** : 3 – 4

Contribution of Each Group Member is Compulsory

Deliverables: Report and Presentation

Duration: 10 Weeks

Thank You!