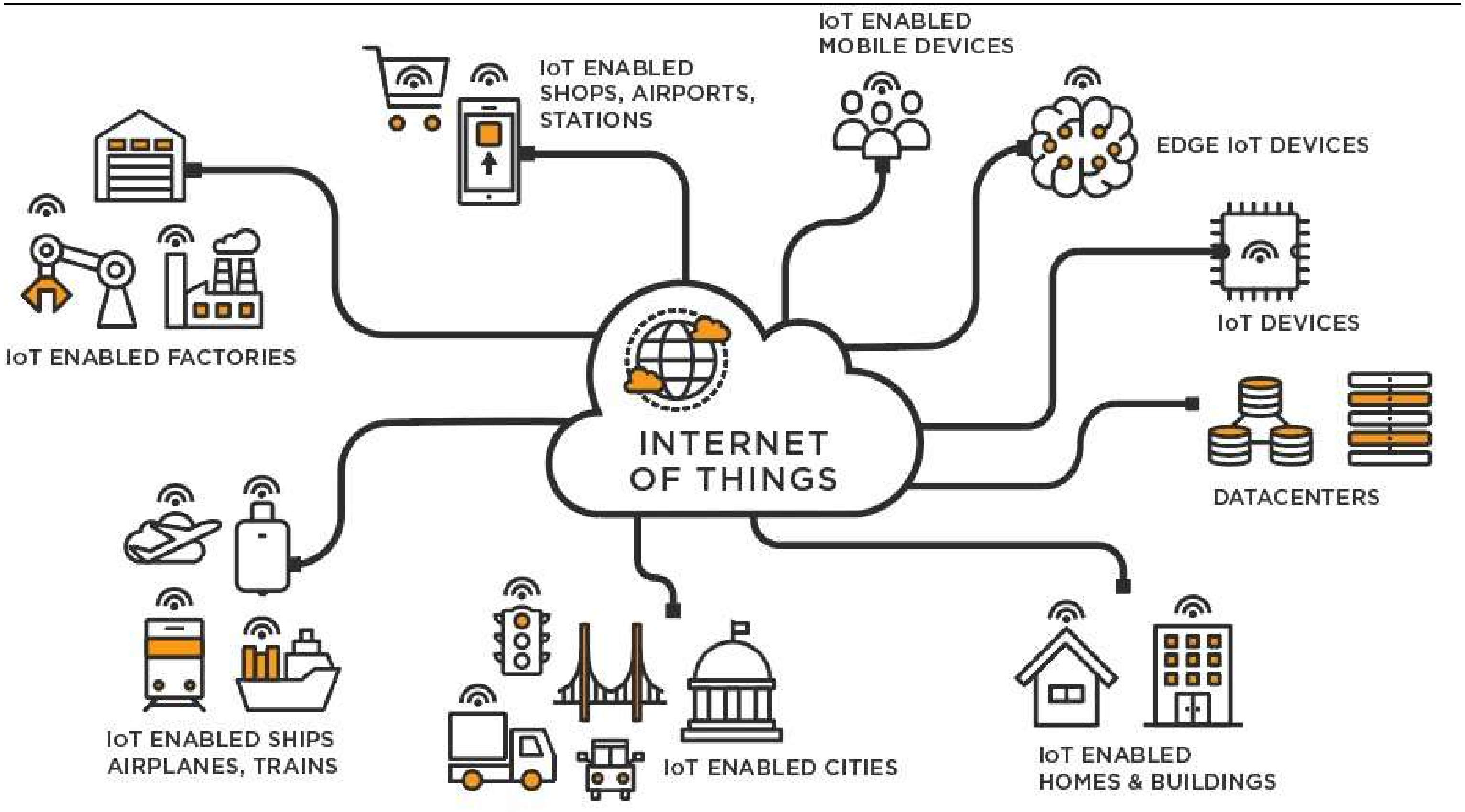
Internet of Things

IT 4030

Dr. Sanika Wijayasekara
Mr.Uditha Dharmakeerthi


IoT ENABLED SHOPS, AIRPORTS, STATIONS
IoT ENABLED MOBILE DEVICES
EDGE IoT DEVICES
IoT DEVICES
DATACENTERS
IoT ENABLED FACTORIES
INTERNET OF THINGS
IoT ENABLED SHIPS AIRPLANES, TRAINS
IoT ENABLED CITIES
IoT ENABLED HOMES & BUILDINGS

IOT

IE 4030

Module Content

Learning Outcomes	At the end of the module student will be able to:	
	LO1:	Describe the IoT concepts.
	LO2:	Explain the IoT technologies and their deployment.
	LO3:	Apply the key technologies of Internet of Things to solve industrial problems.
	LO4:	Design and develop IoT systems.
	LO5:	Evaluate technologies used in industrial IoT networks.

Module Content

Assessment Criteria	During the semester, there will be assignments, and a final exam. The assessments will be based on the practical work. The final examination will be a comprehensive exam based on the lecture materials covered during the semester.			
	Continuous Assessments			
	• Assignments	50	%	LO2 – LO5
	End Semester Assessment			
	• Final Examination	50	%	LO1 – LO5
	TOTAL	100	%	
Estimated Student Workload	Contact Hours			
	• Lecture	26 hours		
	• Tutorial	13 hours		
	• Laboratory	26 hours		
	Time Allocated for Assessments			
	• Continuous Assessments	5 hours		
	• Final Examination	2 hours		
	Reading and Independent Study	128 hours		
	TOTAL	200 hours		

Module Content- In Details

CONTENTS OF THE MODULE	
Topic	**Aligned learning outcomes**
1. The Internet of Things: An overview • Introduction to IoT systems • Cognitive systems	**LO1**
2. IoT eco system • Layers in IoT • Services in IoT • Services in big data management	**LO1, LO2**
3. Design principles for connected devices • MQTT protocol • Node-Red	**LO2 – LO4**
4. IoT Data gathering and warehousing •	**LO2 – LO4**
5. Embedded systems for IoT • Introduction to microcontrollers • Low power embedded systems • Introduction to real-time operating systems	**LO2 – LO4**

Module Content- In Details *(continued)*

6. **Sensors and actuators** • Communication protocols for sensors: I2C, SPI, UART • Sensor interfacing • Principles of sensing elements • Pulse width modulation	**LO2 – LO4**
7. **IoT hardware design technologies** • Design principles for IoT devices • Introduction to circuit designing • Introduction to 3D-modelling for enclosure designing	**LO2 – LO4**
8. **Industrial IoT networks** • Applications of Industrial IoT (IIoT) • IIOT Infrastructure • Over the air updates (OTA)	**LO4**
9. **Security in IoT** • Vulnerabilities in IoT systems • Rules and regulations for data protection • Securing edge devices • Tampering protection for IoT sensor nodes	**LO1, LO2**
10. **Business model development for IoT applications** • Cloud services for IoT • Subscription models for IoT services • Product as a service	**LO5**

SRI LANKA INSTITUTE OF INFORMATION TECHNOLOGY

Faculty of Computing

SLIIT

Discover Your Future

Module Delivery Plan

Year 2023

Module Name	**Internet of Things**	**Module Code**	**IT 4030**
Academic Year	**4**	**Semester**	**1/2**

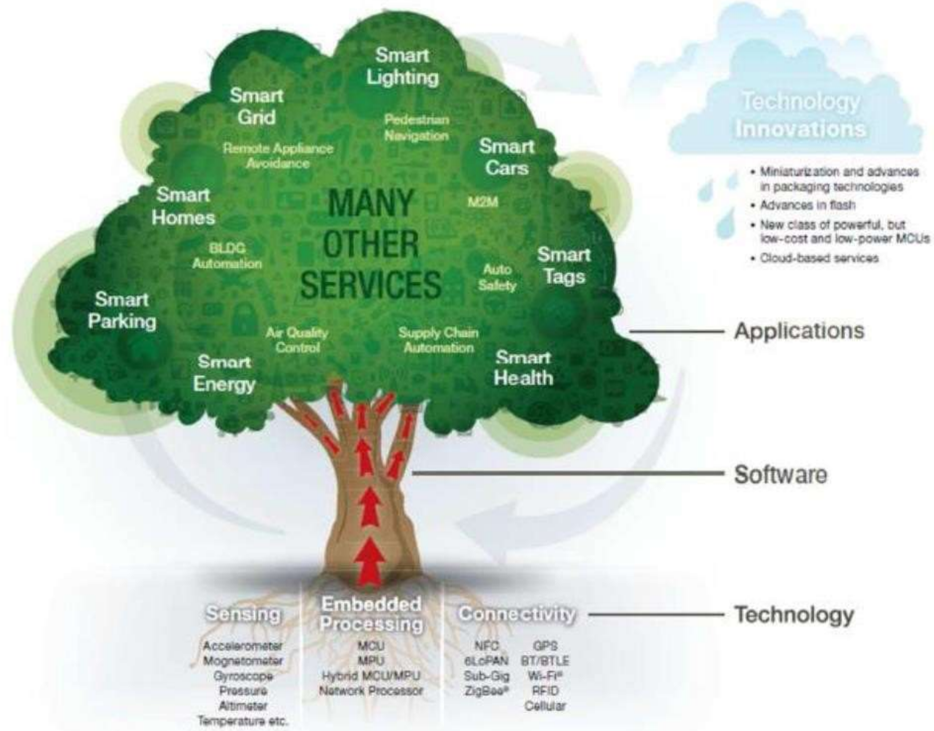
Week	Lecture Content	Lab	Assessment		Resources
1	Lecture 01: Introduction, An overview : The Internet of Things	-	-	Dr. Sanika	-
2	Lecture 02: IoT eco system	Lab sheet 01: Introduction	-	Dr. Sanika	
3	Lecture 03: Sensors in IoT	Lab sheet 02: Controlling the server motor (Actuator)	Releasing the Assignment	Dr. Sanika	
4	Lecture 04: IoT Connectivity	Lab sheet 03: LDR Ardino (Sensor)	Group Registration	Dr. Sanika	
5	Lecture 05 : WSN	Lab sheet 04: RPi /ESP32	Proposal Presentation Submission 27th August 2023	Dr. Sanika	
6	**Evaluation of Proposal Presentations**			Mr. Uditha	-
7	Lecture 06:	Lab sheet 05: MQTT communication	-	Mr. Uditha	

	Embedded systems for IoT, Introduction to microcontrollers, Low power embedded systems, Introduction to real-time operating systems				
8	Mid Exam Week (Progress Presentation Submission 24th August 2023)				
9	**Evaluation of Progress Presentations**			Dr. Sanika	
10	Lecture 07: IoT MQTT	Lab sheet 06: RPi /ESP32		Mr. Uditha	
11	Lecture 08: Industrial IoT networks, Applications of Industrial IoT (IIoT), IIOT Infrastructure, Over the air updates (OTA)	Lab sheet 07: RPi /ESP32		Mr. Uditha	
12	Lecture 09: IOT Security	-	Final Prototype Completion and submission 15th October 2023	Mr. Uditha	
13	**Evaluation of Final Prototype Presentations**			Mr. Uditha	
14	Final Exam				

INTERNET OF THINGS

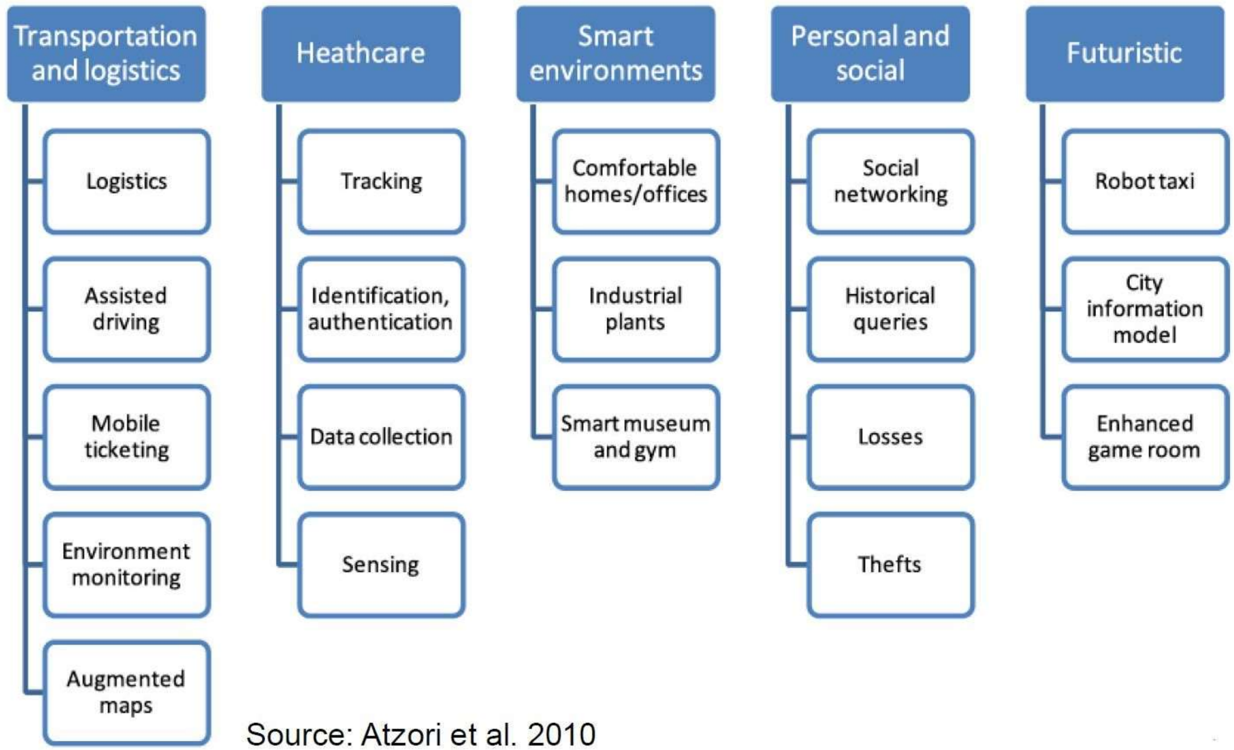
What is Internet of Things?

Putting it All Together



Source: “What the Internet of Things (IoT) Needs to Become a Reality,” White Paper, by K. Karimi and G. Atkinson

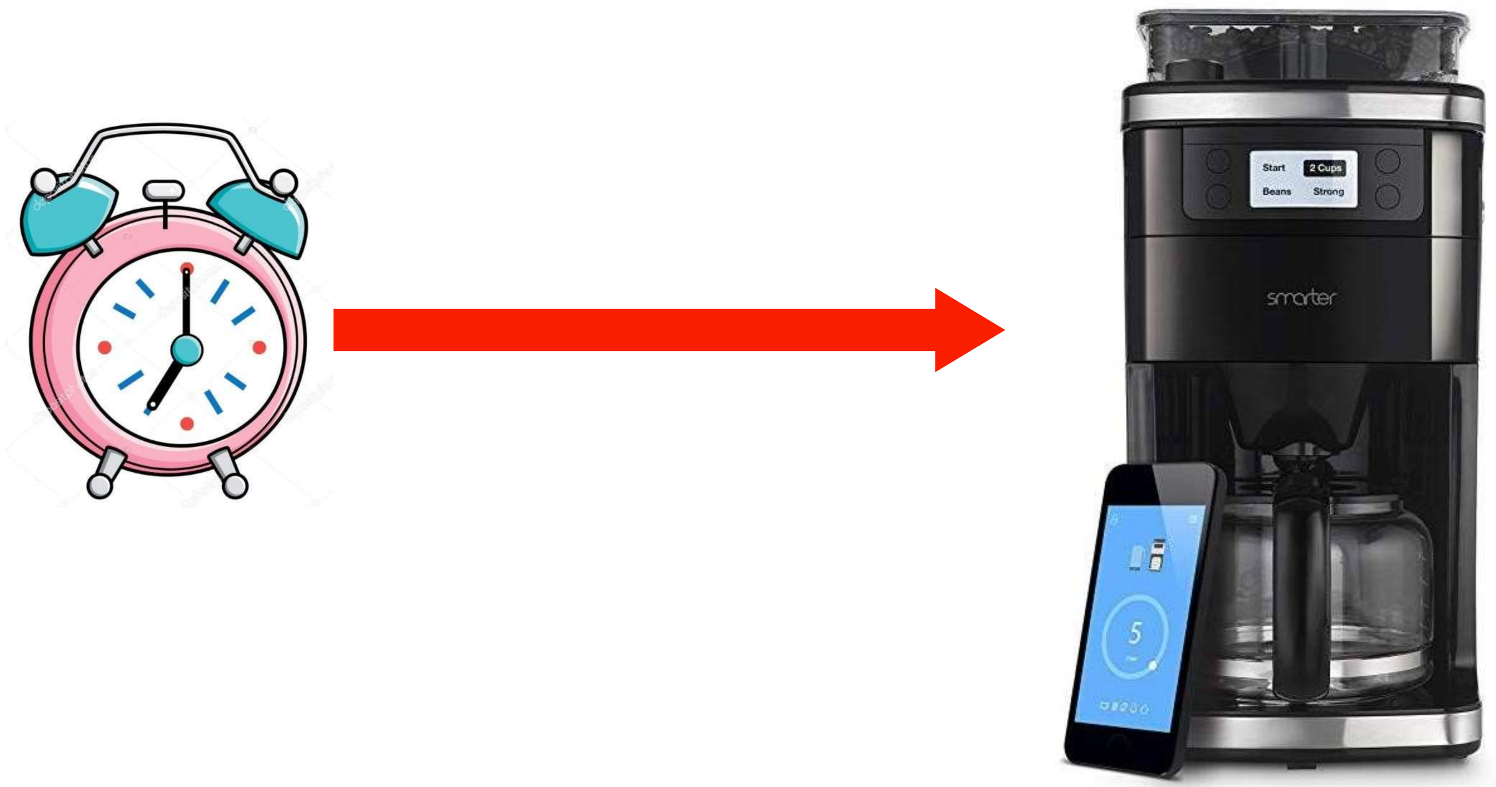
Application Domains & Scenarios



Source: Atzori et al. 2010

How Does This Impact You?

How Does This Impact You?



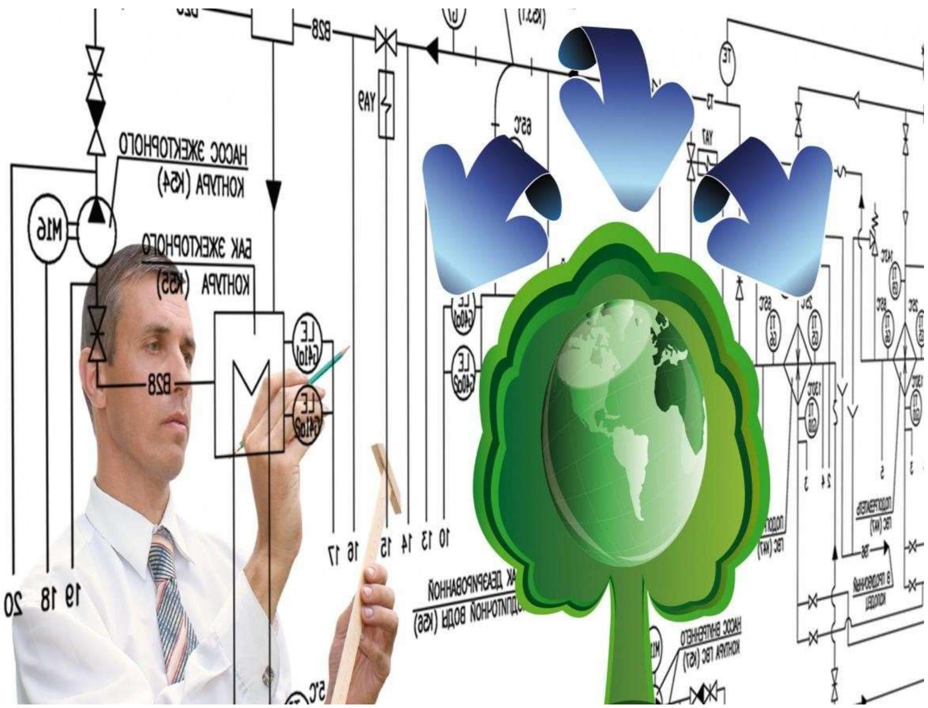
IoT-based Smart Farming

Utilize wireless IoT applications to collect data regarding the location, well-being, and health of their livestock

IoT – Advantages

Technology Optimization - The same technologies and data which improve the customer experience also improve device use, and aid in more effective improvements to technology. IoT unlocks a world of critical functional and field data.

IoT – Advantages Continue..



Reduced Waste - IoT makes areas of improvement clear. Current analytics give us superficial insight, but IoT provides real-world information leading to more effective management of resources.

IoT – Advantages Continue..

Enhanced Data Collection – Modern data collection suffers from its limitations and its design for passive use. IoT breaks it out of those spaces, and places it exactly where humans really want to go to analyze our world. It allows an accurate picture of everything.

IoT – Advantages Continue..

Security – IoT creates an ecosystem of constantly connected devices communicating over networks. The system offers little control despite any security measures. This leaves users exposed to various kinds of attackers.

IoT – Disadvantages

Compliance – IoT, like any other technology in the realm of business, must comply with regulations. Its complexity makes the issue of compliance seem incredibly challenging when many consider standard software compliance a battle.

Q & A

Thank You

INTERNET OF THINGS

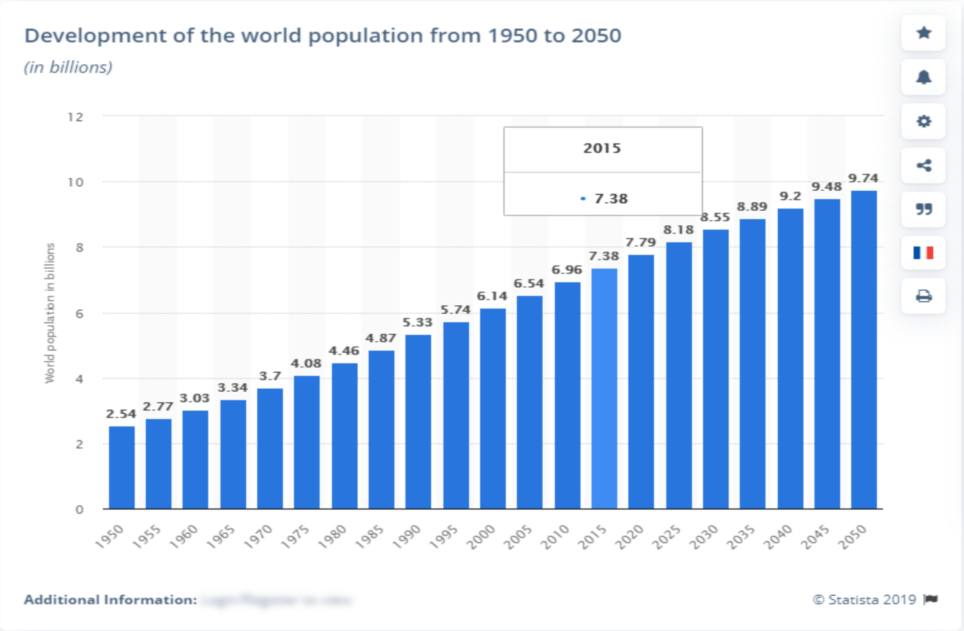
Janaka Wijekoon (PhD)

WHAT IS IOT?

GUESS WHAT

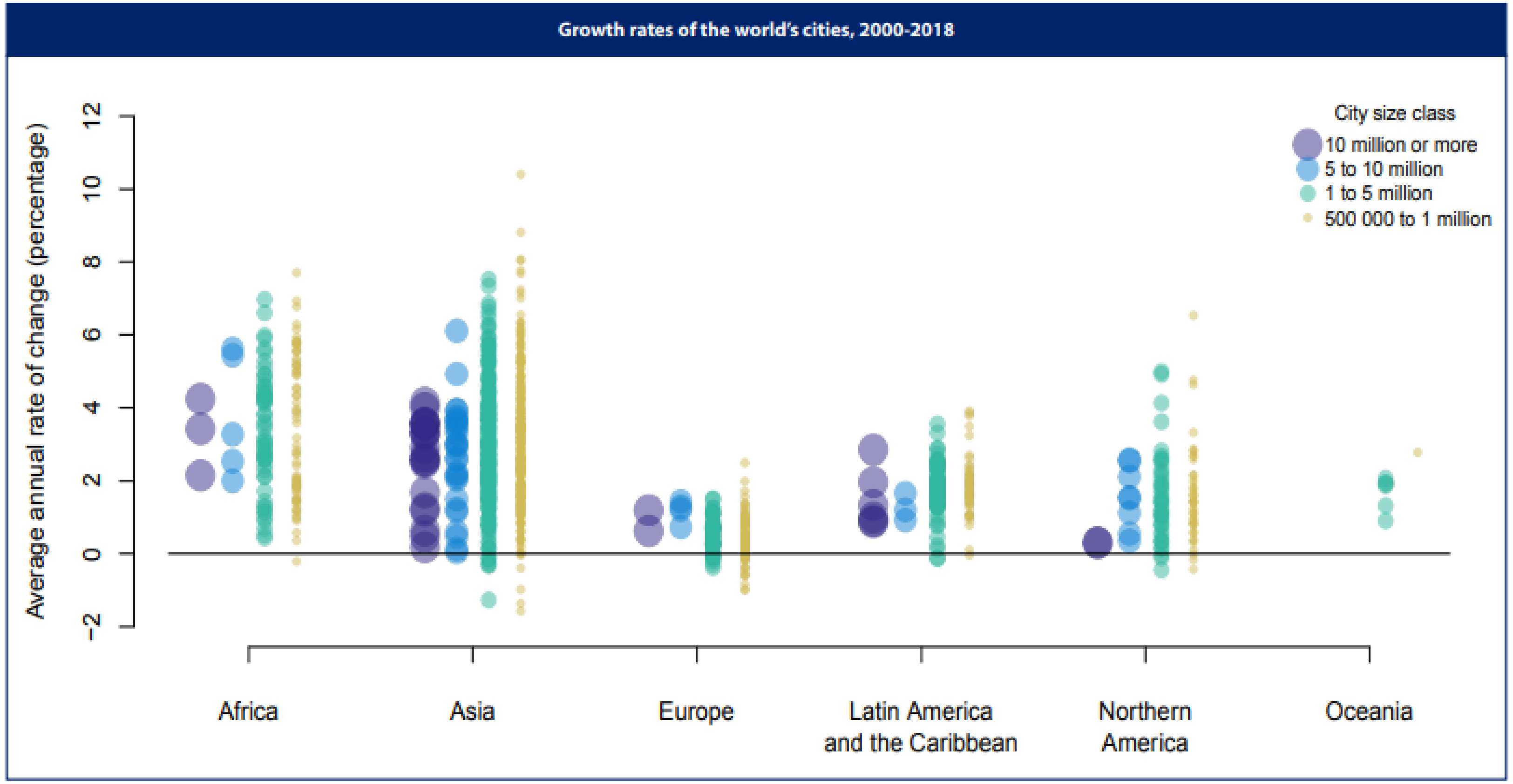
WORLD POPULATION

- **Currently** population is nearly **7.73Bn**.
- By **2030** there will be **8.55Bn** and by **2040** there will be **9Bn**.
- By **2040** nearly **50%** of the people will be concentrated to **cities**.
  - More opportunities
  - Comfortability of life
  - Competitive salaries



https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/

WORLDS FASTEST GROWING CITIES IN ASIA REGION



Between 2000 and 2018, the populations of the world's cities with 500,000 inhabitants or more grew at an average annual rate of 2.4 per cent. However, 36 of these cities grew more than twice as fast, with average growth in excess of 6 per cent per year. Of these, 7 are located in Africa, 28 in Asia (17 in China alone) and 1 in Northern America. Among the 36 fastest growing cities, 25 have a long history of rapid population growth, with average annual growth rates above 6 per cent for the period 1980-2000.

UN, The World's Cities in 2018: https://www.un.org/en/events/citiesday/assets/pdf/the_worlds_cities_in_2018_data_booklet.pdf

SO, HUMANS REQUIRE…

TO MANAGE THE POPULATION

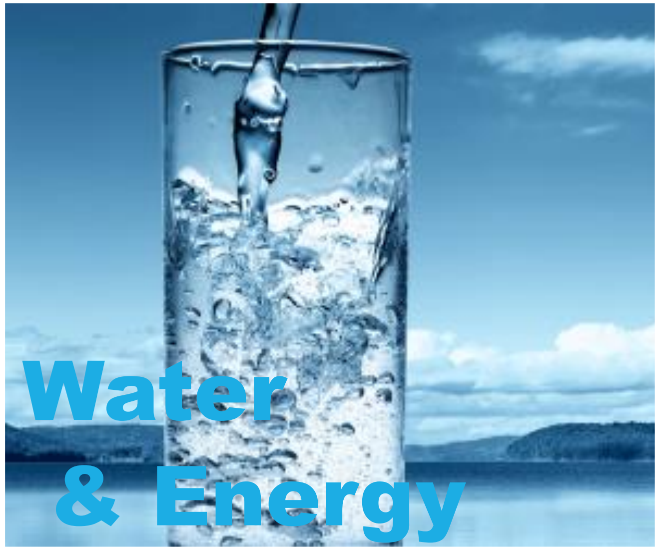
- We need **smart services**
  - Smart Homes
  - Smart Cities
  - Smart Communities
- We need to gather data
- We need common **databases**
- We need common API to use data

"Developing the future vision (Oman 2040) with mastery and high precision in light of broad societal consensus and with the participation.


Housing


Traffic

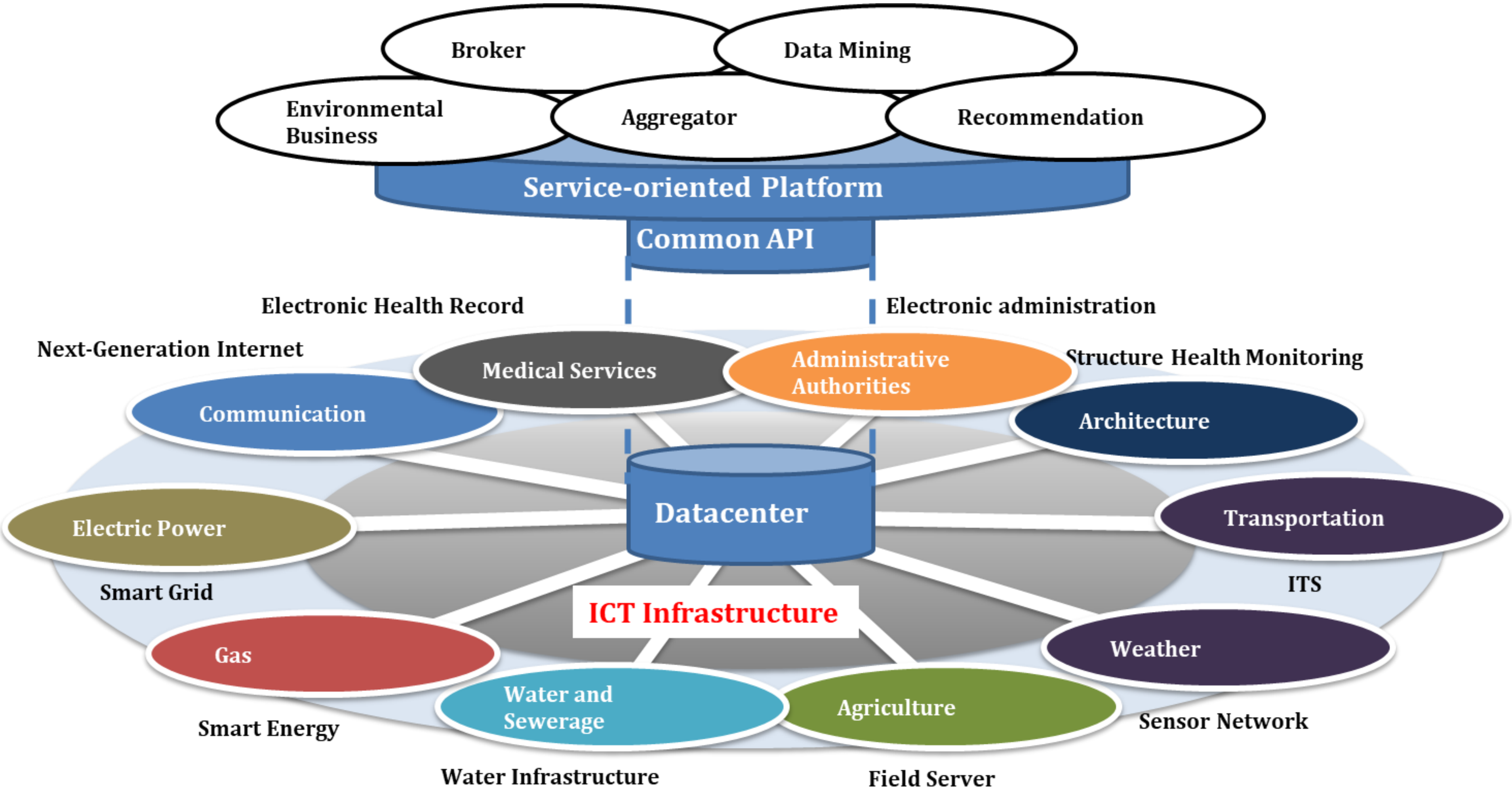

Pollution


Water
& Energy


Health
& Wellbeing


Crime

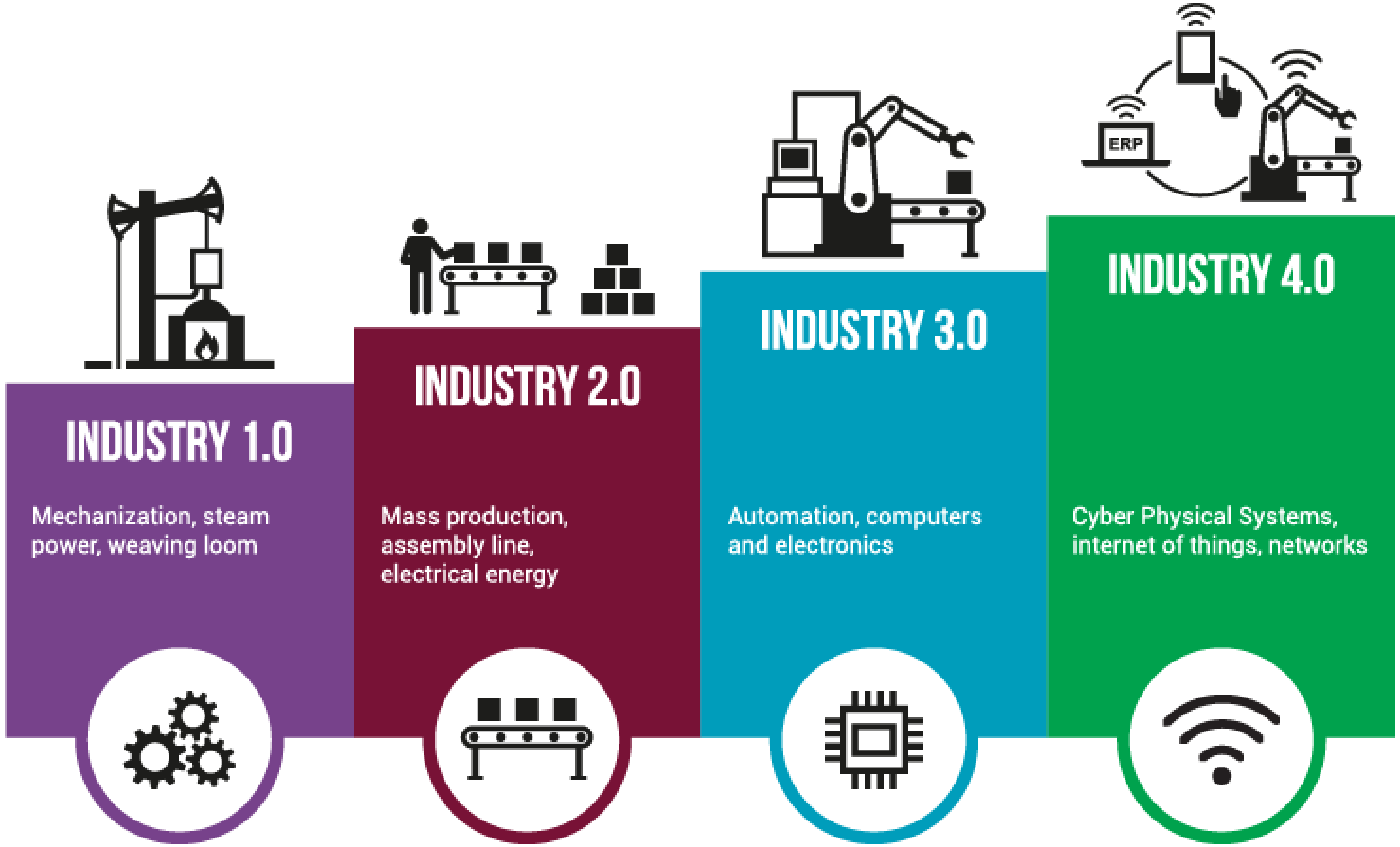
SMART COMMUNITY




AUTOMATION

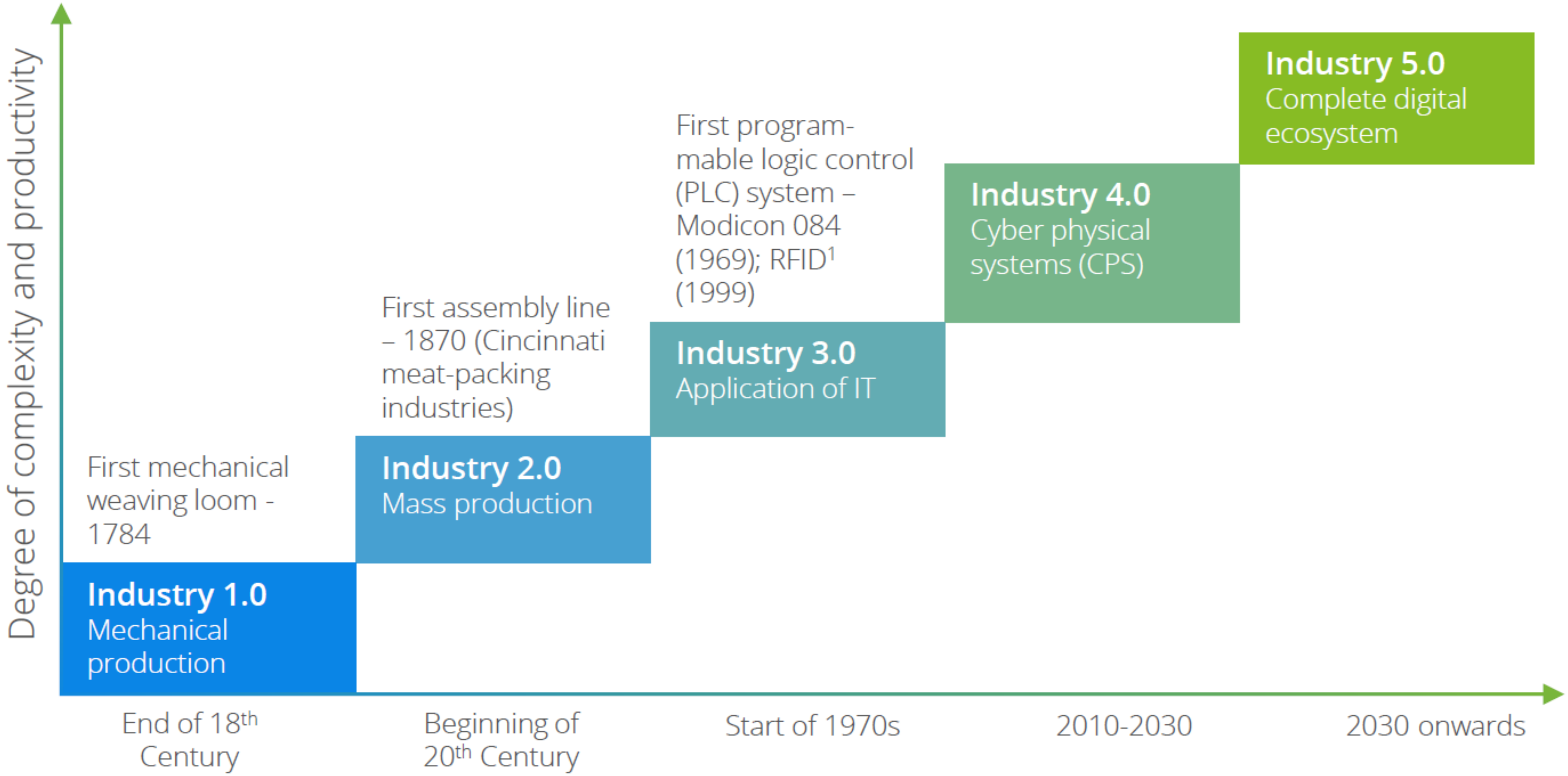
WHAT IS AUTOMATION

INDUSTRY REVOLUTION



Statista.com, “In-depth: Industry 4.0 2019”, August 2019

Industrial evolution timeline



Source: Deloitte, PwC

Statista.com, "In-depth: Industry 4.0 2019", August 2019

INDUSTRY REVOLUTION

https://www.ibm.com/topics/industry-4-0

First industrial revolution

- Starting in the late 18th century in Britain
- mass production by using water and steam power instead of purely human and animal power.

Second industrial revolution

- A century later, introduced assembly lines and the use of oil, gas and electric power.
- more advanced communications via telephone and telegraph
- mass production and some degree of automation to manufacturing processes.

Third industrial revolution

- began in the middle of the 20th century, added computers, advanced telecommunications and data analysis.
- The digitization of factories began by embedding programmable logic controllers (PLCs) into machinery
- automate some processes and collect and share data.

Fourth industrial revolution

- Characterized by increasing automation and the employment of smart machines and smart factories, informed data
- Flexibility is improved so that manufacturers can better meet customer demands using mass customization
- more data from the factory floor and combining that with other enterprise operational data,
- a smart factory can achieve information transparency and better decisions.

CONVERGED NETWORKS

It always works as connected network.

Carry data, voice, video & images over the same network

No separate networks for all these services, convergence in networking allows businesses to use just one network for **all communication**

consolidating multiple IT components to lower costs and increase service availability.

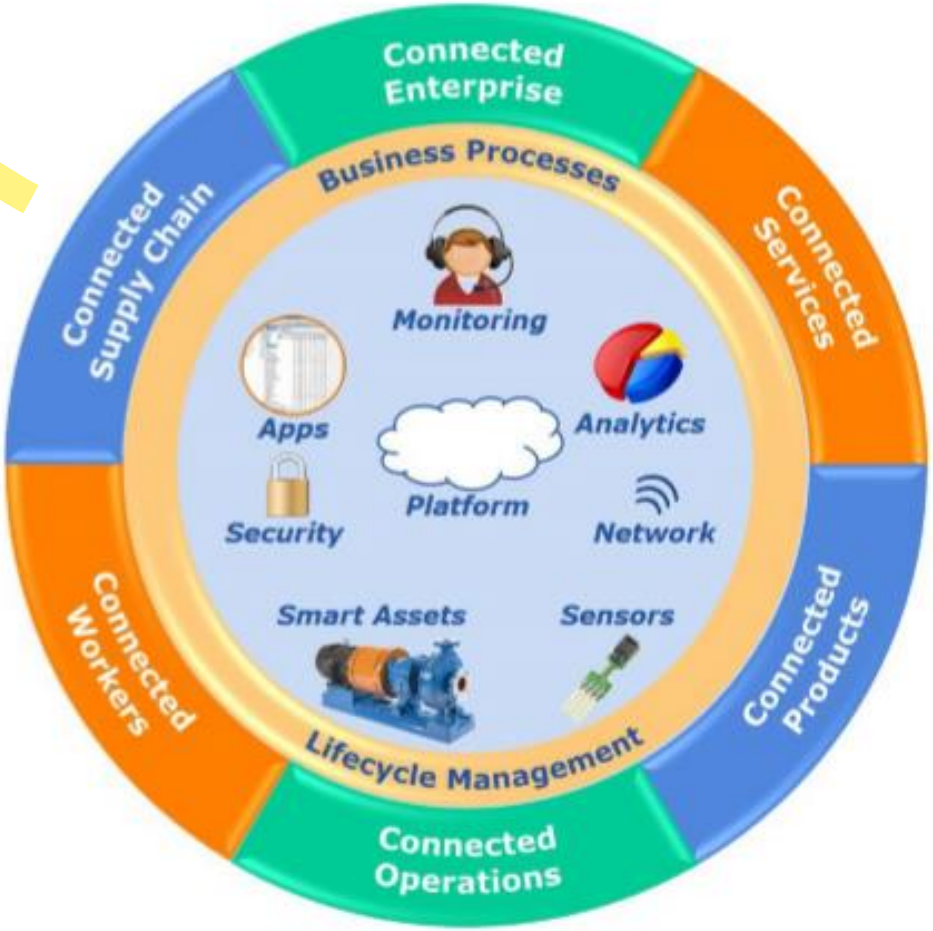
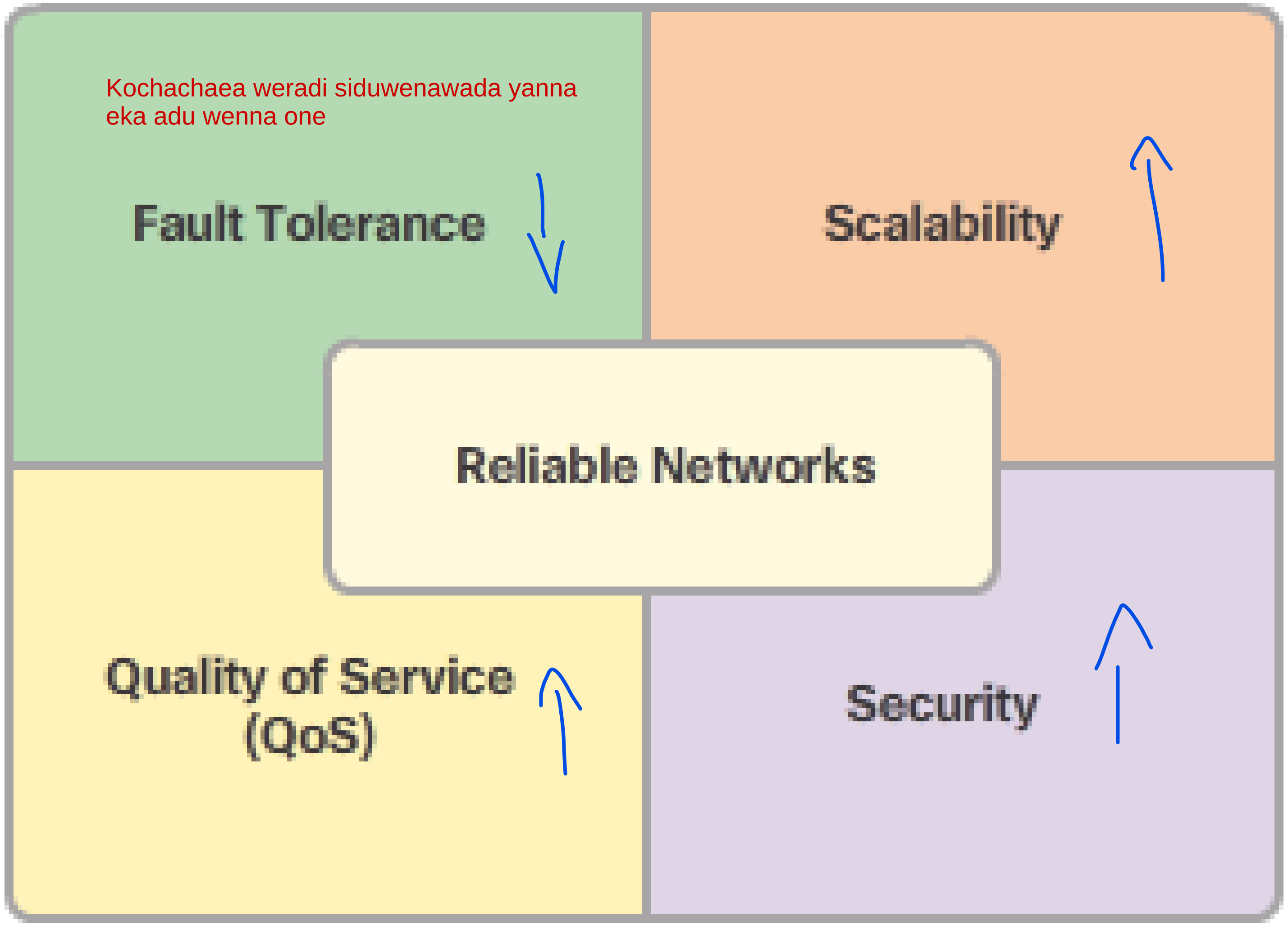


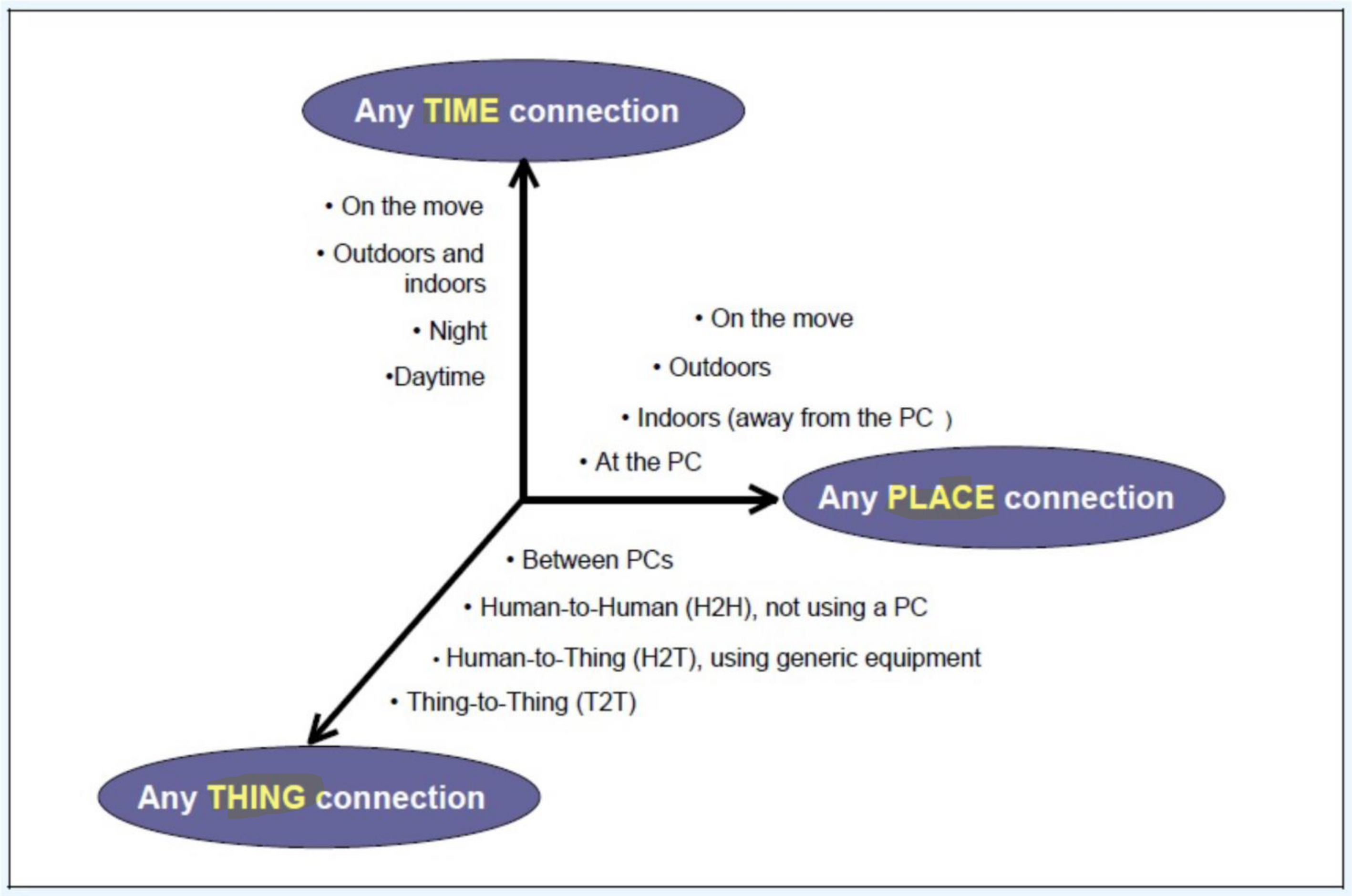
Image courtesy - Automation Research Corp

https://www.iiot-world.com/industrial-iot/connected-industry/converged-networks-a-peek-into-the-future/

RELIABLE NETWORKS

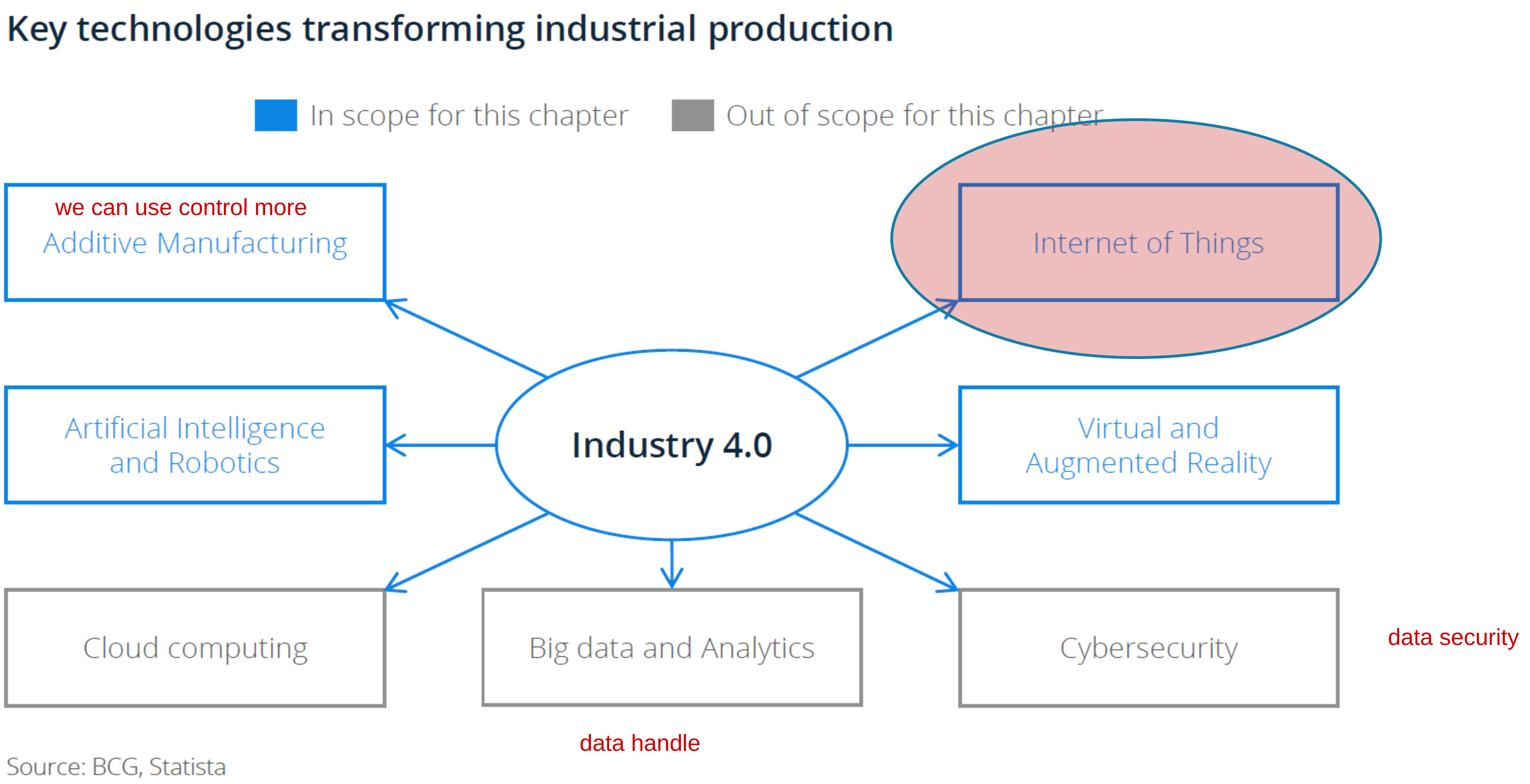


SO TODAY NETWORKING



Source: Towards a definition of the Internet of Things (IoT) Revision 1 – Published 27 MAY 2015

KEYS OF SECRET



HISTORICAL DEFINITIONS FOR IOT

Consider one of the greatest engineering pioneers, Nikola Tesla, who in a 1926 interview with Colliers magazine said:

> *"When wireless is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, all things being particles of a real and rhythmic whole and the instruments through which we shall be able to do this will be amazingly simple compared with our present telephone. A man will be able to carry one in his vest pocket."*

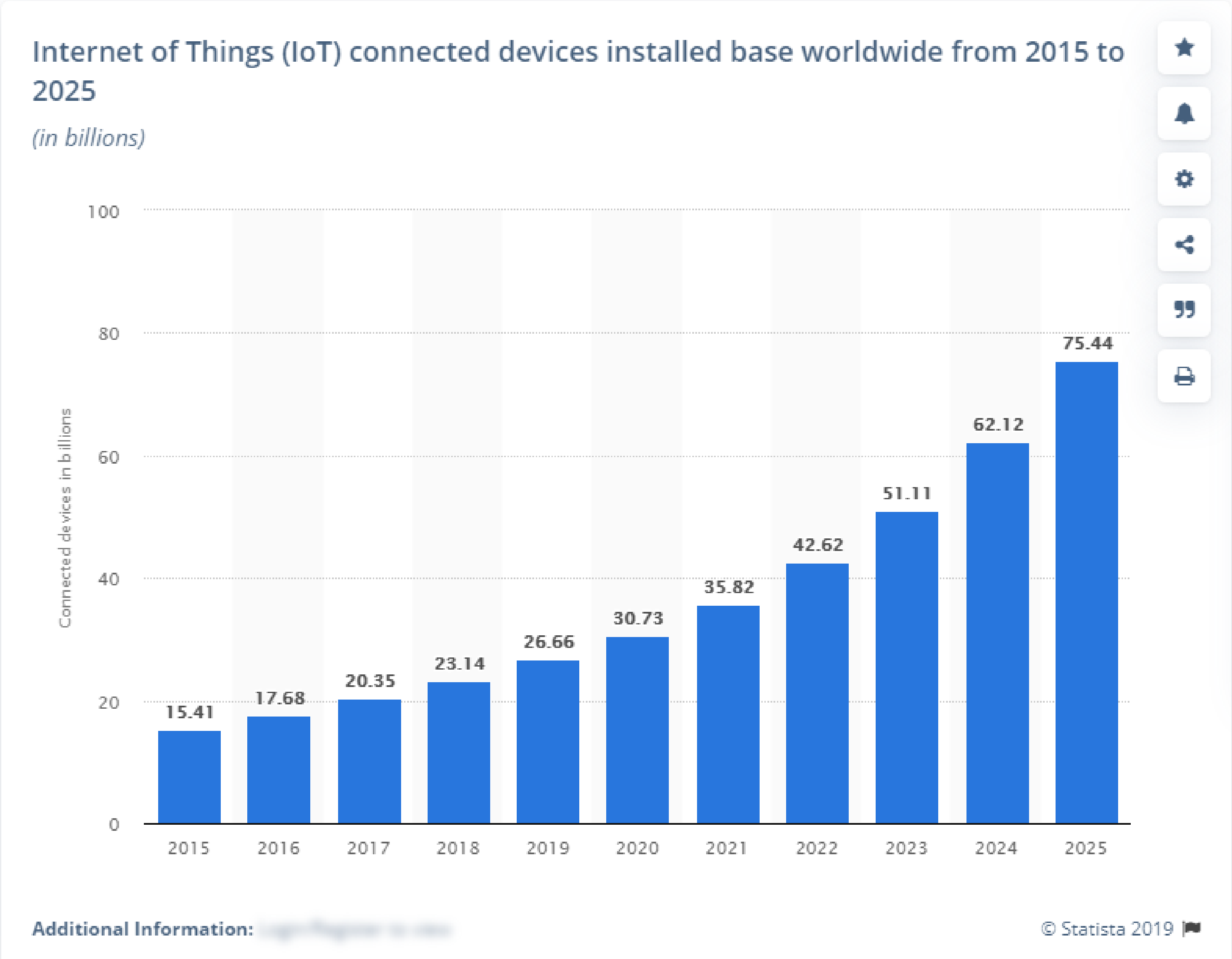
Source: `http://www.tfcbooks.com/tesla/1926-01-30.htmv`

In 1950, the British scientist Alan Turing was quoted as saying:

> *"It can also be maintained that it is best to provide the machine with the best sense organs that money can buy, and then teach it to understand and speak English. This process could follow the normal teaching of a child."*

Source: A. M. Turing (1950) Computing Machinery and Intelligence. Mind 49: 433-460

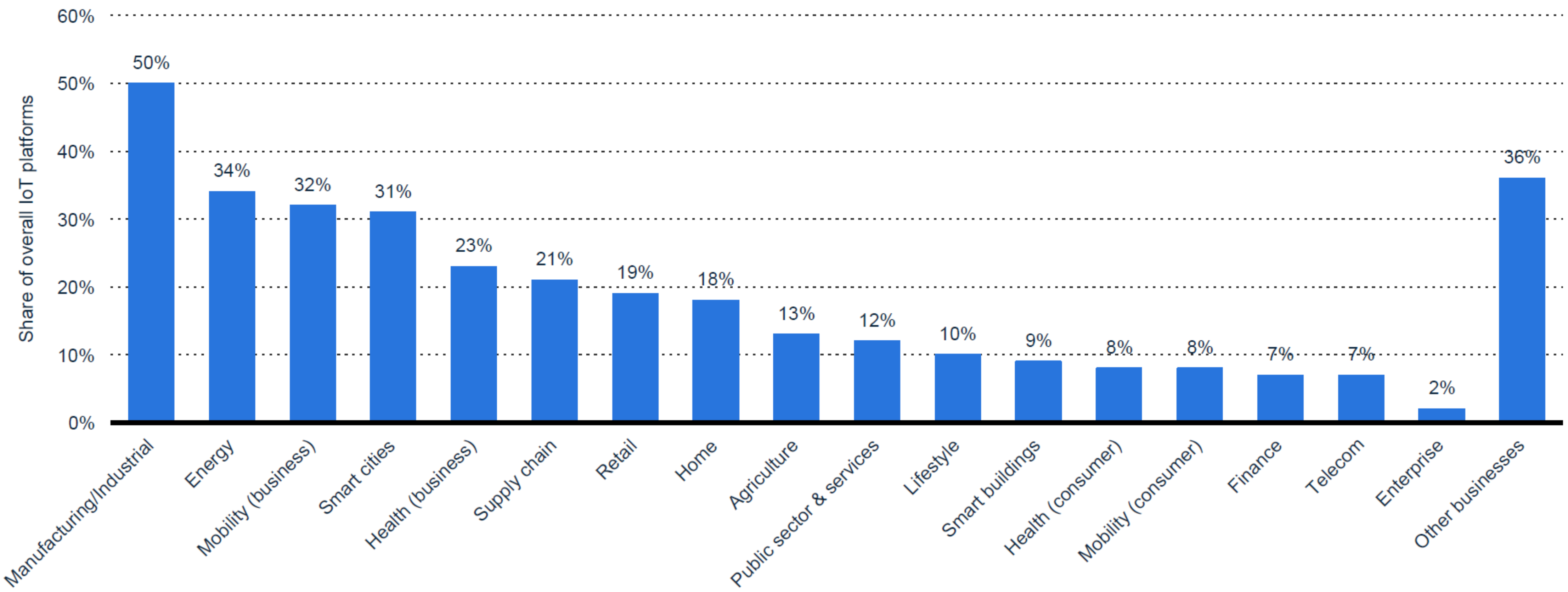
INTERNET OF THINGS (IOT) CONNECTED DEVICES INSTALLED BASE WORLDWIDE FROM 2015 TO 2025 (IN BILLIONS)



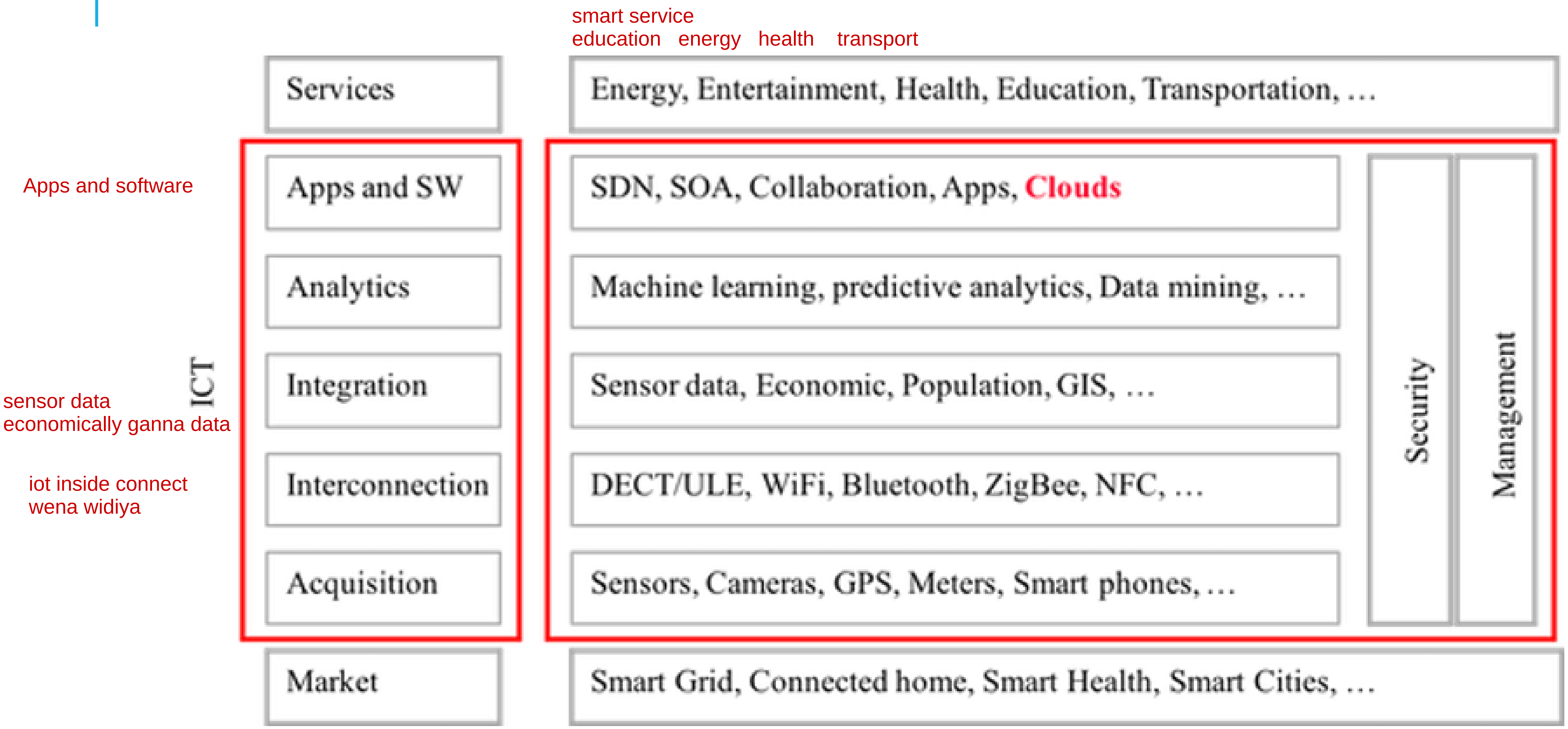
https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/

Share of Internet of Things (IoT) platforms worldwide as of December 2019, by industry*

Global IoT platform share by industry 2019



IOT ECO-SYSTEM



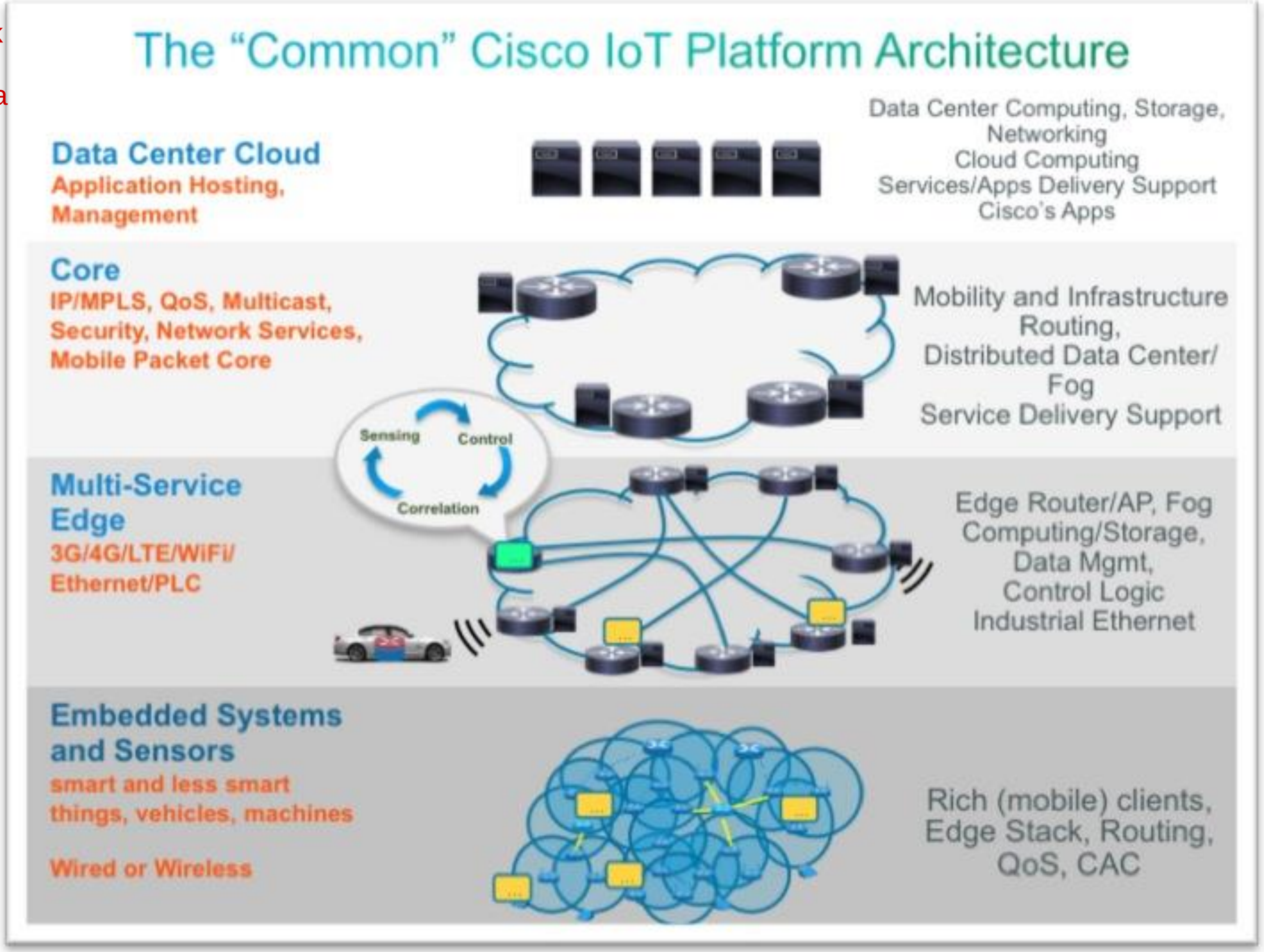
Ref: https://www.cse.wustl.edu/~jain/cse570-15/ftp/iot_prot/ routing

EXAMPLE FOR AN IOT PLATFORM

sensor --> controler --> Actuators

EX: temprature eka wedi unoth fan eka on wenna

sensor godakin ganna data ekakata ekak conneck karala sensors magin data aragena embeded system ekak harahaa ada adaala actuator ekakata denawa.



connect wena widiya

data communicate wena widiya

full system ekaka integration eka

temparature identify --> sensor

increace temprature --> Embeded system

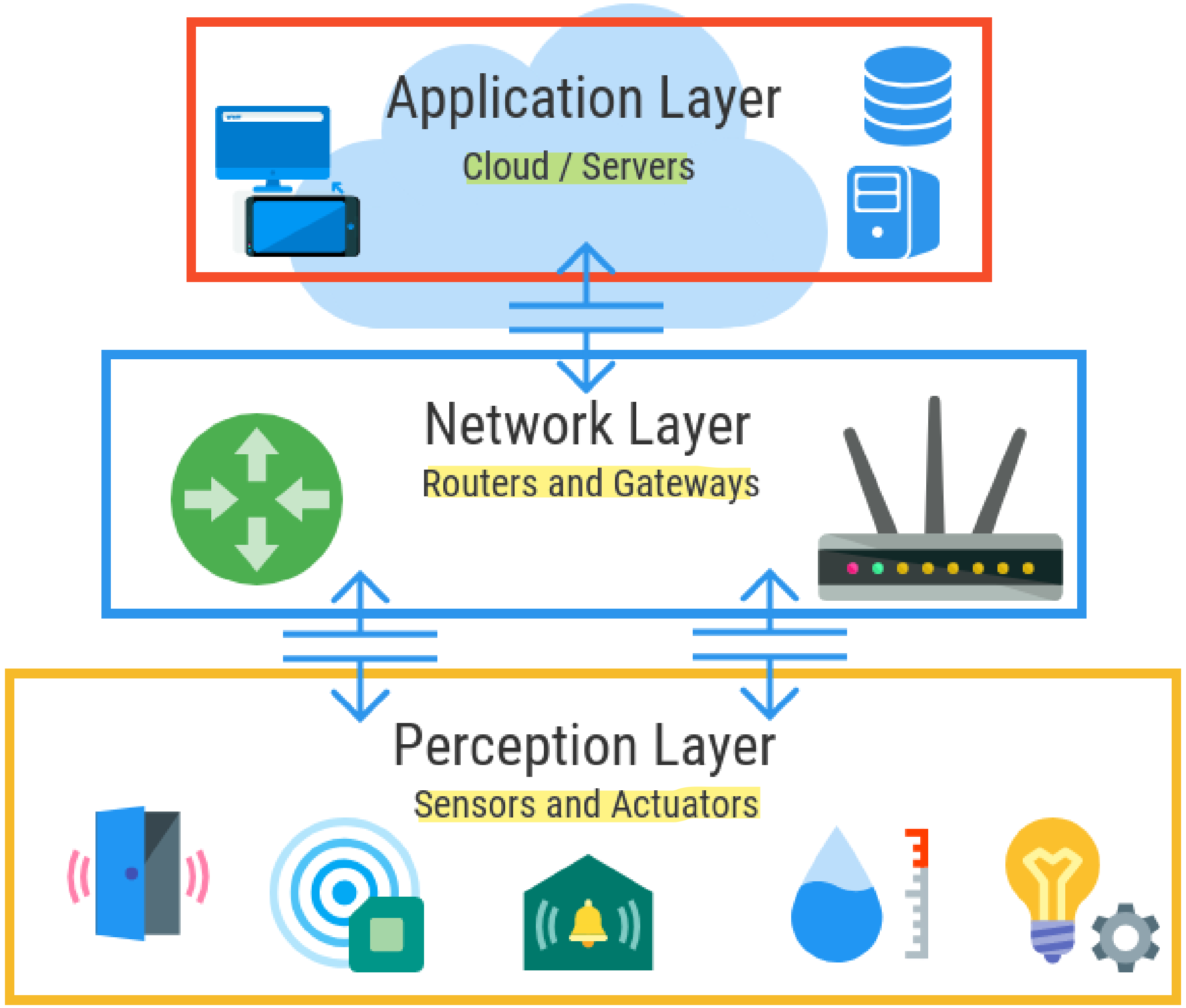
on wena singala --> actuator(fan)

REF: https://www.cisco.com/c/en/us/about/security-center/secure-iot-proposed-framework.html 3

THREE LAYER (TIER) IOT ARCHITECTURE

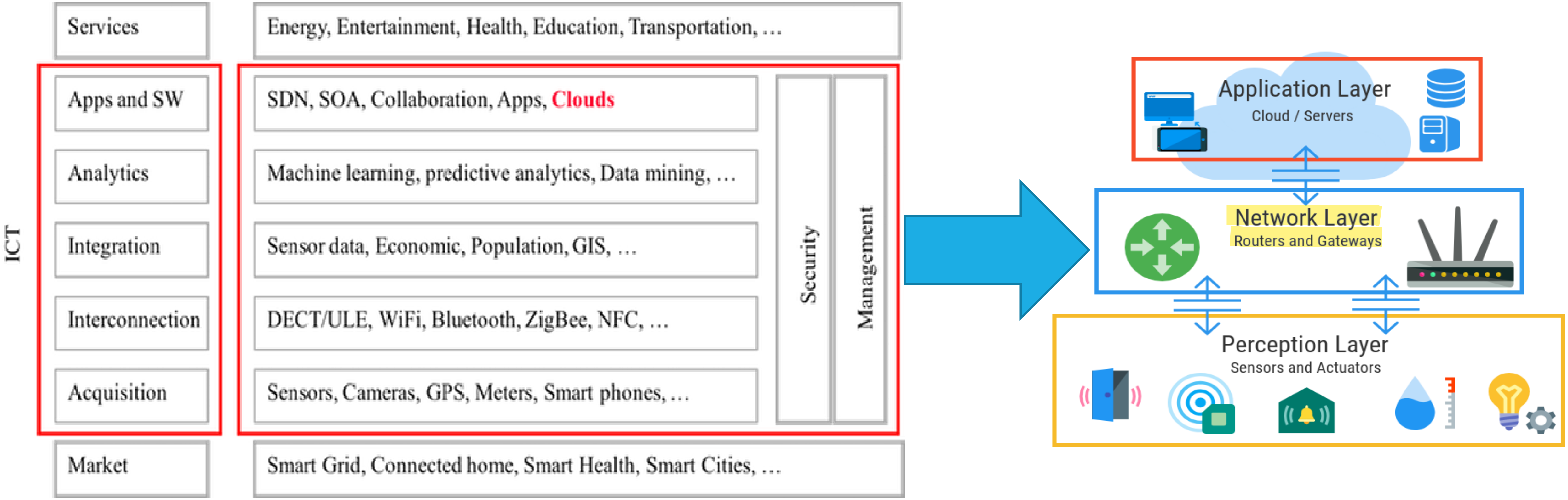
sensor data value identifing

Ex:
: door open
: tapping cards
: alarming
: temparature



https://www.netburner.com/learn/architectural-frameworks-in-the-iot-civilization/

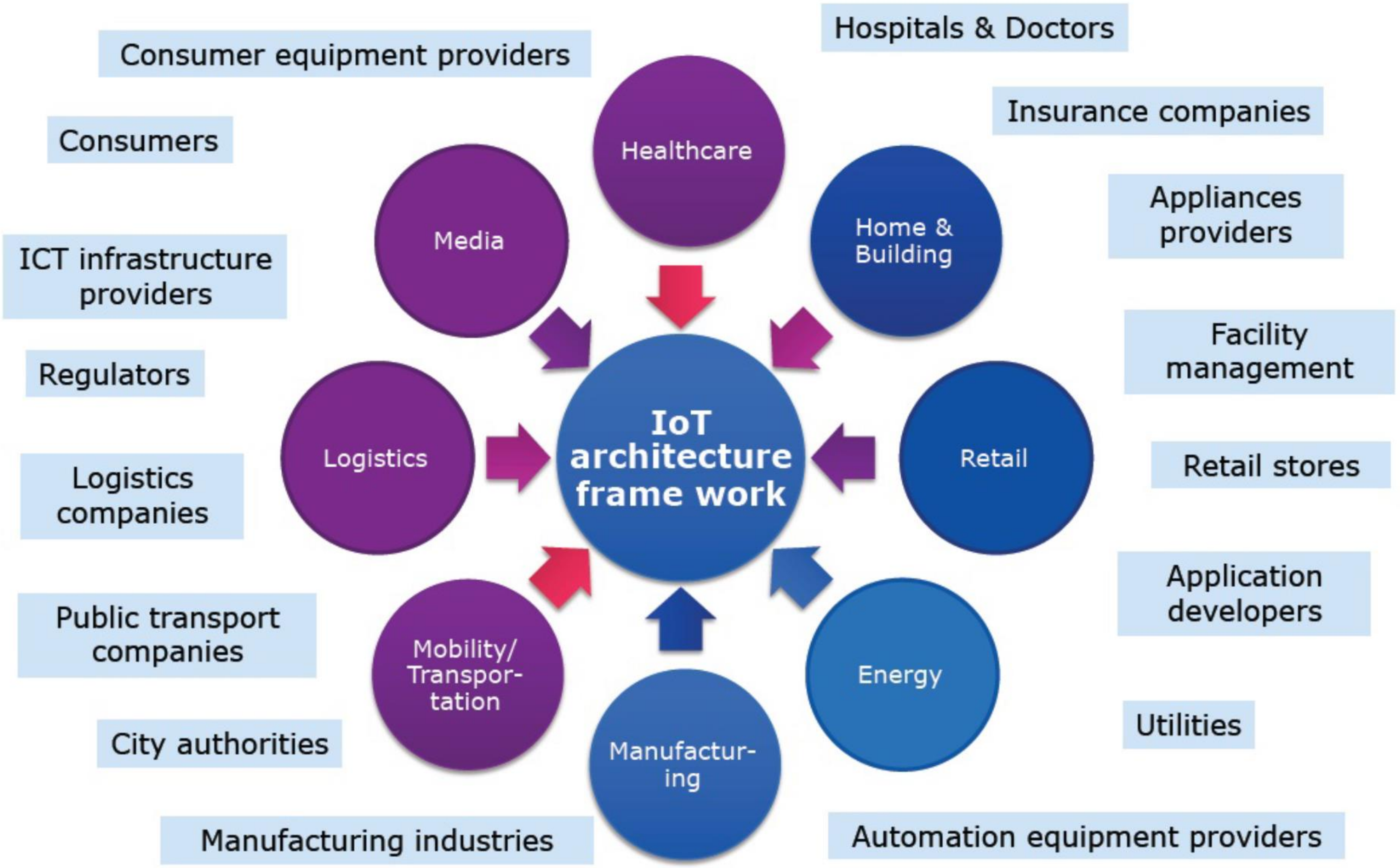
THREE LAYER (TIER) IOT ARCHITECTURE



https://www.netburner.com/learn/architectural-frameworks-in-the-iot-civilization/

MARKET

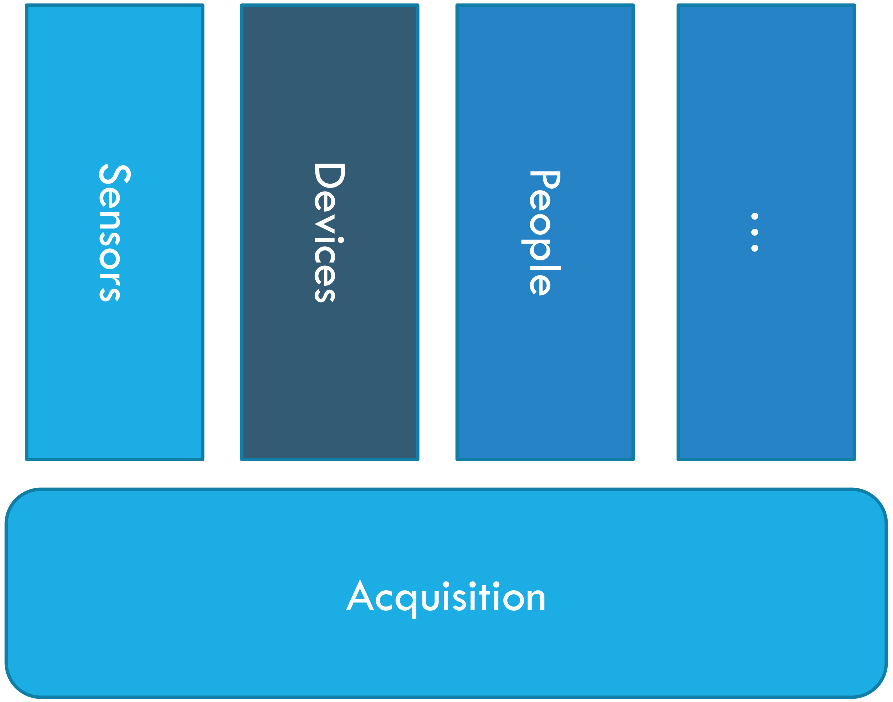
resources --> network
device or hosting sapayana aya



Source: Towards a definition of the Internet of Things (IoT) Revision 1 – Published 27 MAY 2015

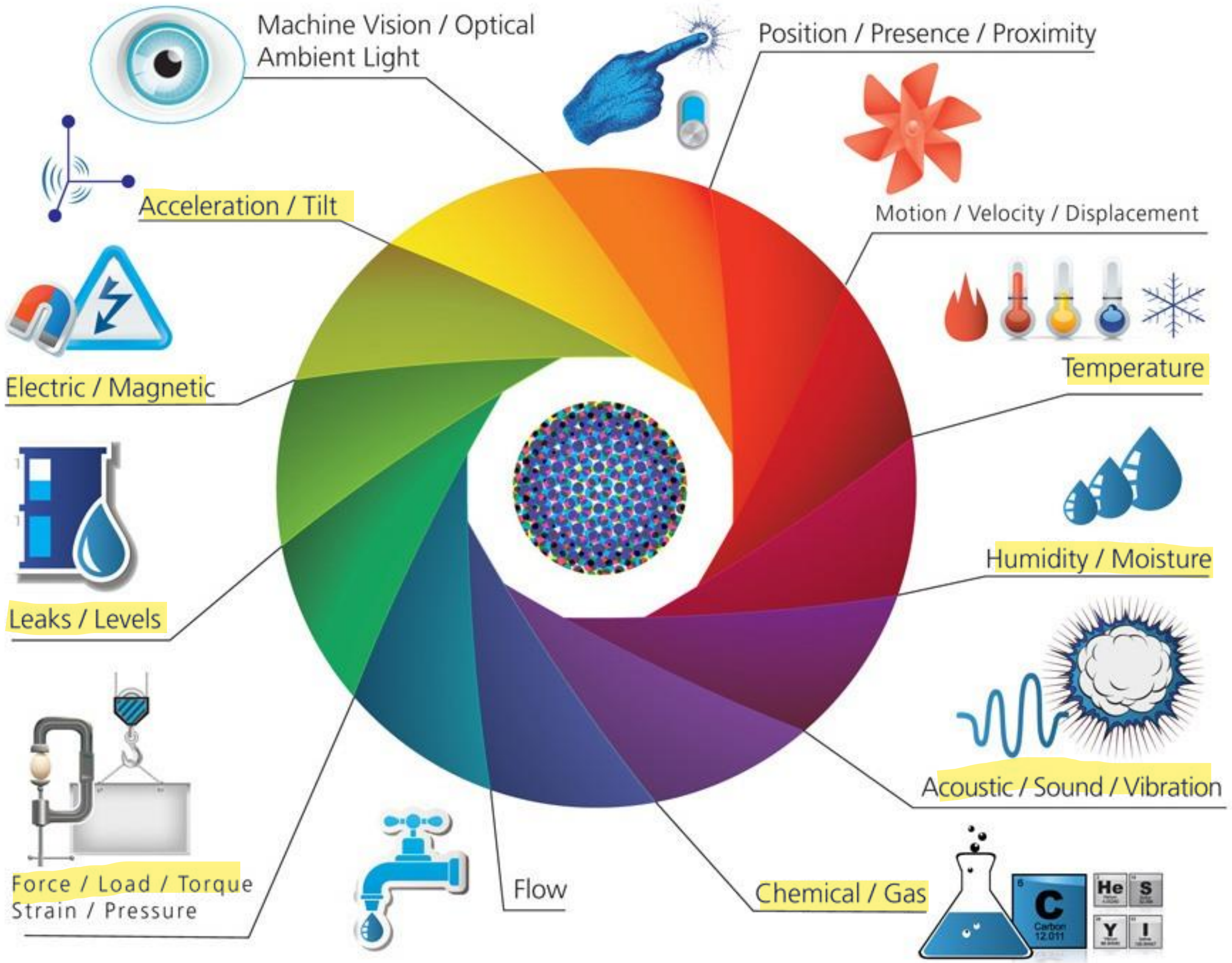
DATA GATHERING / REMOTE SENSING

The layer that the are collected to provide smart services.



Source: https://www.postscapes.com/trackers/video/the-internet-of-things-and-sensors-and-actuators/

ACQUISITION: SENSORS



Source: https://www.postscapes.com/trackers/video/the-internet-of-things-and-sensors-and-actuators/

INTEGRATIONS: THINGS

(data gathering karana widiya)

Tagging things: RFID

tag and track

sticker tapping
card tapping

Feeling things: Sensor technologies

Eyes: Collecting Data

Hands: Implementing actions

Thinking things: Smart technologies

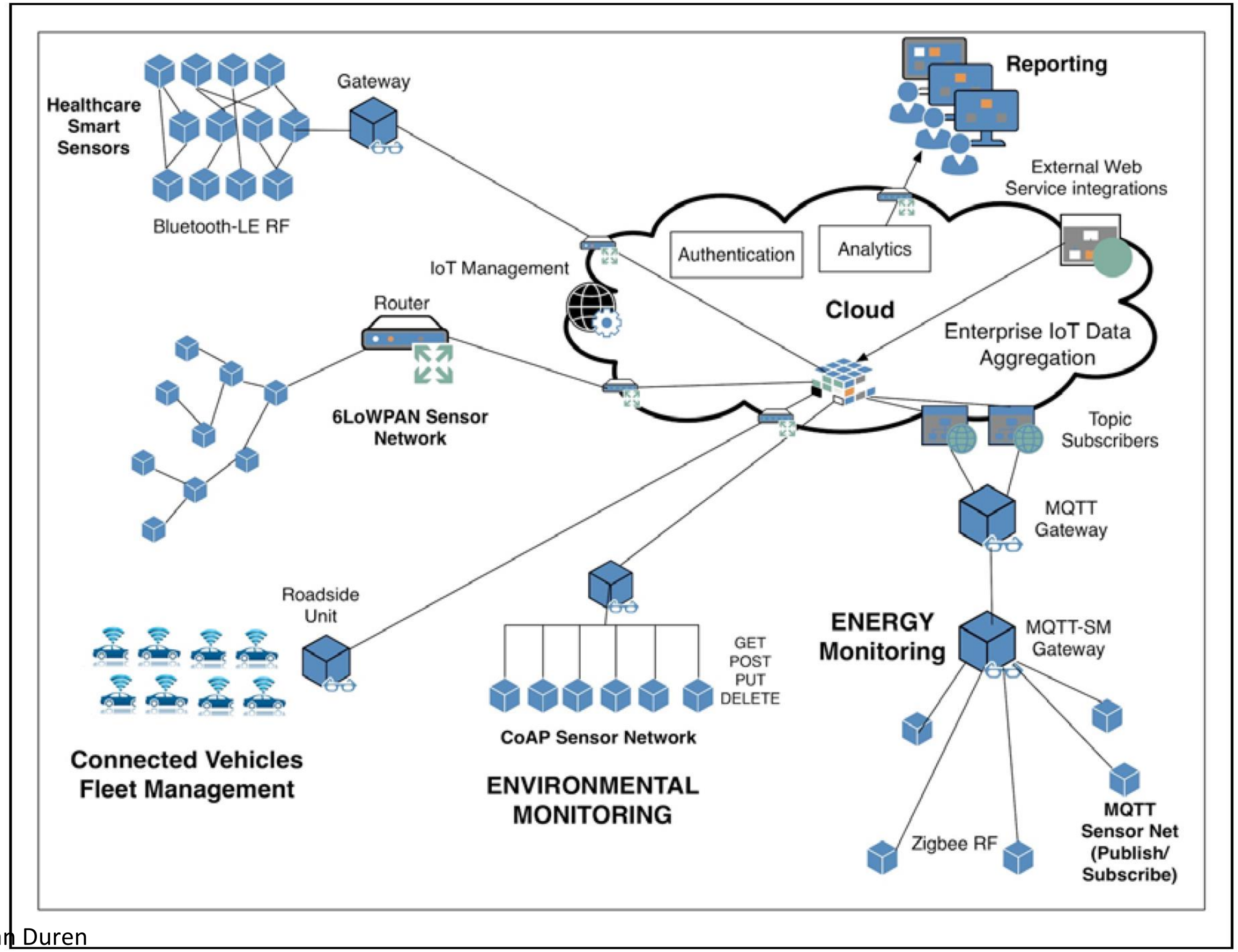
"Passive" smart materials that respond directly and uniformly

"Active" smart materials that can, with a remote controller, sense a signal and determine how to respond

"Autonomous" smart materials that carry fully integrated controllers, sensors and actuators

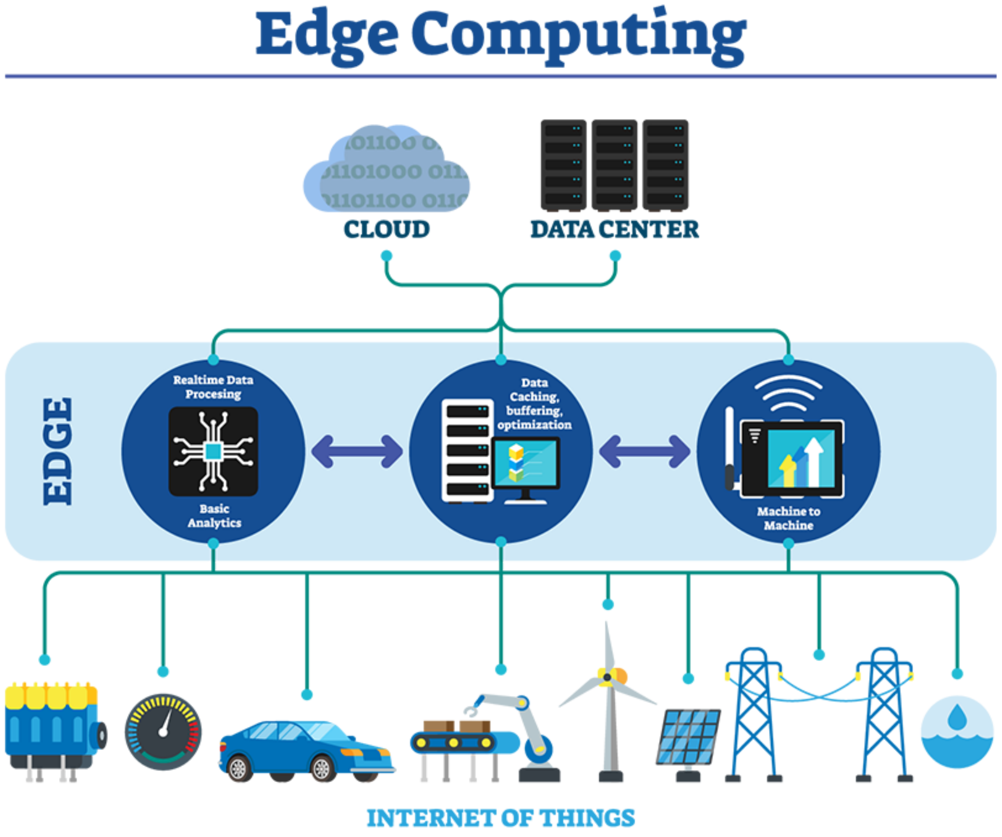
Shrinking things: Nanotechnology

INTERCONNECTION: DATA FLOW IN IOT NETWORKS



Source: Practical Internet of Things Security by Brian Russell, Drew Van Duren

EDGE COMPUTING



https://innovationatwork.ieee.org/real-life-edge-computing-use-cases/

IOT COMMUNICATION

Satellite

WiFi

Radio Frequency (RF)

RFID short range -- > RFID tapping card system

Bluetooth

NFC short range

https://www.getkisi.com/blog/internet-of-things-communication-protocols publisher

onema topic ekaka data
transfer to Exchange brocker

Exchanger

Data cut
for small Queses

send data to
subscriber

Consumer

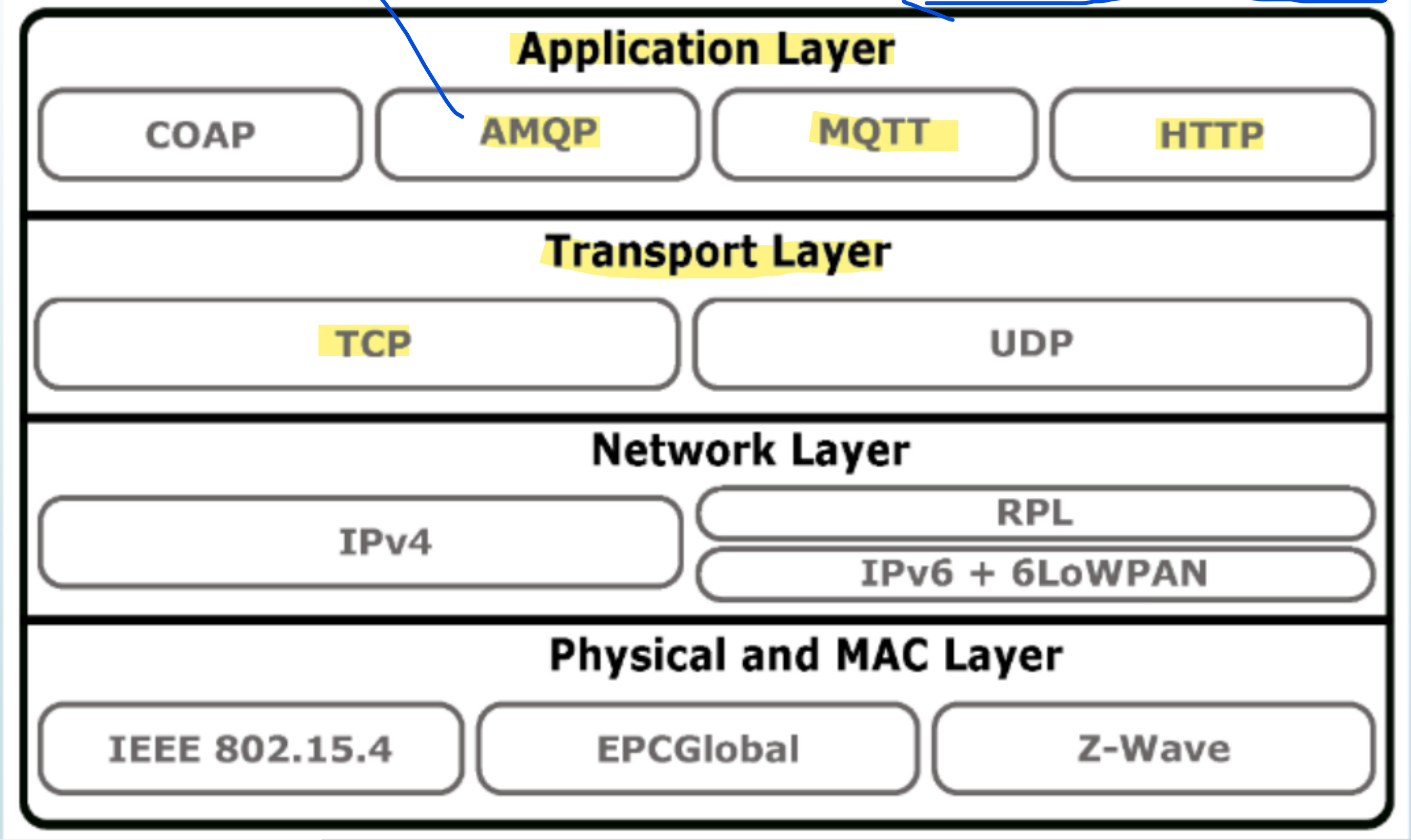
speed

Data cut
for small Queses

send data to
subscriber

Consumer

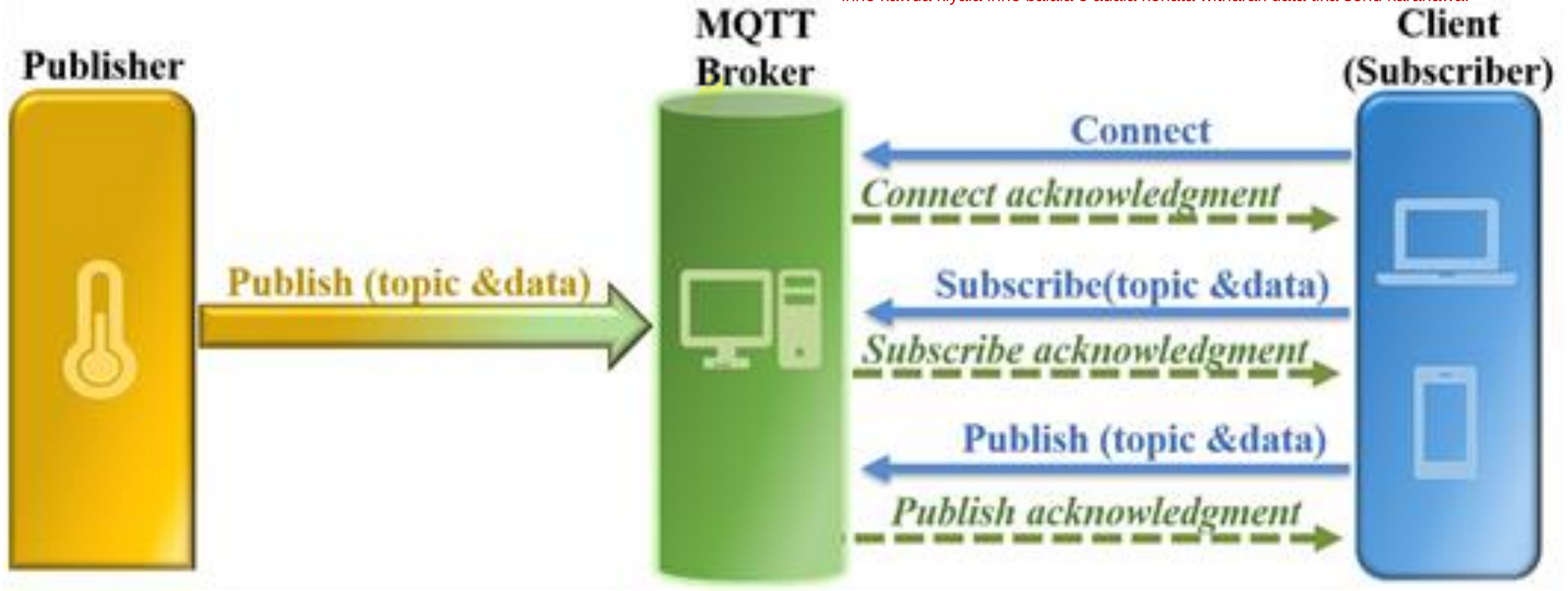
IOT COMMUNICATION PROTOCOLS



How MQTT communication working ?

MQTT COMMUNICATION

publisher karanne menna me topic ekata adala data kiyala data request ekak widiyata MQTT brocker ta kiyanawa. MQTT eka check karala me adala topics walata adala subscriber wela inne kawda kiyala inne balala e adala kenata witharak data tika send karanawa.



https://www.scirp.org/journal/paperinformation.aspx?paperid=108890
https://randomnerdtutorials.com/esp8266-and-node-red-with-mqtt/

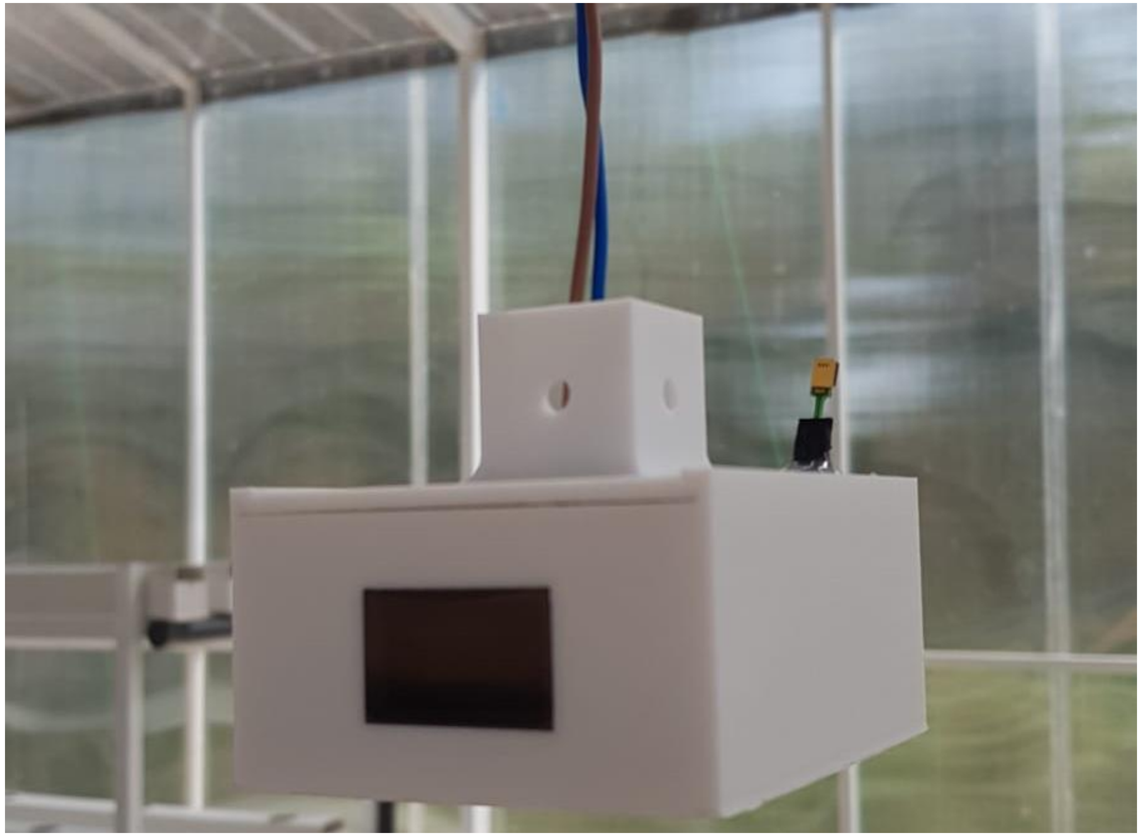
WHY MQTT FOR IOT APPLICATIONS?

HTTP Transport Protocol		MQTT Transport Protocol	
Document centric		Data-centric	
Request-response paradigm		Publish-Subscribe paradigm	
Higher power requirement	more data sending	low power requirement	specific data send only
IoT devices are always ready to receive communication		IoT devices choose when to receive communication	
Directly communication between IoT agent and IoT devices		Indirectly communication between IoT agent and IoT devices	
Slow throughput		Faster throughput	adaala data witharak ganna nisa speed wedii

Table 1. Major differences between MQTT protocol and HTTP protocol.

https://www.scirp.org/journal/paperinformation.aspx?paperid=108890

SLIIT GREENHOUSE AUTOMATION PROJECT



Researchers: Prof. Pradeep Abeygunawardhana
Mr. Rajitha de. Silva

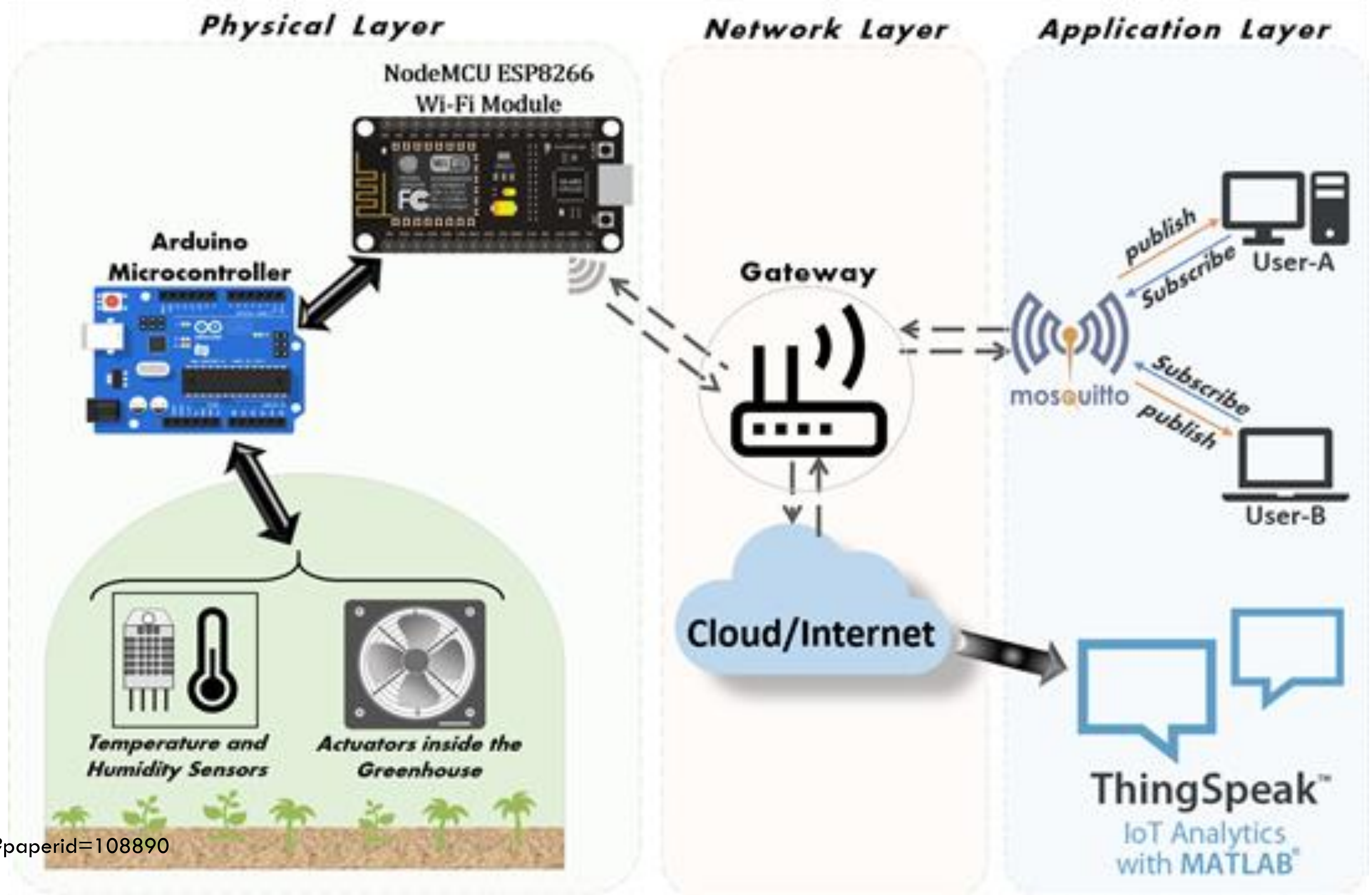
GREENHOUSE AUTOMATION PROJECT

Ardino microcontroller : sensor and actuatord handleng

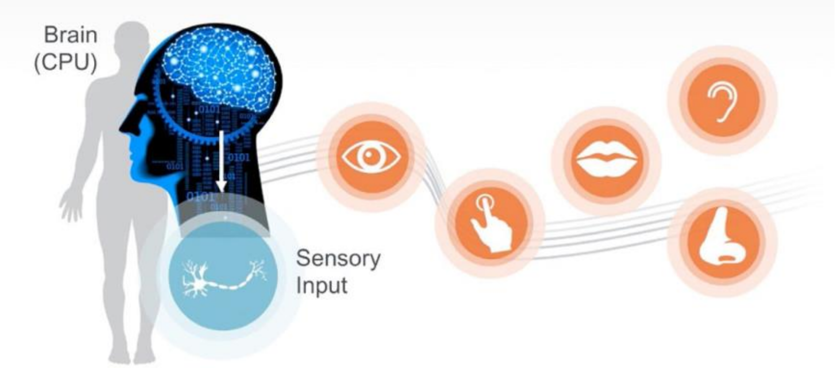
NodeMCU8266 : arduno eke data network ekakata send karanna use karanawa

ThingsSpeak: data analysis

mosqutor : broker kenek with publisher and consumer

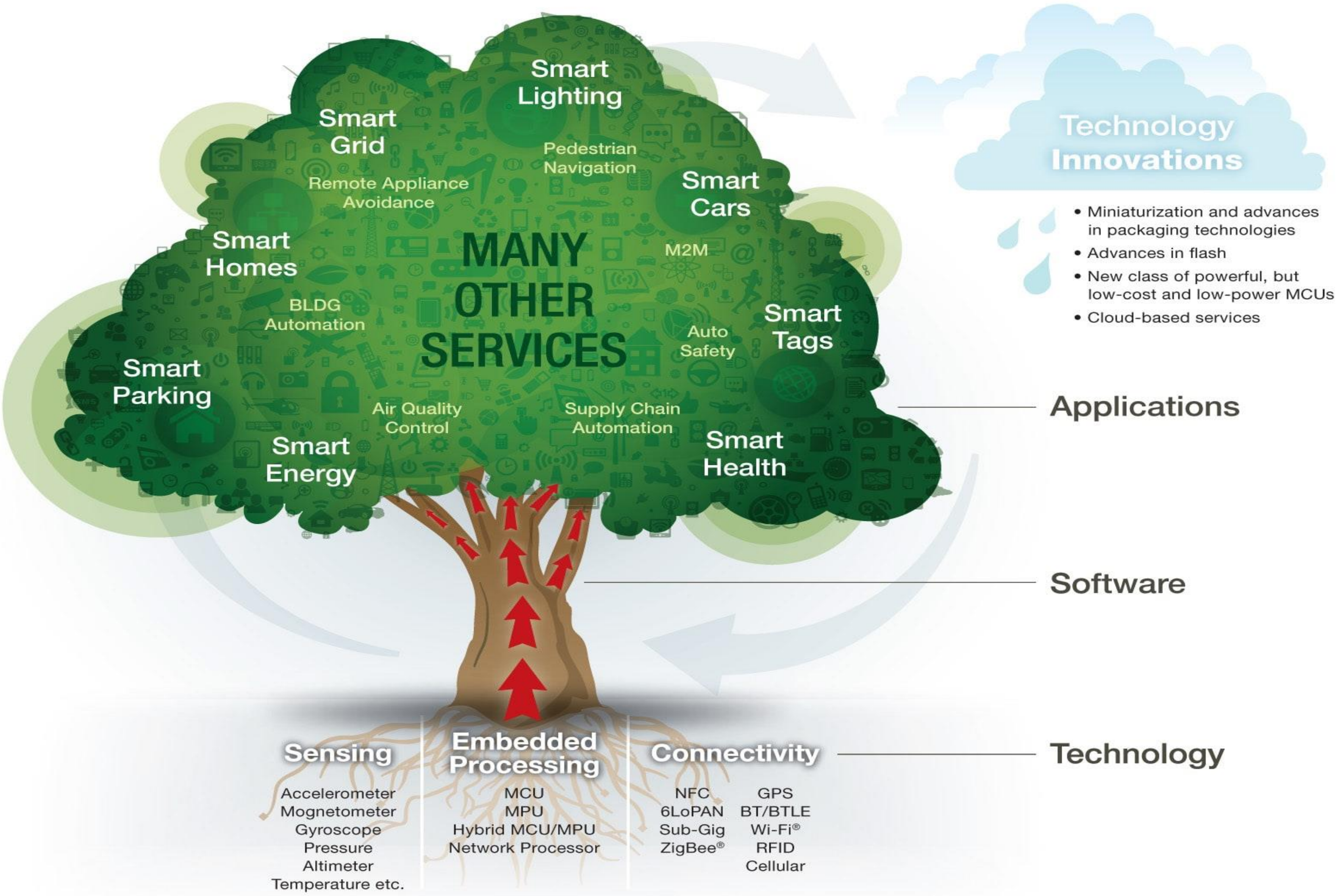


https://www.scirp.org/journal/paperinformation.aspx?paperid=108890



SENSORS IN INTERNET OF THINGS

Pradeep Abeygunawardhana



Smart Lighting
Smart Grid
Pedestrian Navigation
Remote Appliance Avoidance
Smart Cars
Smart Homes
M2M
MANY OTHER SERVICES
BLDG Automation
Smart Tags
Auto Safety
Smart Parking
Air Quality Control
Supply Chain Automation
Smart Energy
Smart Health
Technology Innovations
• Miniaturization and advances in packaging technologies
• Advances in flash
• New class of powerful, but low-cost and low-power MCUs
• Cloud-based services
Applications
Software
Technology
Sensing
Accelerometer
Mognetometer
Gyroscope
Pressure
Altimeter
Temperature etc.
Embedded Processing
MCU
MPU
Hybrid MCU/MPU
Network Processor
Connectivity
NFC
6LoPAN
Sub-Gig
ZigBee®
GPS
BT/BTLE
Wi-Fi®
RFID
Cellular

SENSORS

- Why do we Need Sensors?
- What can be Sensed?
- What Sensors are Out There?
- What can They do?
- How Much do They Cost?
- How Easy are They to Use?

WHY DO NEED SENSORS?

- Provides "awareness" of surroundings
  - What's ahead, around, "out there"?
- Allows interaction with environment
  - Robot lawn mower can "see" cut grass
- Protection & Self-Preservation
  - Safety, Damage Prevention, Stairwell sensor
- Gives the machine capability to goal-seek
  - Find colorful objects, seek goals
- Makes things "interesting"

SENSORS – WHAT CAN BE SENSED?

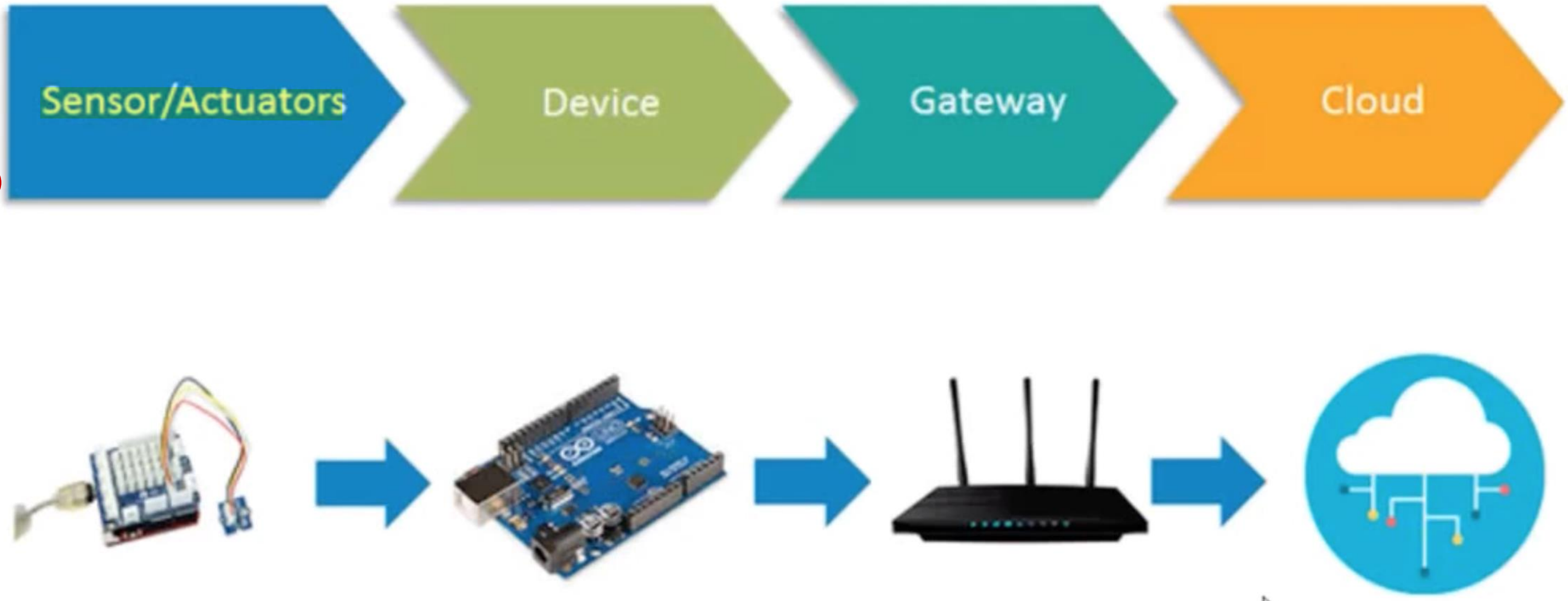
- Light
  - Presence, color, intensity, content (mod), direction
- Sound
  - Presence, frequency, intensity, content (mod), direction
- Heat
  - Temperature, wavelength, magnitude, direction
- Chemicals
  - Presence, concentration, identity, etc.
- Object Proximity
  - Presence/absence, distance, bearing, color, etc.
- Physical orientation/attitude/position
  - Magnitude, pitch, roll, yaw, coordinates, etc.

IoT Architecture

actuators magin data pass wenawada nedda kiyala theeranaya wenne api use karana connection eka matha. eka open loop and close loop widiyata kotas 2i.

open loop: room switch on light on
(no feedback)

close loop: switch on --> light on
(provide system to feedback light on)



Ardino UNO
NANO
ESP32
NODEMCU

- How many sensors are there in this image?

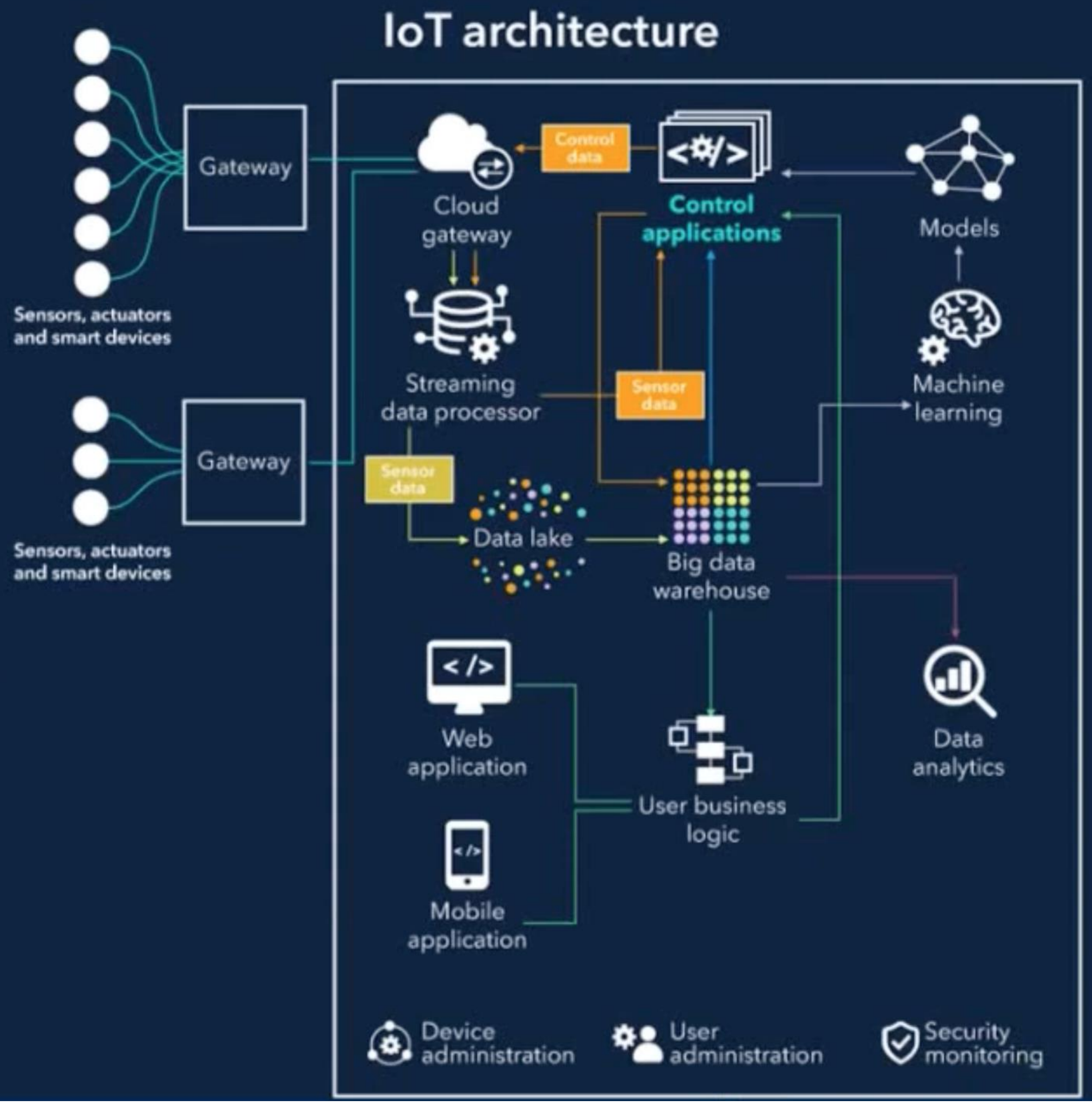
mona hari measure karanna use karanna onema deyak sensor widiyata ganna puluwa

phone
man
eye
hearing
touch

IoT Hardware

- The Internet of Things is developing at a rapid pace, thanks to the availability of small, inexpensive computing hardware.
- IoT prototyping kits and development boards combine microcontrollers and processors with wireless chips and other components like sensors and actuators in a pre-built, ready-to-program package.
- They come in nearly infinite configurations, from tiny battery-powered chips that work on Bluetooth to credit card-sized computers with USB power supplies and high-bandwidth Wi-Fi radios. Whatever the needs of your project or product, there's sure to be a board that fits your exact requirements.
- IoT Hardware includes a wide range of devices such as devices for routing, sensing, actuating, computing etc.
- These IoT devices manage key tasks and functions such as system activation, security, action specifications, communication, and detection of support-specific goals and actions.

IoT Architecture

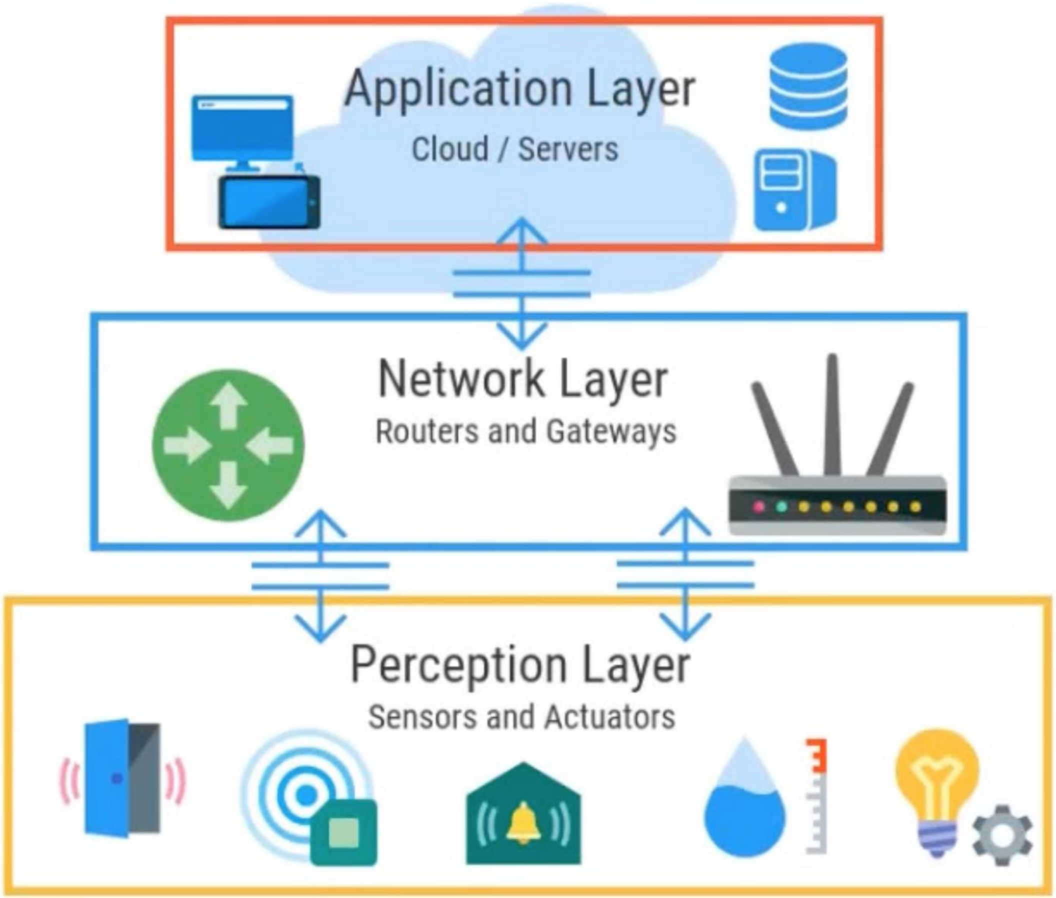


Components of IoT Architecture

- Sensors/Devices
- Gateways and Networks
- Cloud/Management
- Application Layer

IoT Architecture

- The perception layer is the physical layer, which has sensors for sensing and gathering information about the environment.
- The network layer is responsible for connecting to other smart things, network devices, and servers. Its helps in transmitting the edge device/sensor data to cloud.
- The application layer is responsible for delivering application specific services to the user. It defines various applications in which the Internet of Things can be deployed, for example, smart homes, smart cities, and smart health.

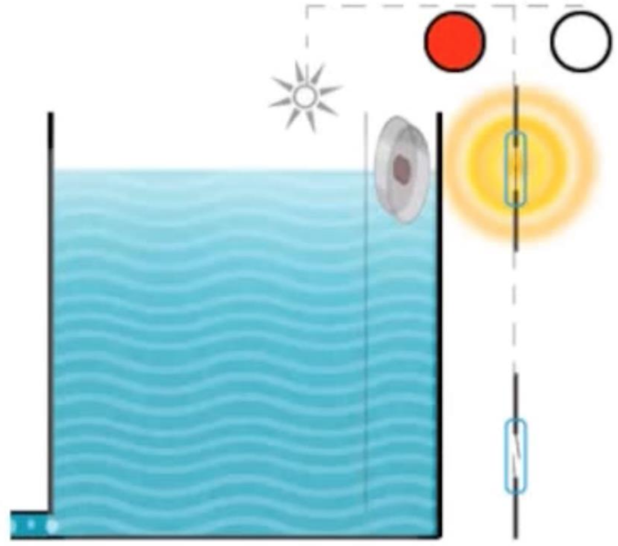


IoT Hardware: Sensors & Actuators

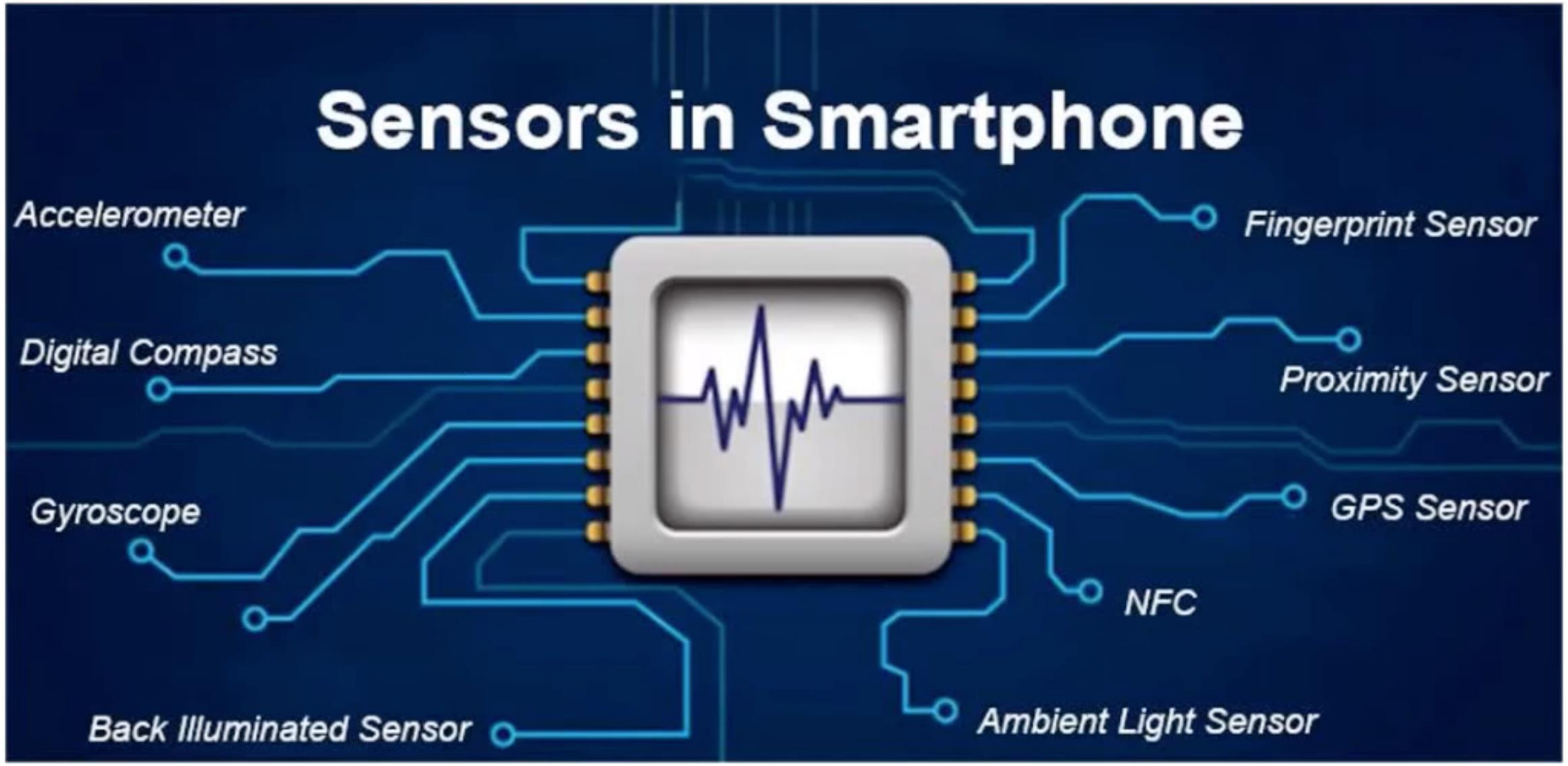
Sensors: Sensor is a device that is able to detect changes in an environment. By itself, a sensor is useless, but when we use it with a controller or a processor, it plays a key role. A sensor is able to measure a physical phenomenon (like temperature, pressure, and so on) and transform it into an electric signal. For example: Temperature sensor

Actuators: Actuators can also intervene to change the physical conditions that generate the data. An actuator might, for example, shut off a power supply, adjust an air flow valve, or move a robotic gripper in an assembly process.

Sensing/Actuating stage covers everything
Example: Industrial devices to robotic camera systems, water-level detectors, air quality sensors, accelerometers, and heart rate monitors

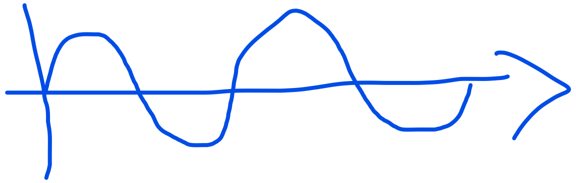


Sensors



Sensors in Smartphone
Accelerometer
Digital Compass
Gyroscope
Back Illuminated Sensor
Fingerprint Sensor
Proximity Sensor
GPS Sensor
NFC
Ambient Light Sensor

Analog Vs Digital Sensor

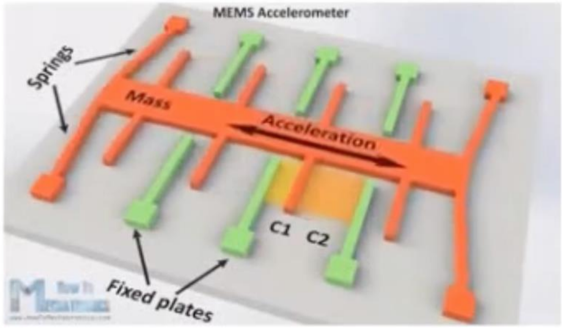


Analog Sensor

variable physical parameters: ekinekata wenas wena (temparature --> 0 , 100, 150) widiyata wenas weema

Produces continuous analog voltage proportional to the measured.

Examples: Accelerometer, Light, Sound, Pressure etc…

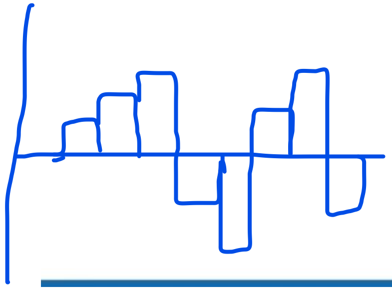


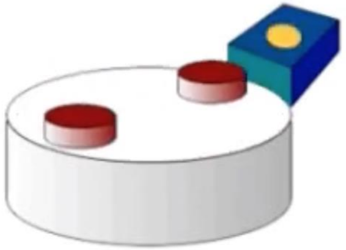
Digital Sensor

1 and 0 use karana sensser

Produces digital voltage i.e., discrete output.

Examples: Joystick, Switch etc…





voltage monitoring : ardino uno --> 0 - 5 V

5v/1024 = 0.0048mv --> 1 step

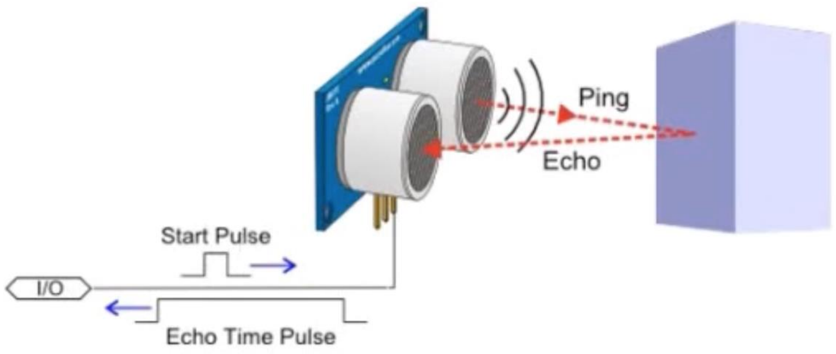
yam kisi sensor ekaka wenas wena step gaana anuwa
eka convert karagannawa analog signal eka digital widiyata.

active : always sensor yawa yawa check karanawa eyata data enawada nedda kiyala

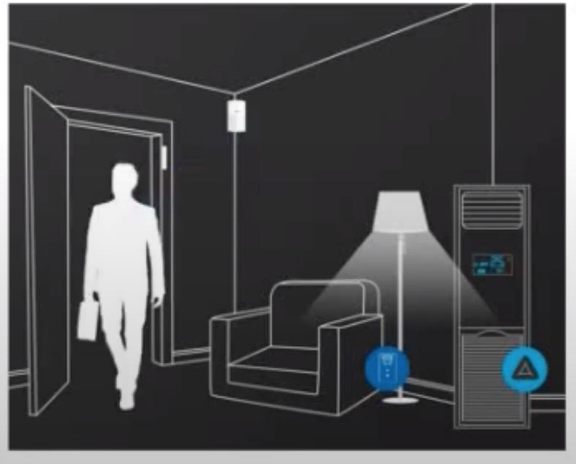
active ekakata aniwaryen energy source ekak tiyenna one

Active Vs Passive Sensors

- Active Sensors always needs it's own energy source, (like a battery) to work.
- Ex: Ultrasonic Sensors. In ultrasonic sensors power is needed to generate and transmit the ultra sound waves.



- Passive Sensors uses external factors to work.
- Ex: Infrared Camera or PIR sensor uses external heat energy to capture images.

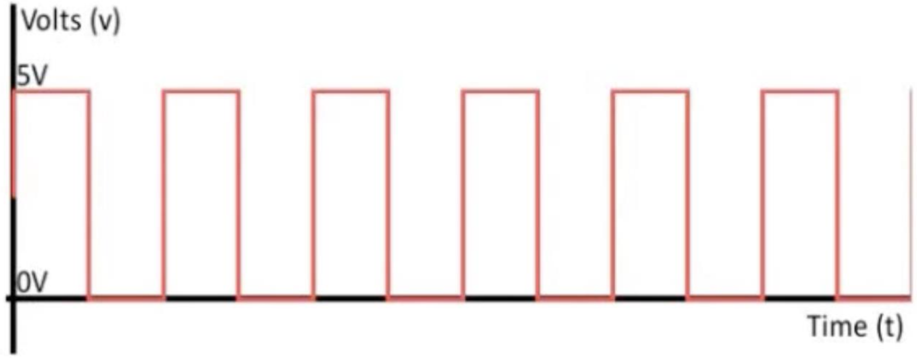


passive : hama welawema sence wenne ne. mokak hari wishesha elawaka witharai sensor on wenne

Digital Vs Analog signals

DIGITAL SIGNALS

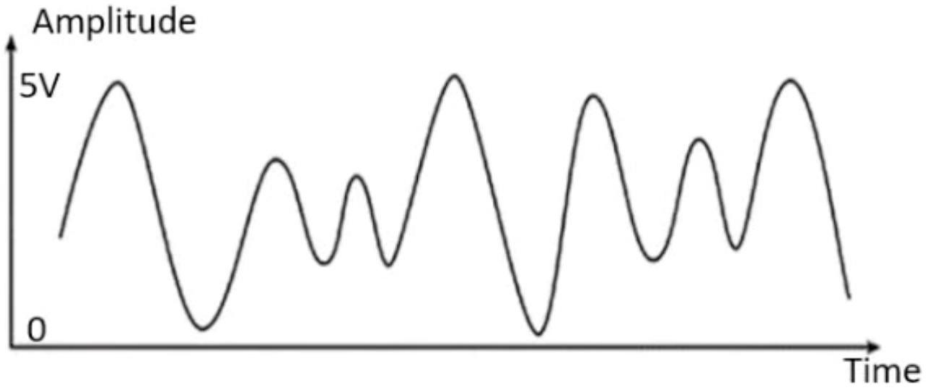
- Most commonly digital signals will be one of two values – like either 0V or 5V
- 0V corresponds to OFF state (binary 0)
- 5V corresponds to ON state (binary 1)



analog system ekaka 0 - 5 athare onaama agayak tiyenne puluwan. digital ekaka 1 and 0 only

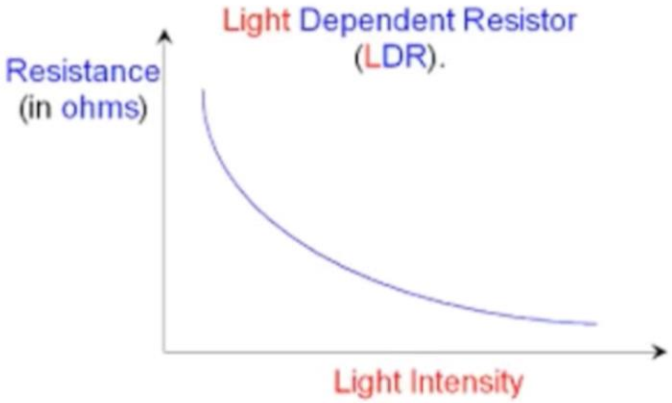
ANALOG SIGNALS

- Time-versus-voltage graph of an analog signal should be smooth and continuous
- Can take any values from 0 to 5 at different instants of time like (0.3, 1.2, 3.3, 4.7 etc.)



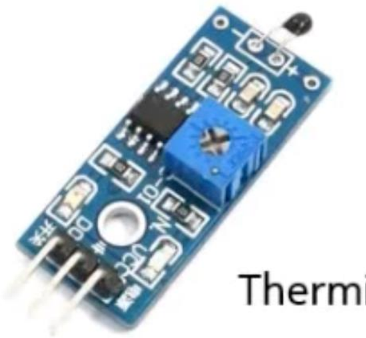
Light Dependent Resistor(LDR)

- LDR stands for "**Light Dependent Resistor**" , a light-controlled variable resistor
- Resistance of an LDR changes depending on the incident light
- Current through it changes as its resistance varies
- It's an Analog Sensor



Temperature Sensor LM35

- The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in °C).
- The LM35 does not require any external calibration or trimming and maintains an accuracy of +/-0.4°C at room temperature and +/-0.8°C over a range of 0°C to +100°C.



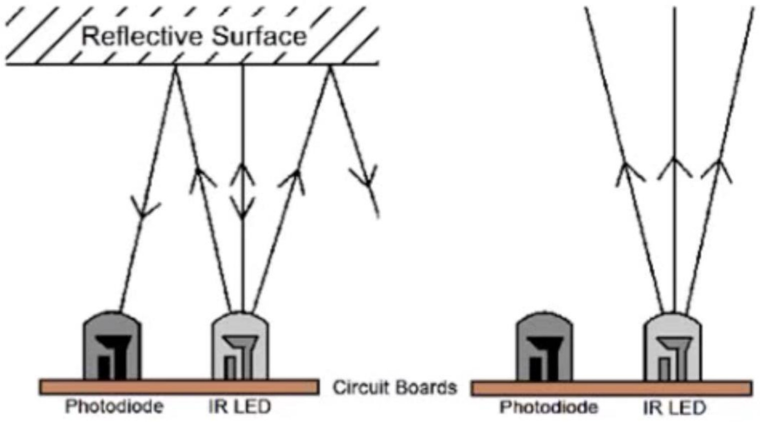
Thermistor

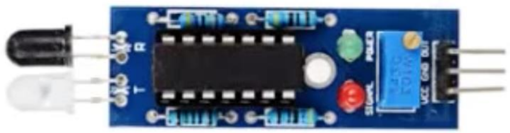
* line finding robots la hadanna use karana sensors

IR Photodiode Sensor

* black arenna anith onama color ekaka reflect karanawa

- This Sensor module works on the principle of Reflection of Infrared Rays from the incident surface.
- A continuous beam of IR rays is emitted by the IR LED.
- Whenever a reflecting surface (white/obstacle) comes in front of the Receiver (photo diode), these rays are reflected back and captured.
- It can be used both as Analog and Digital Sensor





SENSORS – IR

ekakin emit karana sensor eka anith eken read karanawa

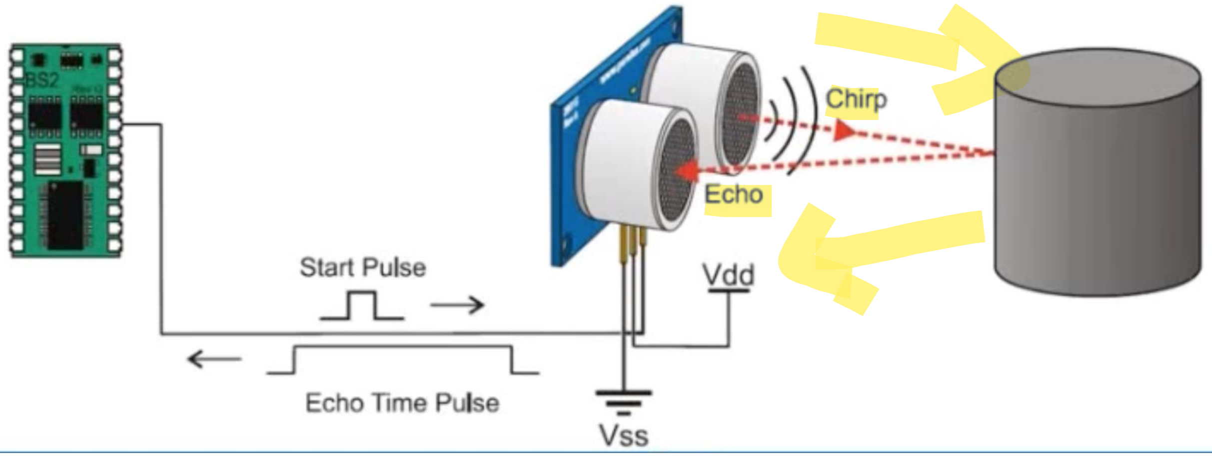
- Active (emitting)
  - Oscillator generates IR reflections off objects
  - Filtered receiver looks for "reflections"
  - Pulses may be encoded for better discrimination
  - Typically frequencies around 40KHz
  - Doesn't work well with dark, flat colored objects

- Passive (sensor only)
  - Pyro-electric (heat sensor)
  - Look for IR emissions from people & animals
  - Used in security systems & motion detectors

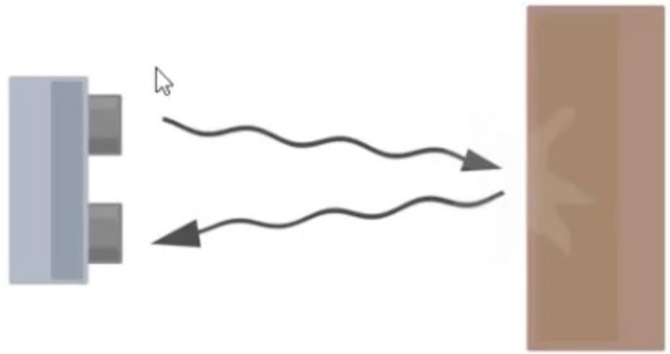
Ultrasonic Sensor

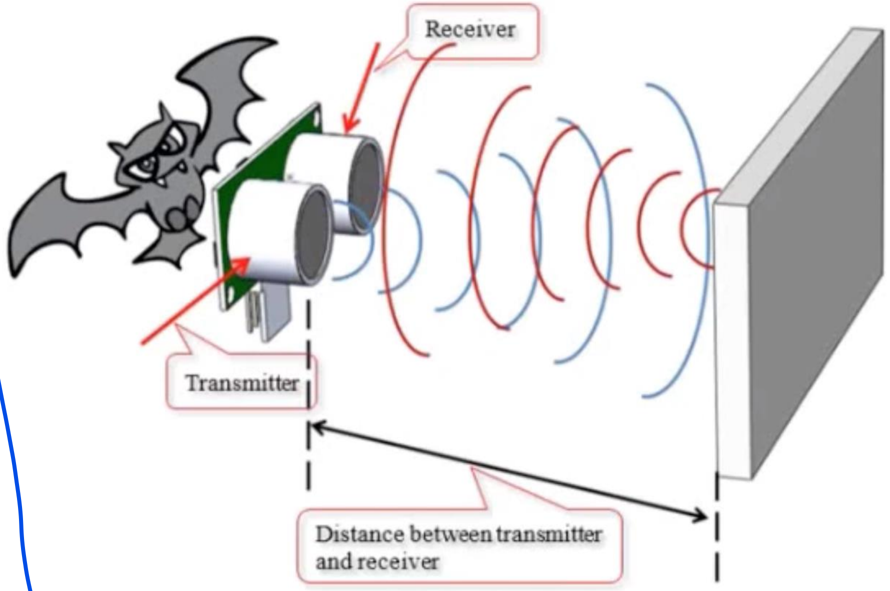
ping karana sound wave eka object ekaka wedila nawatha enna yana time eka measure karanawa.
for object detection

- An Ultrasonic sensor is a device that can measure the distance to an object by using sound waves.
- Sound waves travels through air at about 344 m/s (1129 ft/s)
- Distance is measured by sending out a sound wave (Chirp) at a specific frequency and listening for that sound wave(Echo) to bounce back.
- By recording the elapsed time between the chirp and echo, the distance between the sonar sensor and the object is measured.



Ultrasonic Sensor

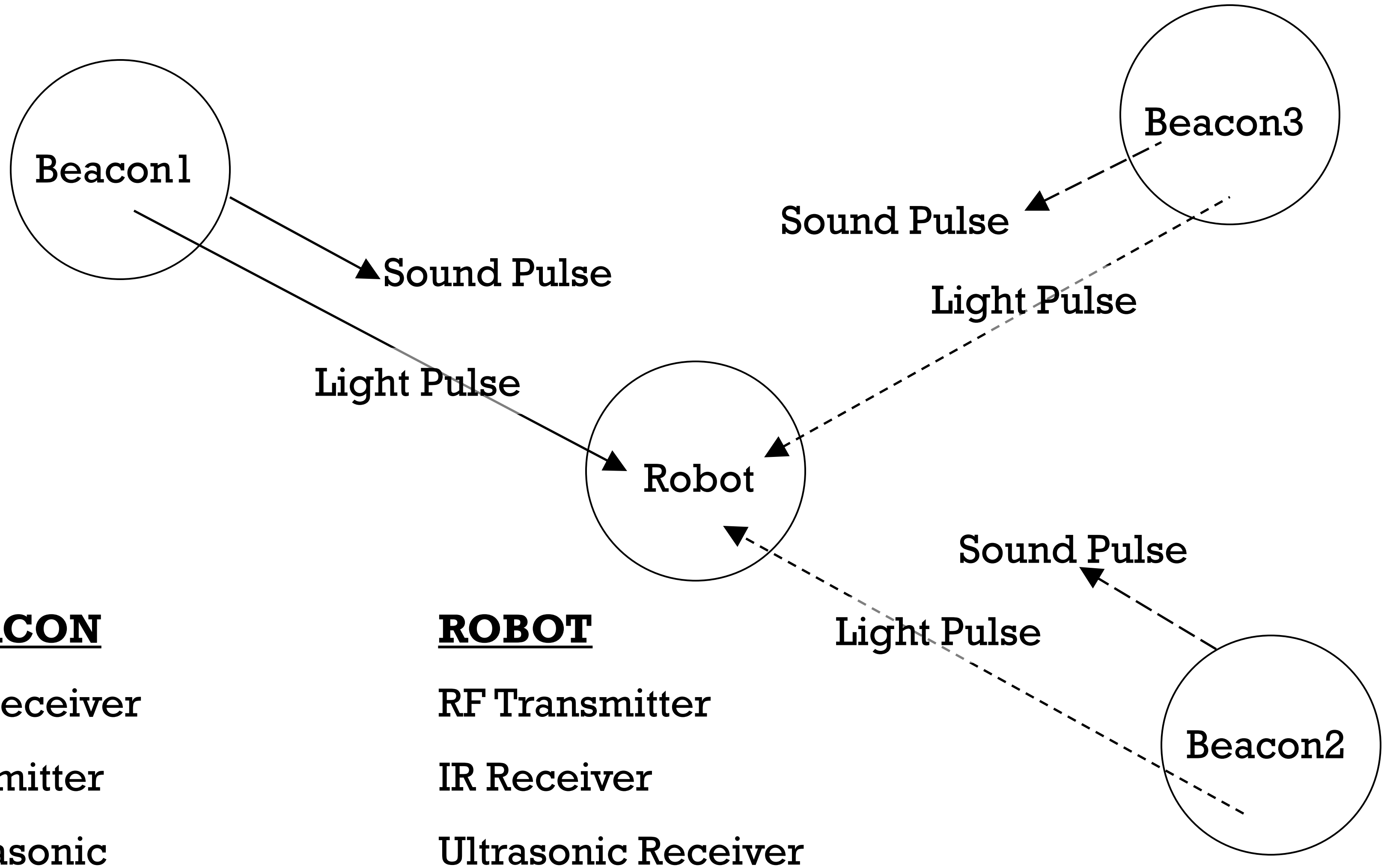




$$distance = \frac{speed\ of\ sound\ \times time\ taken}{2}$$

$$d = \frac{330\,ms^{-1} \times 15}{2} = 115\,m$$

ULTRASONIC - PASSIVE



BEACON

RF Receiver

IR Emitter

Ultrasonic Emitter

ROBOT

RF Transmitter

IR Receiver

Ultrasonic Receiver

any person or animal move unoth ight on wenawa. : ape gedara camera light eka

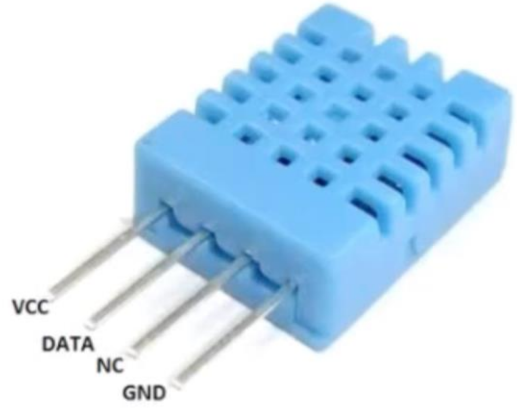
PIR Motion Sensor

- PIR sensors allow you to sense motion, whether a human has moved in or out of the sensors range
- Small, inexpensive, low-power and easy to use
- Commonly found in appliances and gadgets used in homes or businesses
- They are often referred to as PIR, "Passive Infrared", "Pyroelectric", or "IR motion" sensors

DHT11 Sensor

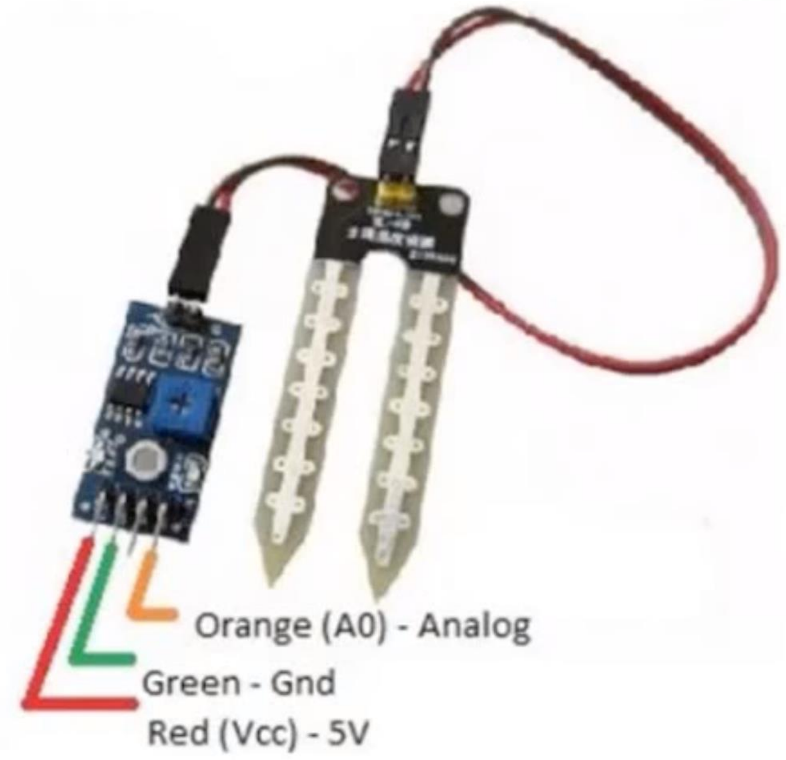
- Basic, ultra low-cost digital temperature and humidity sensor.
- Uses a capacitive humidity sensor and a thermistor to measure the surrounding air's humidity & Temperature
- Simple to use

- 3 to 5V power and I/O
- 2.5mA max current use
- Good for 20-80% humidity
- Good for 0-50°C temperature
- Body size 15.5mm x 12mm x 5.5mm
- 4 pins with 0.1" spacing



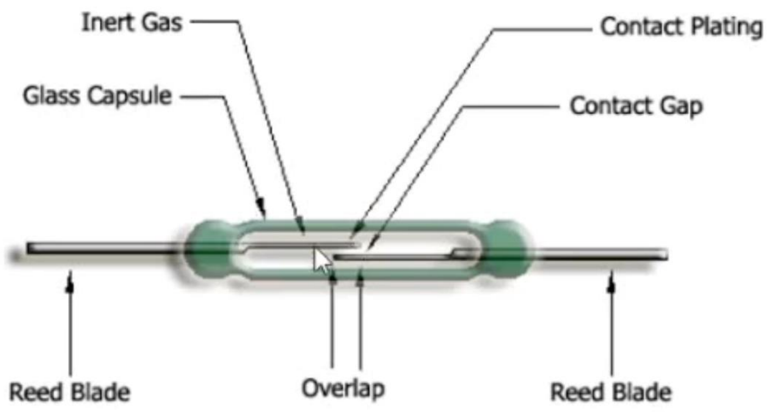
Moisture Sensor

- Analog Sensor
- Used for measuring the moisture in soil and similar materials
- Two large exposed pads function as probes for the sensor, together acting as a variable resistor
- The more water, the better the conductivity between the pads
- Better conductivity will result in a lower resistance, and a higher signal out.

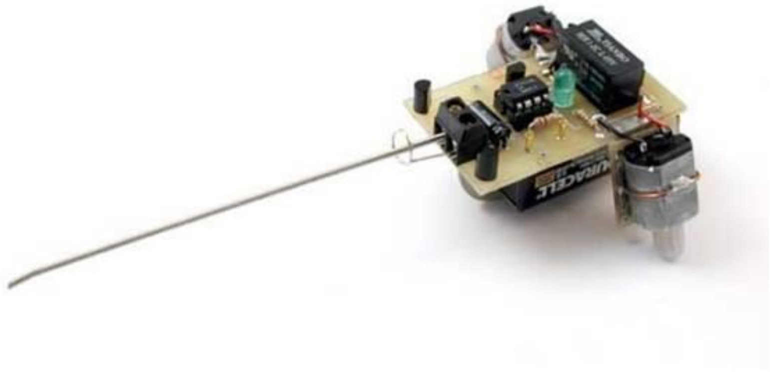


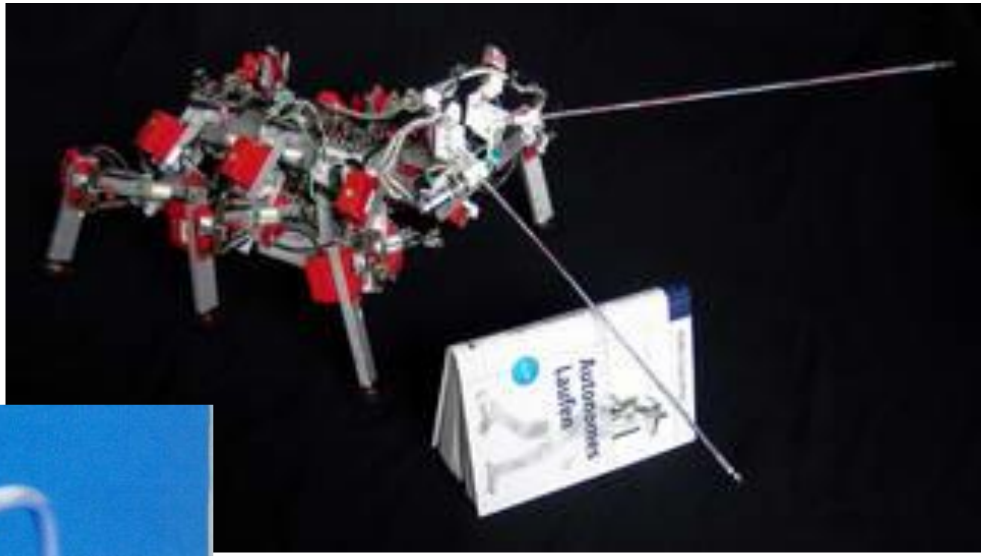
Reed Switch

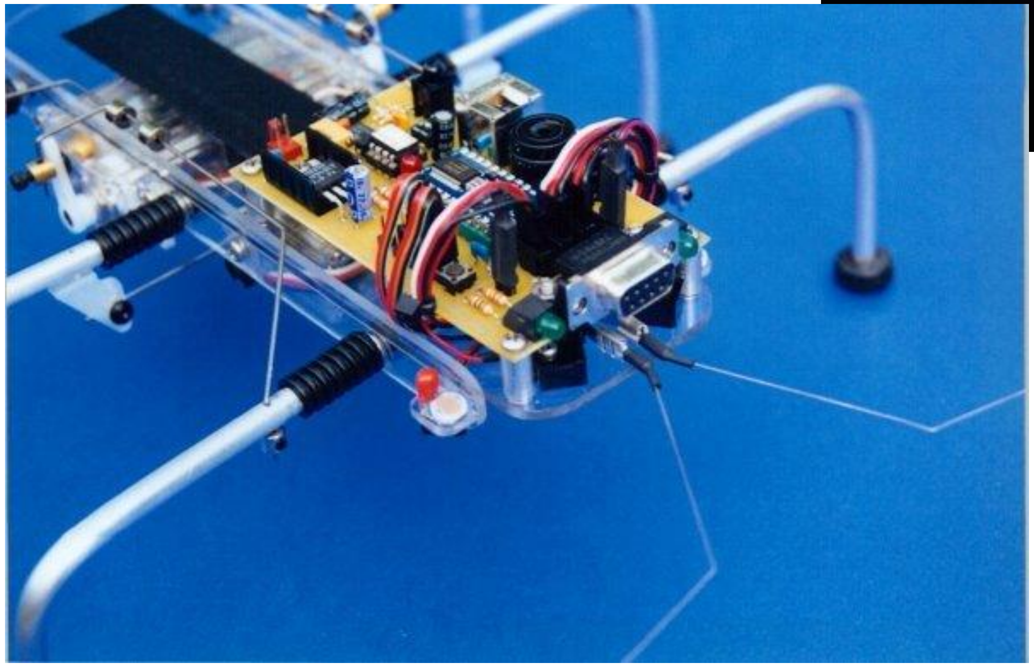
- Digital switch
- In a typical reed switch, the two metal contacts made from a ferromagnetic material
- Sealed inside a thin glass envelope filled with an unreactive gas (typically nitrogen) to keep them free of dust and dirt.



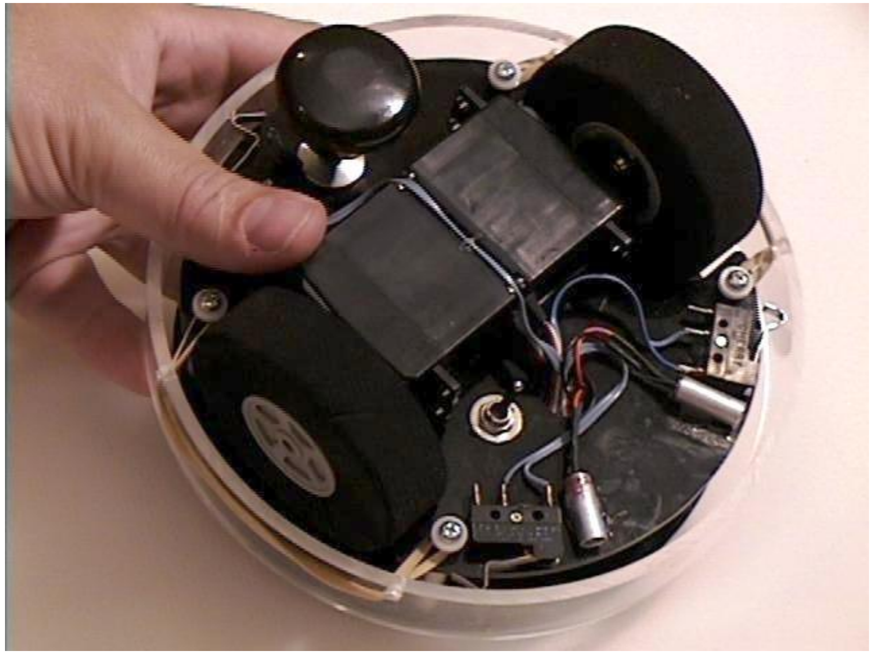
FEELERS - WHISKERS

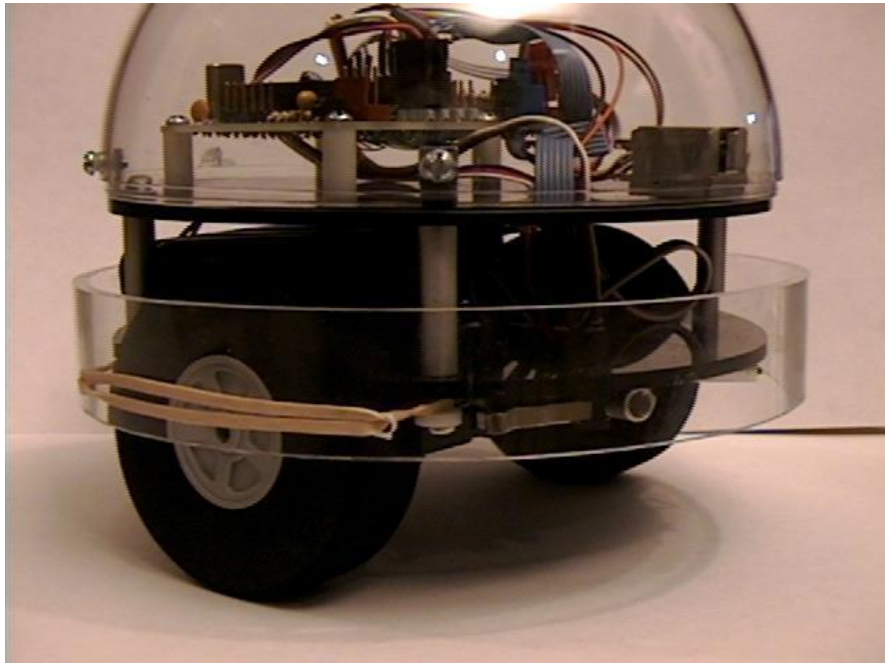






FEELERS - BUMPERS & GUARDS





From Kevin Ross's "Getting Started Article (SRS Website)

SENSORS – SONIC (ACOUSTIC)

- Active
  - Emit pulses & listen for echos
  - Times round trip sound travel (~1ft/mS)
  - Reaches far fairly beyond robot (30-50 ft)
  - Relatively simple, not cheap, analog output
  - Directional, not everything reflects sound
  - Noisy!!!!
- Passive (sensor only)
  - Sensor listens to ambient sounds
  - Filters or scans selected frequencies
  - ADC measures conditioned signal amplitude
  - CPU performs signal analysis on what it hears

SENSORS – RESISTANCE

- Passive (sensor only)
  - Measures elec. resistance between objects
  - Measure sensor that varies resistance
  - Use absolute or differential readings
  - Other ideas?

SENSORS - CAPACITIVE

- Emit an electric field below the sensor.
- Nulled to a known "void" wall area.
- Detect capacitance difference due to underlying material density.

SENSORS - INDUCTIVE

- Passive
  - Really doesn’t work (Needs excitation)

- Active (emitting)
  - Metals affect sensor
  - Current flows through inductor
  - Magnetic field mostly ignores non-metals
  - Inductance changes with metallic proximity
  - Short range applications (~cm or mm)

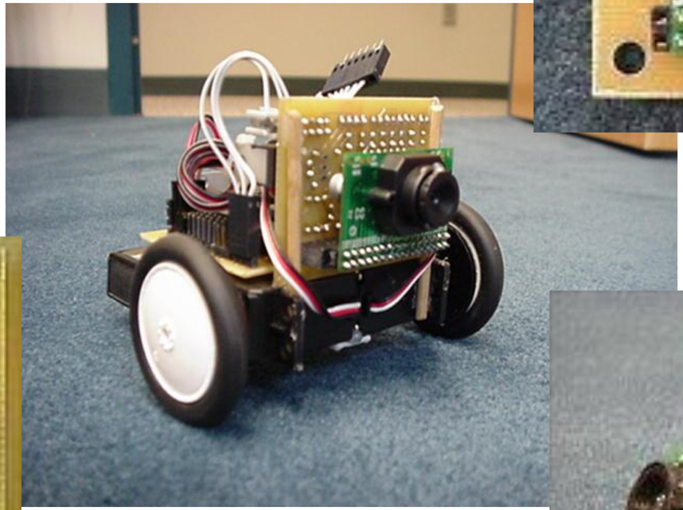
SENSORS – VISUAL

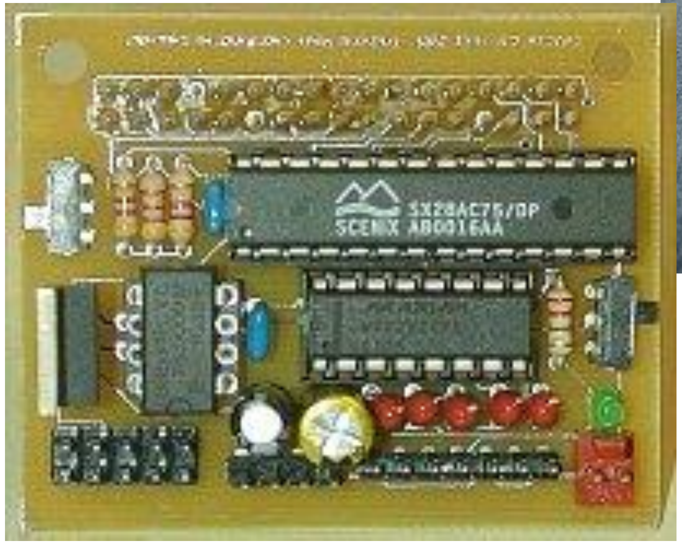
- Active (emitting)
  - Camera with field of view illumination
  - Looks for particular reflections
  - Filter removes non-significant light sources
  - Linear array senses single axis of motion

- Passive (camera only)
  - Scans field of interest
  - Looks for objects, artifacts, features of interest
  - Processes digital data to simplified interpretation

SENSORS – VISUAL

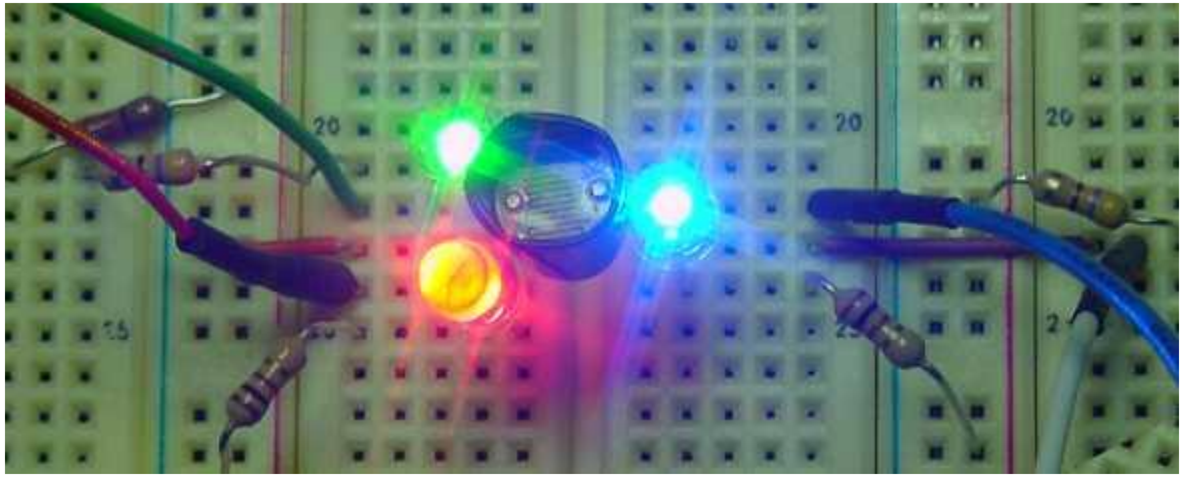
- CMUCam
- Linear Optical Array





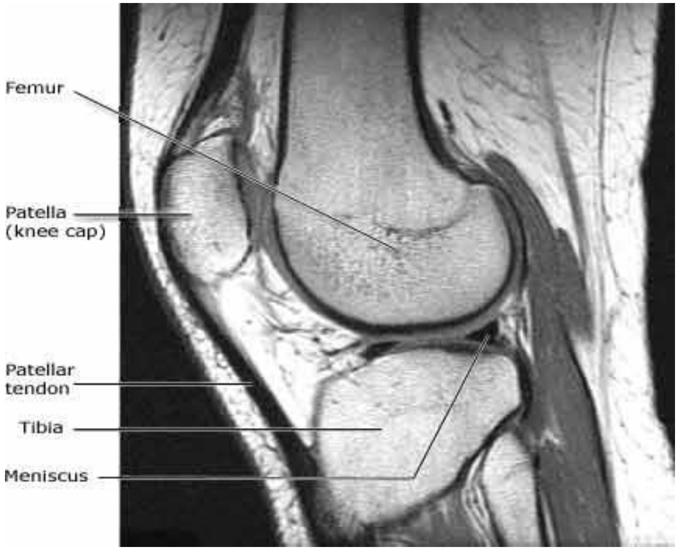
SENSORS – COLOR

http://robotroom.com/ColorSensor.html



SENSORS – MAGNETIC

From HowStuffWorks.com & RadiologyInfo.org



MRI
Scanner

SENSORS – ORIENTATION

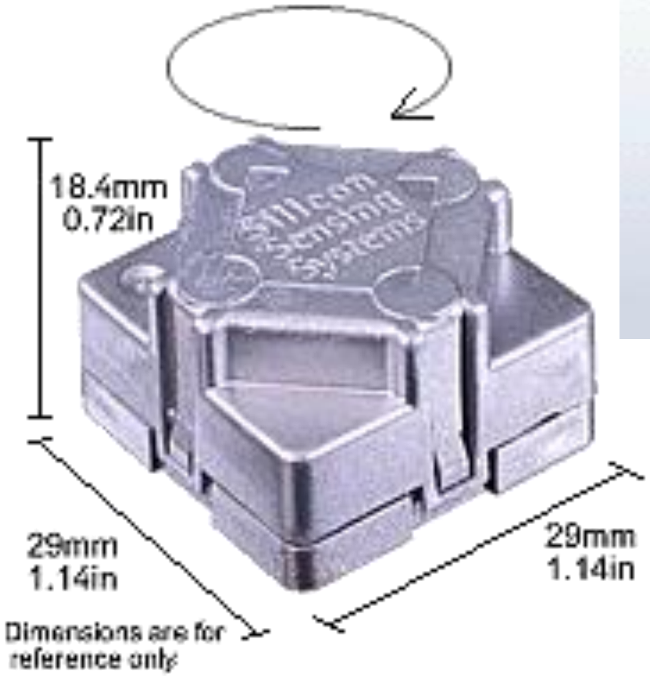
- Rate Gyros
  - Output proportional to angular rotation speed
  - Integrate to get position
  - Differentiate to get acceleration

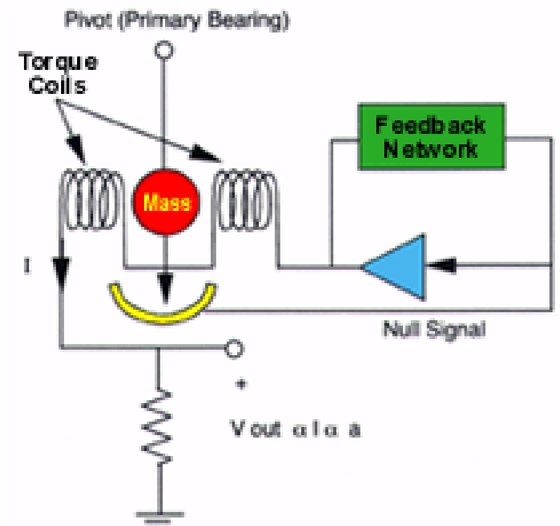
- DC Accelerometer
  - Output proportional to sine of vertical angle

SENSORS – MOTION

Rate Gyro – Silicon Sensing Systems

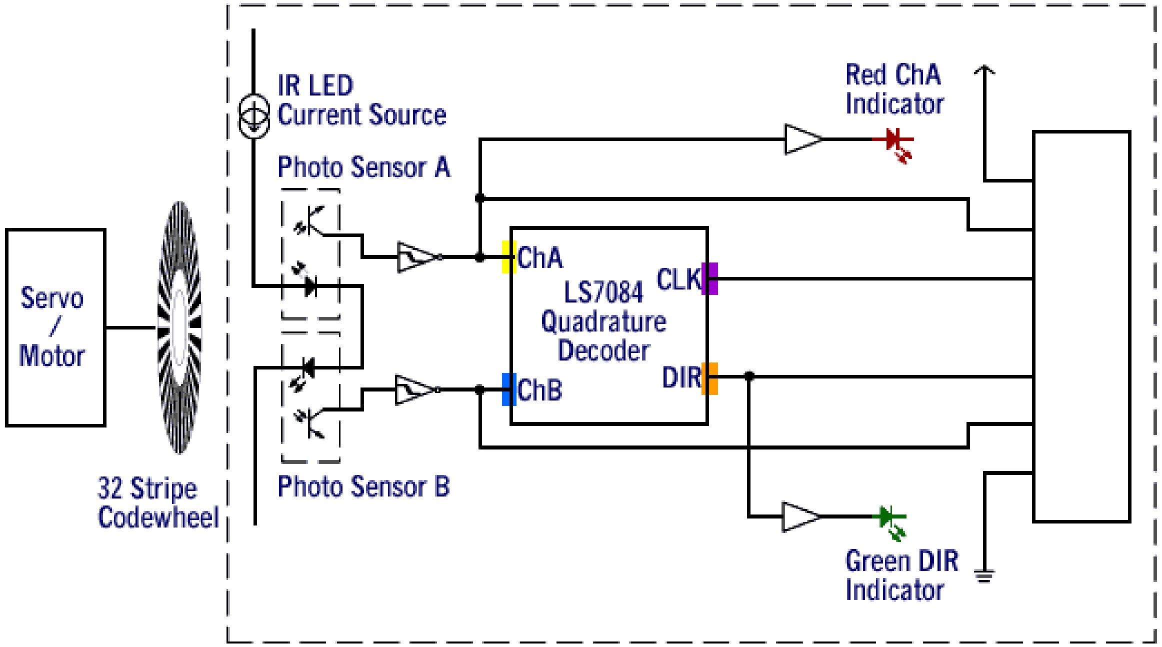
Servo Accel – Sensorland.com



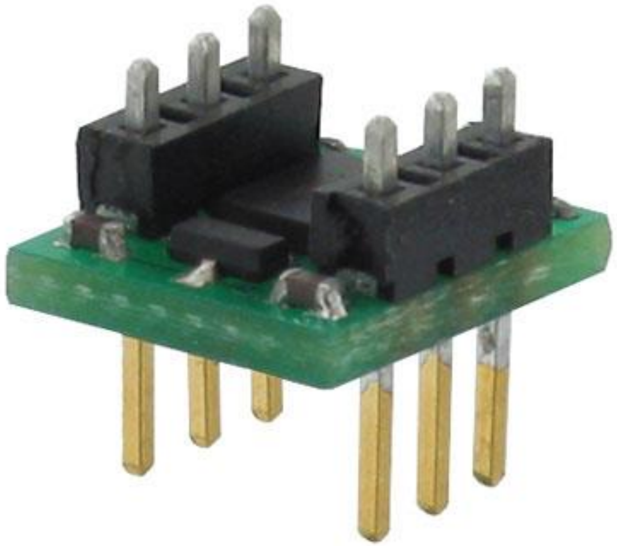


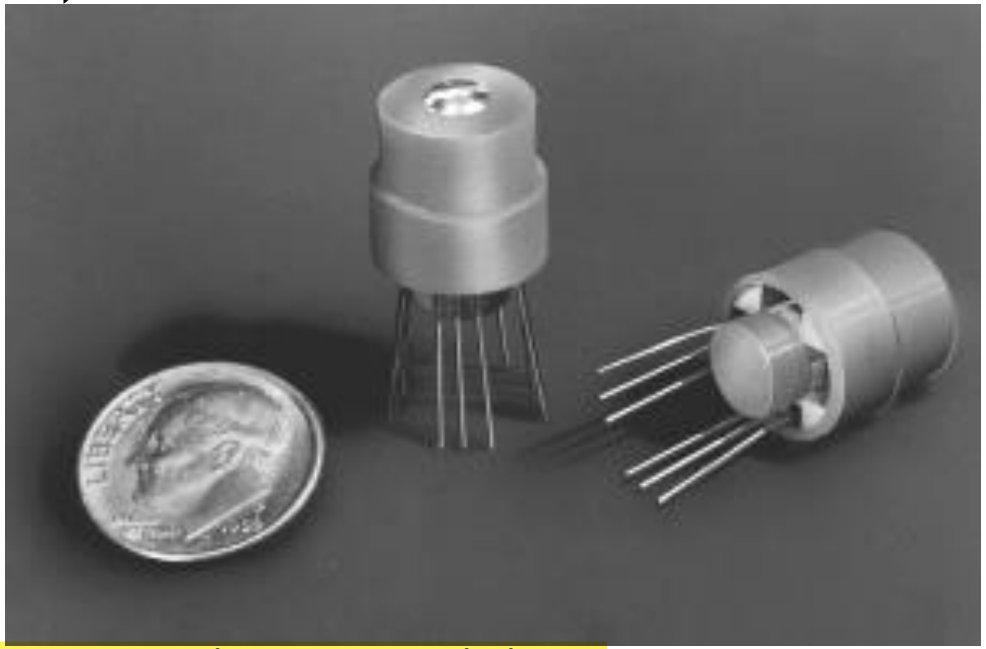
WHEEL ENCODERS

- Nubotics.com, $27
- Jun 98, Oct 2000 Encoder



SENSORS – COMPASS (ORIENTATION)





- Track bearing & distance to determine position
- L: Parallax.com, $30
- R: Dinsmoresensors.com, $13-$37

SENSORS – VOLTAGE

- Passive – Senses electric field
- Fluke Electric Field Sensors

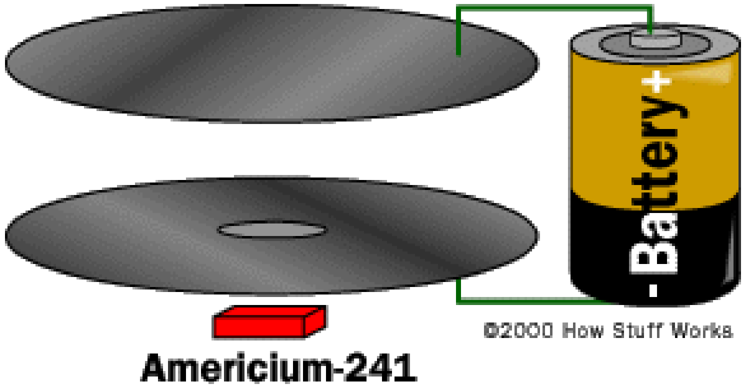
$23

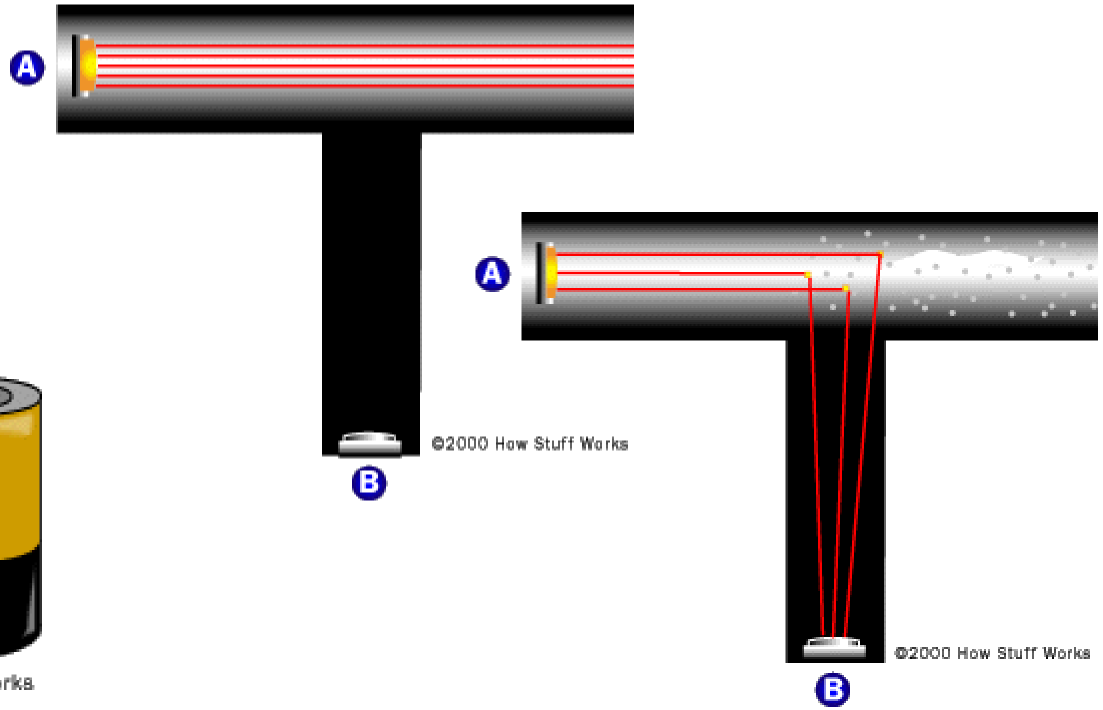
$25

$24

SENSORS – CHEMICAL

- Smoke Detectors - Cheap, readily available, $5
- Oxygen concentration sensors - CO, H_4S, CH_4, pricey
- See HowStuffWorks.com





SENSOR VENDOR/INFO LINKS

http://www.dinsmoresensors.com
http://www.fluke.com
http://www.howstuffworks.com
http:// www.lynxmotion.com
http://www.magnetometer.org
http:// www.nubotics.com
http:// www.parallax.com
http://www.raztec.co.nz
http:// www.robotics.com
http:// www.robotroom.com
http://www.sensorland.com
http://www.seattlerobotics.org/encoder
http:// www.solarbotics.com

WHAT IS NFC (NEAR FIELD COMMUNICATION?

NFC--> short range ekaka radio frequency use karala communication karana eka

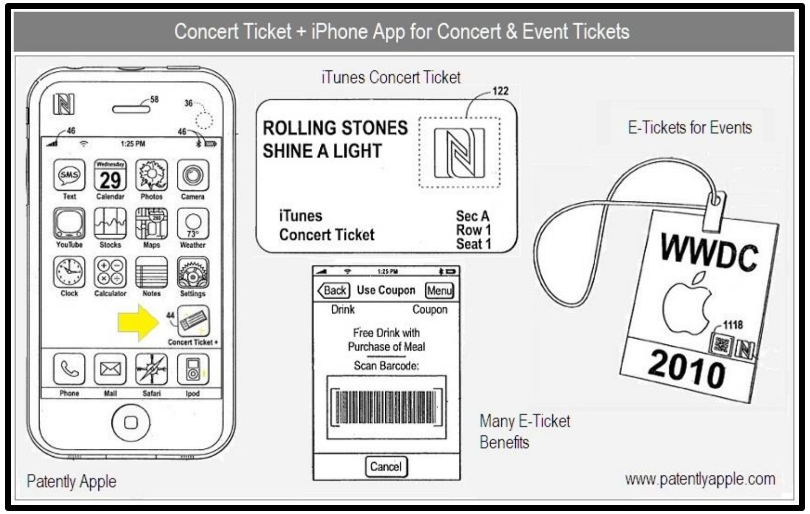
- Short range radio communication
- Builds on specifications laid out for earlier RFID (Radio Frequency Identification) technology[2]
- Usually operates within a 4 cm range, but specifications allow for a range up to 20 cm[2]
- Uses a frequency of 13.56 MHz[2]
- Possible transfer rates are 106, 212, 424kbps[15]

COMPARISON BETWEEN SIMILAR TECHNOLOGIES

	NFC	RFID	Bluetooth	Wi-Fi
Maximum Operating Range	10 cm	3 m	100 m	100 m
Operating Frequency	13.56 MHz	Varies[1]	2.4 GHz	2.4/5 GHz (802.11n)
Directional Communication	Two way card --> device device -- > card	One way	Two way	Two way
Bit Rate	106/212/ 424 Kbps	Varies[13]	22 Mbps	144 Mbps
Potential Uses	e-Tickets, Credit card payment, Membership card	Tracking items, EZ-Pass	Communicate between phones, peripheral devices	Wireless internet

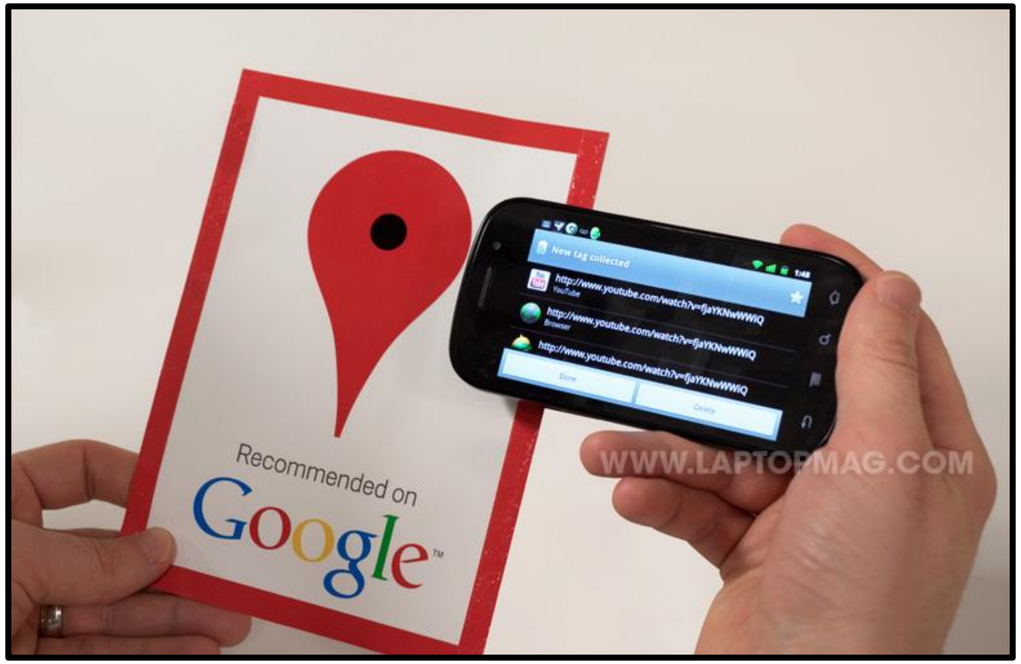
APPLICATIONS FOR NFC

- Use phone like a contactless credit card [11]
  - Also could work as a coupon or gift card
- Apple patent (lower image) shows ideas for digital concert tickets, coupons [10]
  - Can download tickets to phone with NFC enabled computer



APPLICATIONS FOR NFC

- Smart posters/tags [12]
  - These tags can link to relevant websites
  - Can be used to perform actions in applications that are NFC enabled
  - Could be used to download and run a guide program in a museum



Internet of Things (IoT)

Lecture 4

IoT Network Connectivity

IoT: 4-layer Model

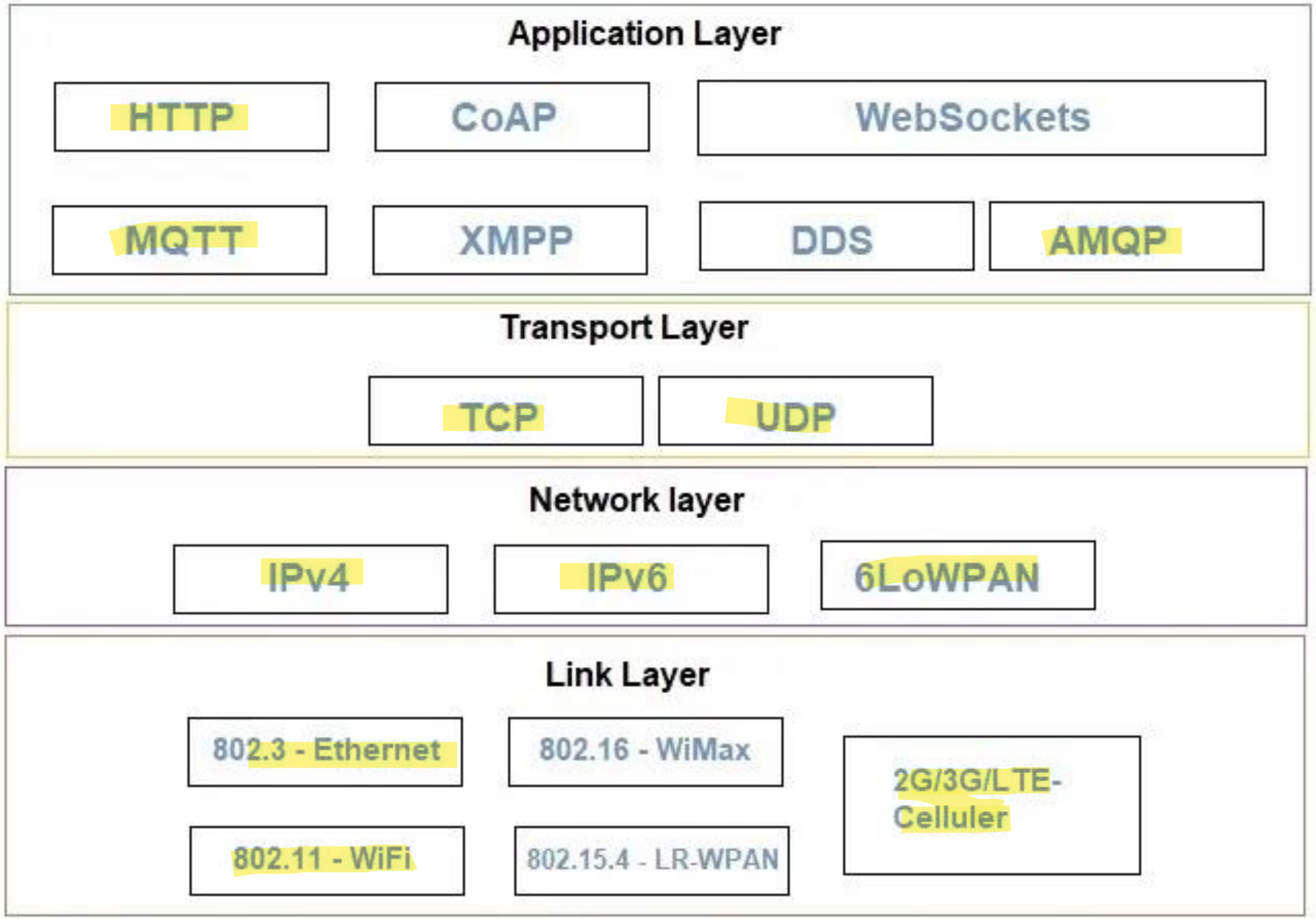
Integrated Applications

Information Processing

Network Infrastructure

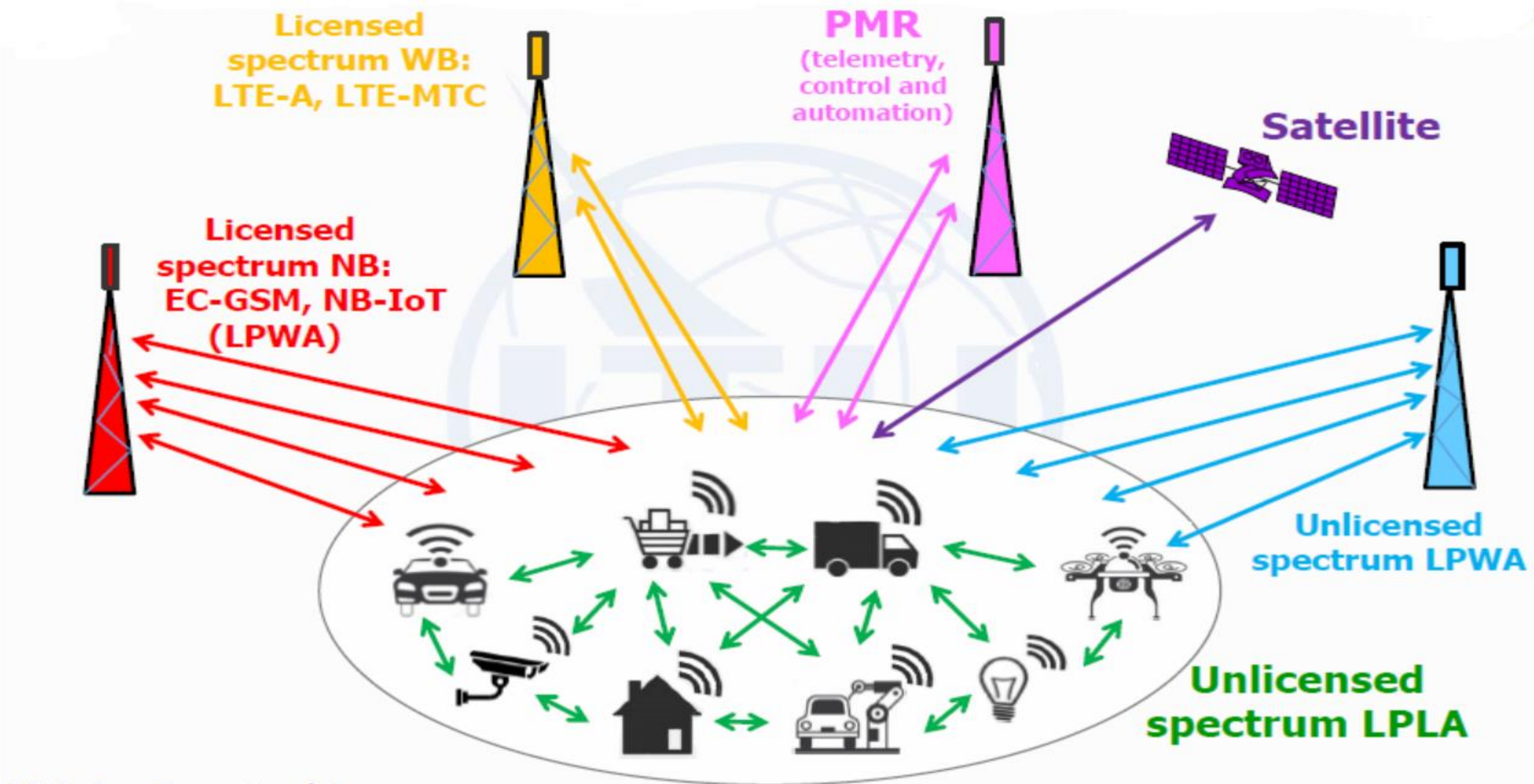
Sensing and Identification

IoT: 4-layer Model Protocols



Network Connectivity

IoT Connectivity Options



LPLA: Low Power Local Area
LPWA: Low Power Wide Area

Source: ITU Workshop on Spectrum Management for Internet of Things Deployment, 22 November 2016, Geneva

IoT design requirements

IoT Network	Impact on IoT Systems Design
Scale	**Tens of thousand sensors in a given site; or millions distributed geographically** More pressure on application architectures, network load, traffic types, security, non-standard usage pattern
Heterogeneous end-points	**Vast array of sensors, actuators, and smart devices – IP or non-IP** Diverse data rate exchange, form factor, computing and communication capabilities, legacy protocols
Low Capex and Opex requirement	**May be deployed before activation, maybe or cannot-be accessed once deployed** • Low numbers of gateways Link budget: e.g: UL: 155 dB (or better), DL: Link budget: 153 dB (or better) • Devices deliver services with little or no human control, difficult to correct mistakes, device management is key
Criticality of services	**Human life critical (Healthcare), Critical infrastructure (Smart Grid)** Stringent latency (10ms for SG) and reliability requirements, may challenge/exceed network capabilities of today
Intrusiveness	**Things with explicit intent to better manage end-users (eHealth, Smart Grid)** Issues of Privacy become major obstacles
Geography	**Movement across borders** Issues of numbering for unique identification

Source: ITU CoE training on BB networks planning, Bangkok, Sep 2017

IoT network connectivity requirements

IoT Network	Impact on IoT Systems Design
Resource-constrained endpoints	**Severely resource constrained (memory, compute)** Cost motivation: compute/memory several orders of magnitude lower, limited remote SW update capability, light protocols, security
Low Power	**Some end-point types may be mostly ‘sleeping’ and awakened when required** • Sensors cannot be easily connected to a power source • Reduced interaction time between devices and applications (some regulations state duty cycle of no more than 1%) • Idle mode most of the time (energy consumption of around 100 µW). Connected mode just for transmission (mA) • < 100 MHz clock frequency • Embedded memory of few Mb
Embedded	**Smart civil infrastructure, building, devices inside human beings** Sensors deployed in secure or hostile operating conditions, difficult to change without impacting system, Security
Longevity	**Deployed for life typically, have to build-in device redundancy** Very different lifetime expectancy, rate of equipment change in IoT business domains much lower than ICT Industry
High Sensitivity on reception	**Gateways and end-devices with a high sensitivity around** -150 dBm/-125 dBm with Bluetooth lower than -95 dBm in in cellular

Source: **ITU CoE training on BB networks planning, Bangkok, Sep 2017**

IoT Technical Solutions

- **Fixed & Short Range**
  - RFID
  - Bluetooth
  - Zigbee
  - WiFi
  - ….
- **Long Range technologies**
  - Non 3GPP Standards (LPWAN)
  - 3GPP Standards

Short Range IoT Solutions

- RFID
- Bluetooth
- ZigBee
- WiFI
- 6LoWPAN

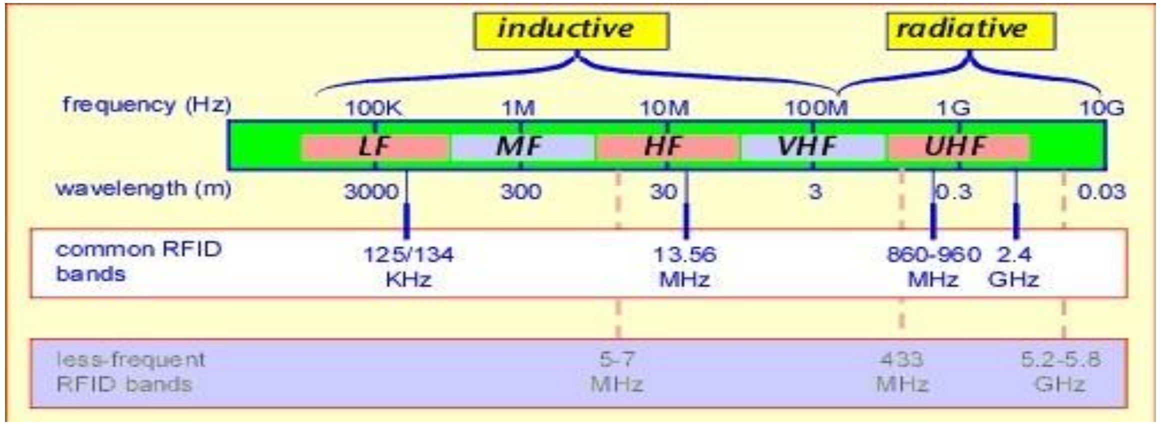
RFID: Radio Frequency Identification

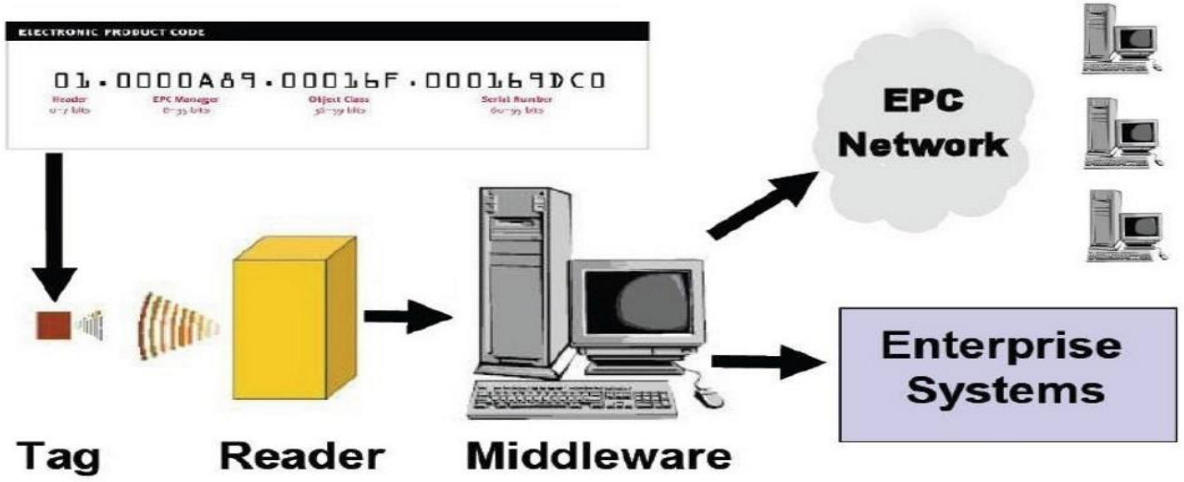
- **Appeared first in 1945**

card --> passive device
sensor move --> card active and send to data in sensor

- **Features:**
  - Identify objects, record metadata or control individual target
  - More complex devices (e.g., readers, interrogators, beacons) usually connected to a host computer or network
  - Radio frequencies from 100 kHz to 10 GHz

- **Operations:**
  - Reading Device called Reader (connected to banckend network and communicates with tags using RF)
  - One or more tags (embedded antenna connected to chip based and attached to object)





Bluetooth

- **Features:**
  - Low Power wireless technology
  - Short range radio frequency at 2.4 GHz ISM Band
  - Wireless alternative to wires
  - Creating PANs (Personal area networks)
  - Support Data Rate of 1 Mb/s (data traffic, video traffic)
  - Uses Frequency Hopping spread Spectrum

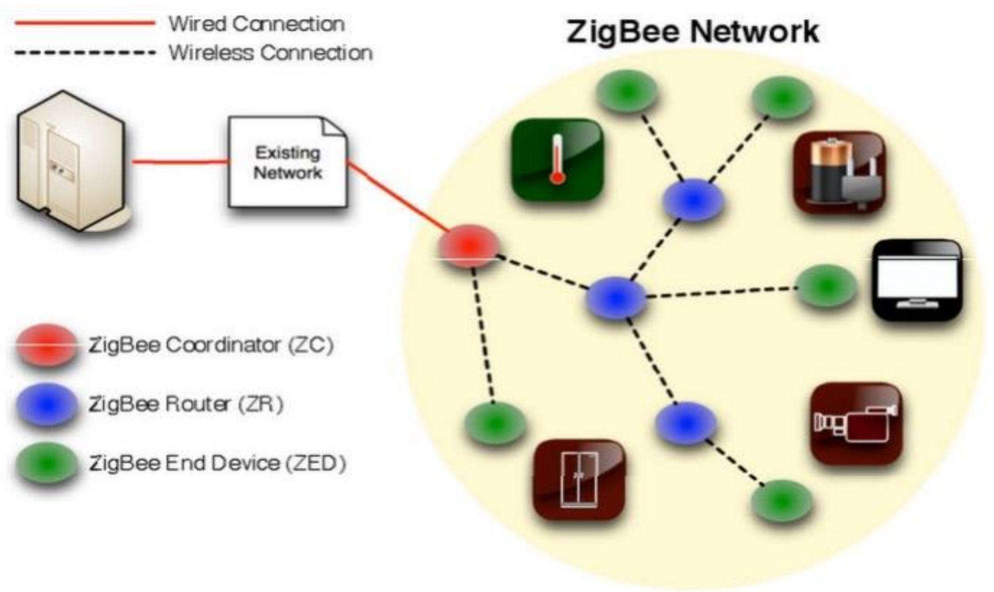
- **Bluetooth 5:**
  - 4x range, 2x speed and 8x broadcasting message capacity
  - Low latency, fast transaction (3 ms from start to finish) Data Rate 1 Mb/s: sending just small data packets

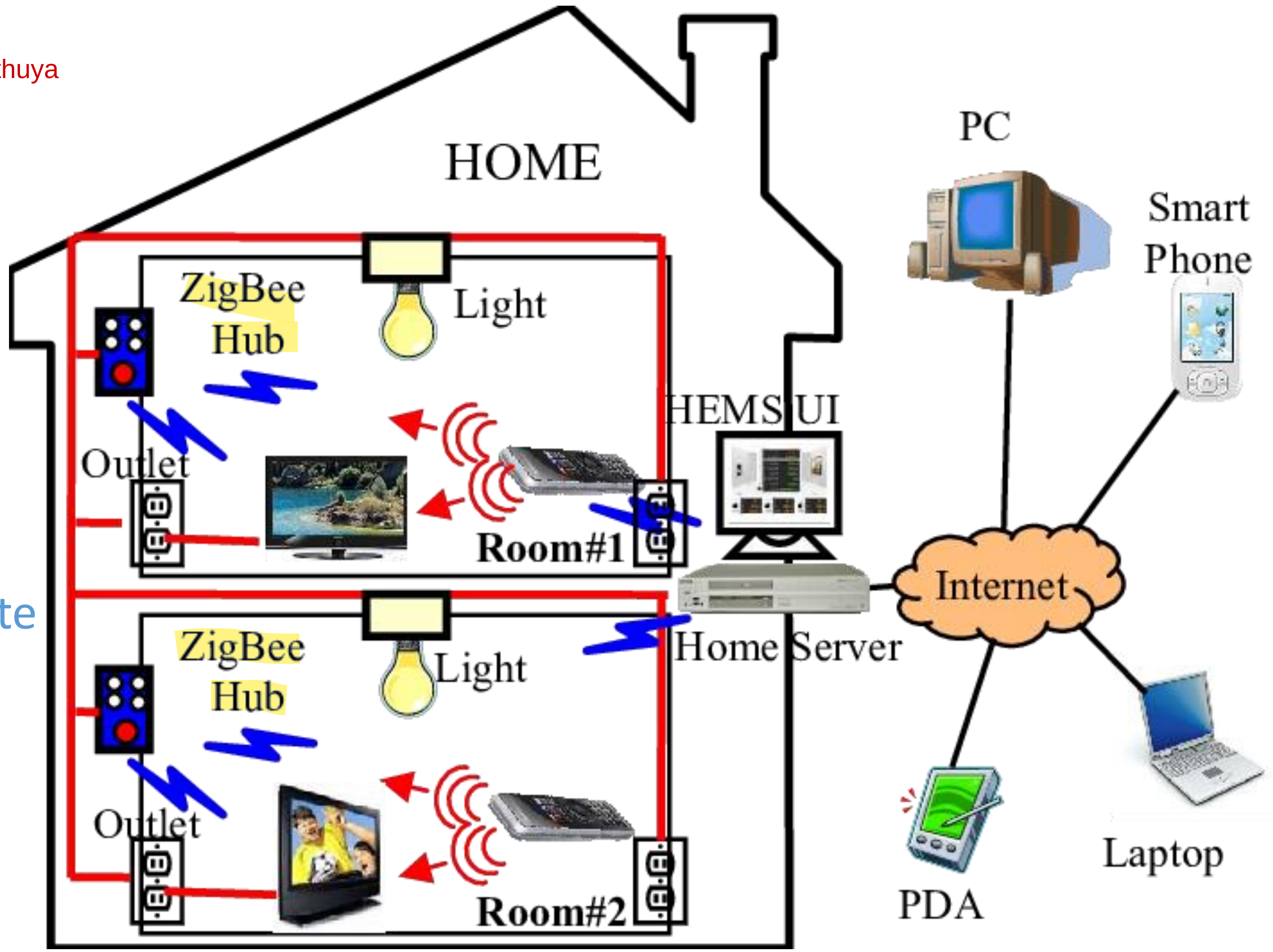
Class	Maximum Power	Range
1	100 mW (20 dBm)	100 m
2	2,5 mW (4 dBm)	10 m
3	1 mW (0 dBm)	1 m

ZigBee

zigbee hub ekak thibiya yuthuya

- **Operations:**
  - **Coordinator**: acts as a root and bridge of the network
  - **Router**: intermediary device that permit data to pass to and through them to other devices
  - **End Device**: limited functionality to communicate with the parent nodes



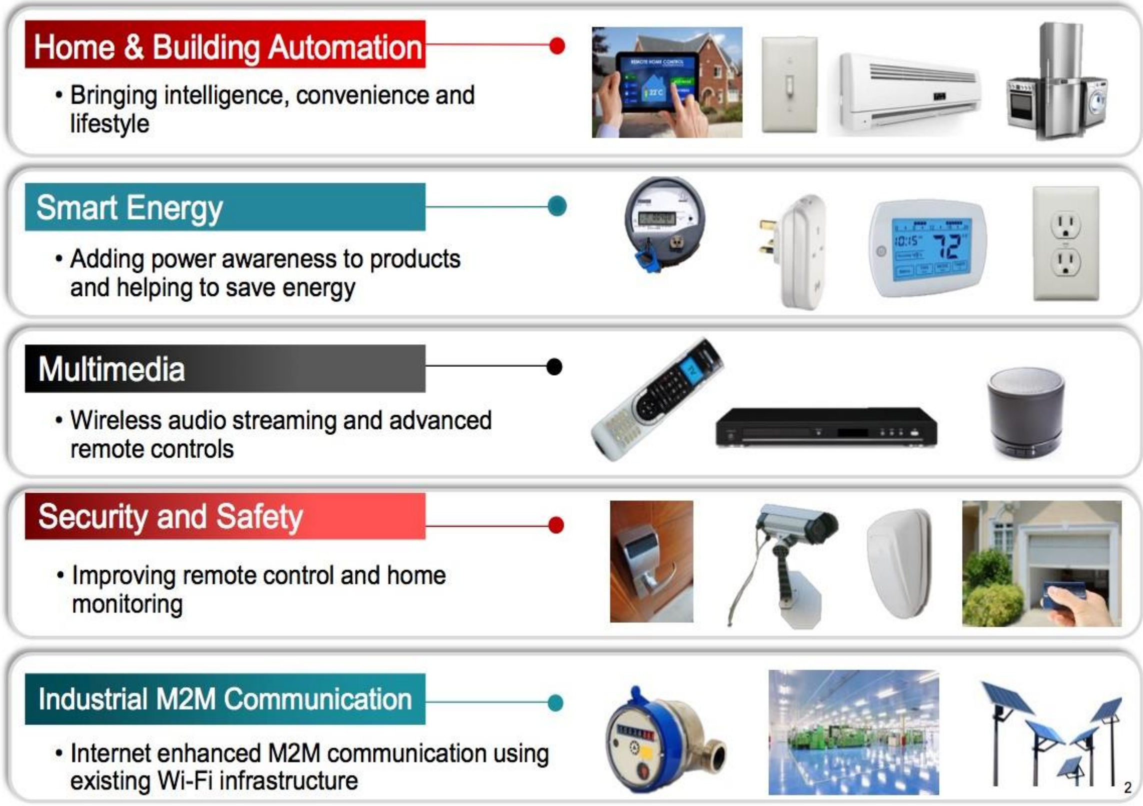


Low cost and available

WiFi

- Wireless Alternative to Wired Technologies
- Standardized as IEEE 802.11 standard for WLANs

Standard	Frequency bands	Throughput	Range
WiFi a (802.11a)	5 GHz	54 Mbit/s	10 m
WiFi B (802.11b)	2.4 GHz	11 Mbit/s	140 m
WiFi G (802.11g)	2.4 GHz	54 Mbit/s	140 m
WiFi N (802.11n)	2.4 GHz / 5 GHz	450 Mbit/s	250 m
IEEE 802.11ah	900 MHz	8 Mbit/s	100 M



WiFi HaLow

A new low-power, long-range version of Wi-Fi that bolsters IoT connections

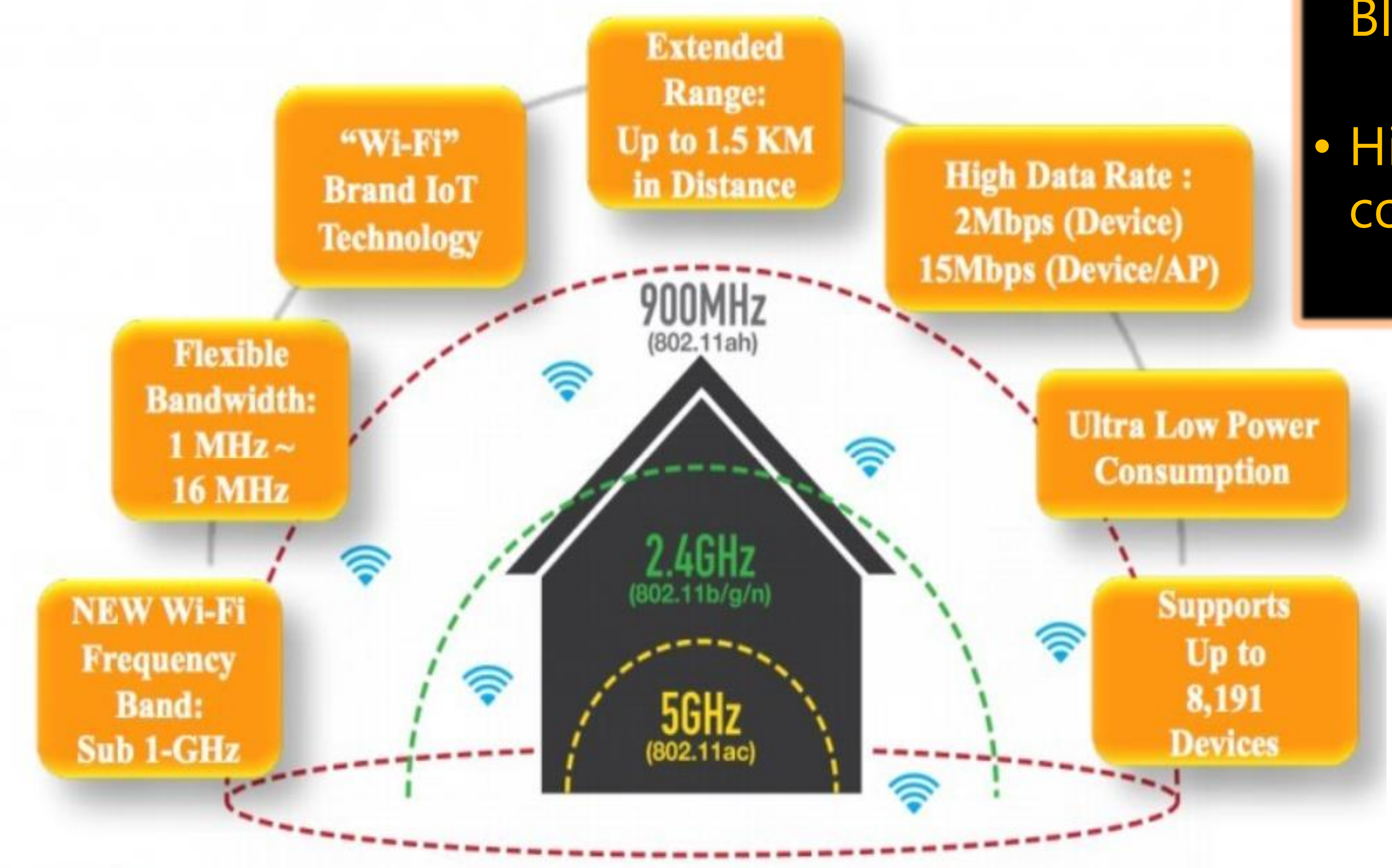
Wi-Fi HaLow is based on the **IEEE 802.11ah** specification

Wi-Fi HaLow will operate in the unlicensed wireless spectrum in the 900MHz band

Its range will be nearly double today's available Wi-Fi (1 kilometer)

- More flexible
- The protocol's low power consumption competes with Bluetooth
- Higher data rates and wider coverage range

WiFi HaLow

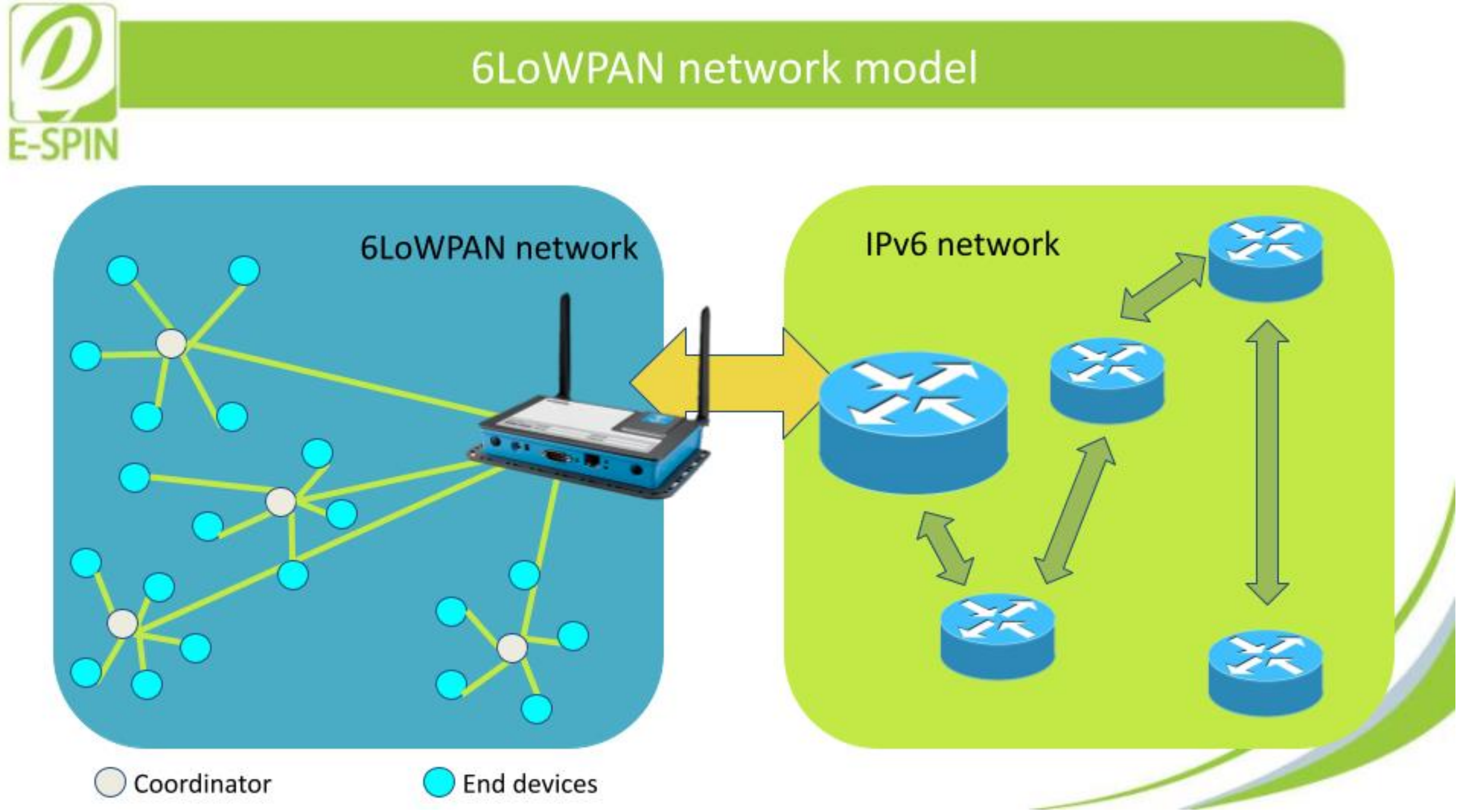


- More flexible
- The protocol's low power consumption competes with Bluetooth
- Higher data rates and wider coverage range

Picture Source: Newracom

6LoWPAN

- IPv6 over Low -Power Wireless Personal Area Networks

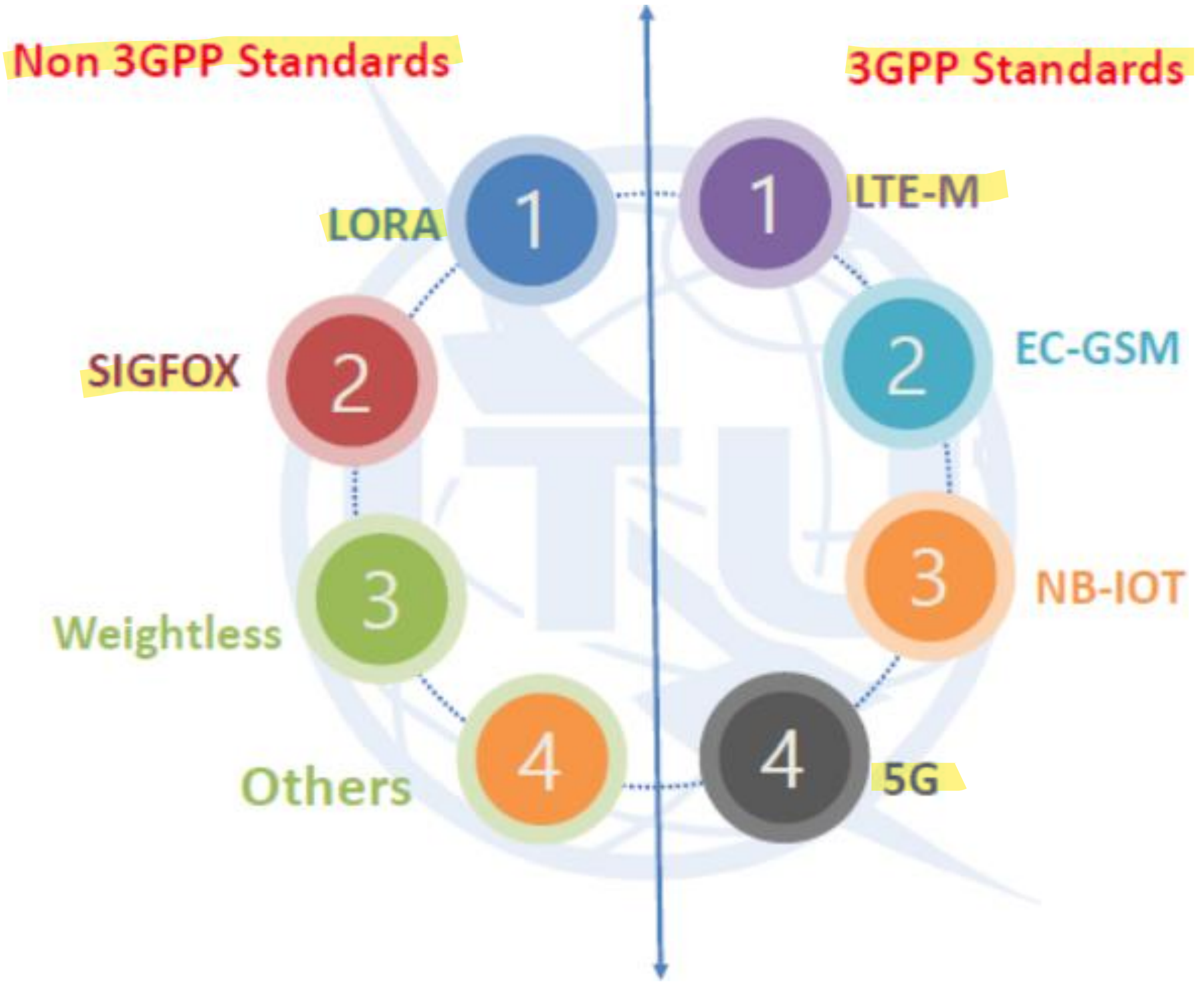


Long Range IoT Solutions

- Non 3GPP
- 3GPP

- The 3rd Generation Partnership Project (3GPP) unites [Seven] telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners" and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies.

IoT Long Range Technical Solutions



LORA (Long Range)

2010

Cycleo developed LoRa technology

2013

Semtech develop LoRaWAN network

2015

Creation of LoRa alliance

LoRa Alliance
Wide Area Networks for IoT

Jun 2015

Amsterdam become the first city covered by the LoRaWAN network

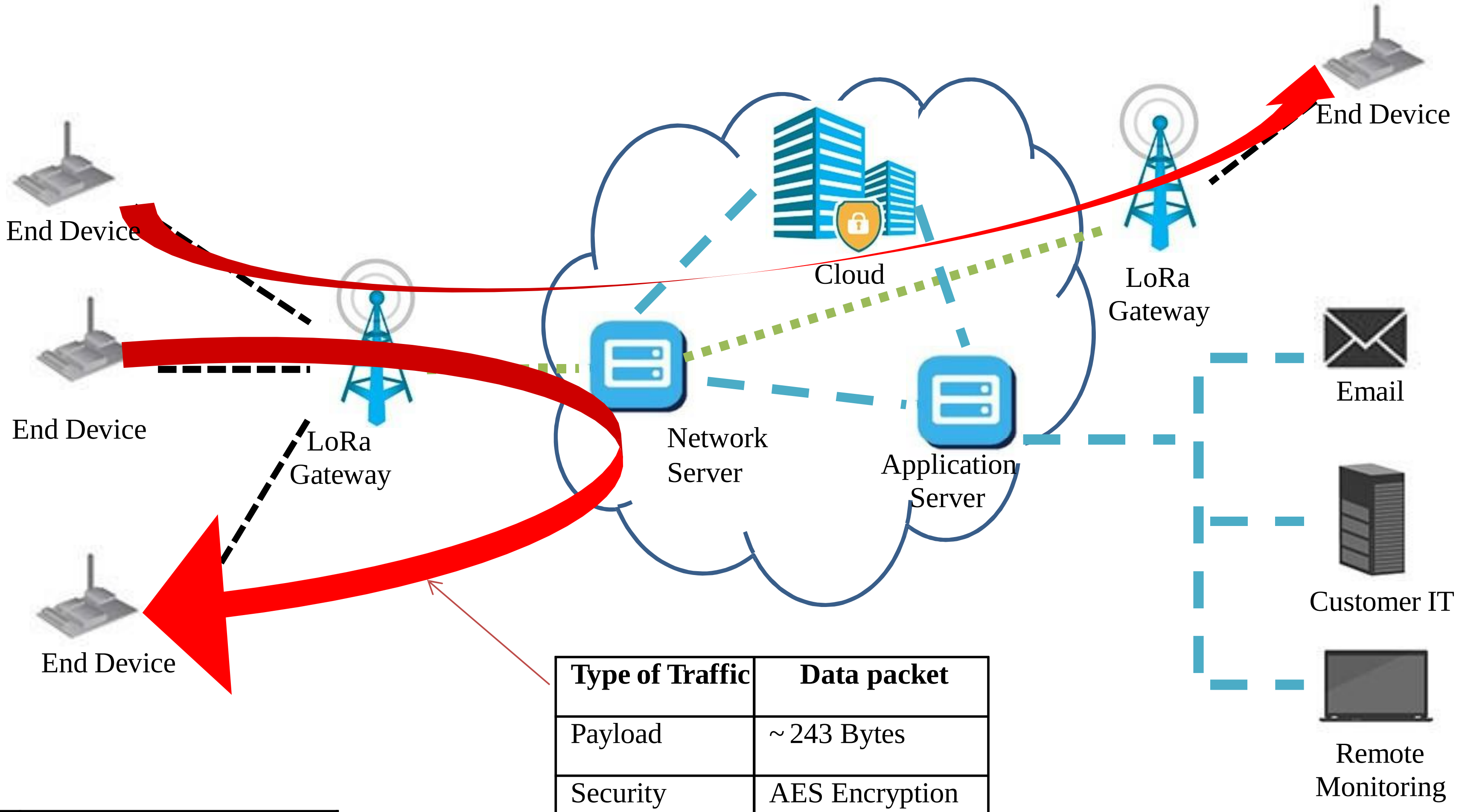
By the end of 2016

All France territory covered by LoRaWAN network: Bouygues Telecom

LORA - Features

- **LoRaWAN is a Low Power Wide Area Network**
- **Modulation:** a version of Chirp Spread Spectrum (CSS) with a typical channel bandwidth of 125KHz
- **High Sensitivity:** End Nodes: Up to -137 dBm, Gateways: up to -142 dBm
- **Long range:** up to 15 Km
- **Strong indoor penetration:** With High Spreading Factor, Up to 20dB penetration (deep indoor)
- **Robust** Occupies the entire bandwidth of the channel to broadcast a signal, making it robust to channel noise
- **Resistant to Doppler effect multi-path and signal weakening.**

LORA - Architecture



Type of Traffic	Data packet
Payload	~ 243 Bytes
Security	AES Encryption

Modulation	LoRa RF (Spread Spectrum)
Range	~ 15 Km
Throughput	~ 50 Kbps

LORA – Device Classes

Classes	Description	Intended Use	Consumption	Examples of Services
A (« all »)	Listens only after end device transmission	Modules with no latency constraint	The most economic communication Class energetically.. Supported by all modules. Adapted to battery powered modules	• Fire Detection • Earthquake Early Detection
B (« beacon »)	The module listens at a regularly adjustable frequency	Modules with latency constraints for the reception of messages of a few seconds	Consumption optimized. Adapted to battery powered modules	• Smart metering • Temperature rise
C (« continuous »)	Module always listening	Modules with a strong reception latency constraint (less than one second)	Adapted to modules on the grid or with no power constraints	• Fleet management • Real Time Traffic Management

Any LoRa object can transmit and receive data

Sigfox – Development

2012

Launch of the Sigfox network

2013

First fundraising of Sigfox company to cover France

2014

All France territory is covered by Sigfox network

Mar 2016

San-Francisco become the first US. State covered by Sigfox

2017

42 countries, 1000 customers

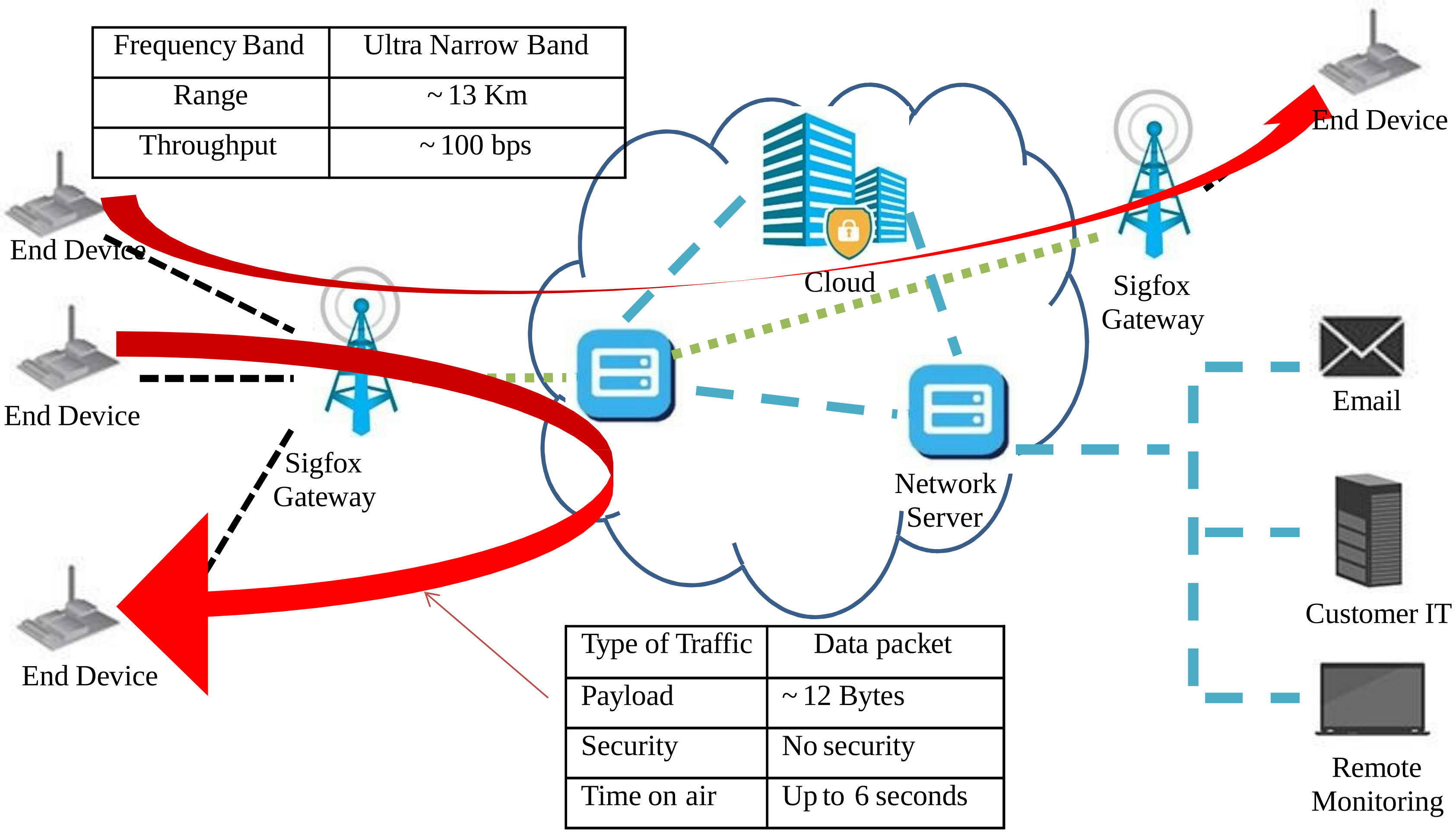
60 countries covered by the end of 2018

Sigfox – Overview

- **First LPWAN Technology (BPSK based transmission)**
- **The physical layer based on an Ultra-Narrow band wireless modulation**
- **Proprietary system**
- **Low throughput (~100 bps)**
- **Low power**
- **Extended range (up to 50 km)**
- **140 messages/day/device**
- **Subscription-based model**
- **Cloud platform with Sigfox –defined API for server access**
- **Roaming capability**
- **Takes very narrow parts of spectrum and changes the phase of the carrier radio wave to encode the data**

Sigfox - Architecture

Frequency Band	Ultra Narrow Band
Range	~ 13 Km
Throughput	~ 100 bps



Type of Traffic	Data packet
Payload	~ 12 Bytes
Security	No security
Time on air	Up to 6 seconds

Weightless - Overview

WEIGHTLESS™

- Low cost technology to be readily integrated into machines
- Operates in an unlicensed environment where the interference caused by others cannot be predicted and must be avoided or overcome.
- Ability to operate effectively in unlicensed spectrum and is optimized for M2M.
- Ability to handle large numbers of terminals efficiently.

Frequency Band	Narrow Band
Range	~ 13 Km
Throughput	~ 10 Mbps

Type of Traffic	Data packet
Payload	~ 200 Bytes
Security	AES Encryption

Weightless – Development

2012

Starts specification

Creation of Weightless Special Interest Group

2014

White Space spectrum is coming - ratified in USA Q3 2012, UK expected Q2 2014

First version released

First Weightless-N network deployed in London

Weightless – Versions

	Weightless-N	Weightless-P	Weightless-W
Communication	1-way	2-ways	2-ways
Range	5Km+	2Km+	5Km+
Battery life	10 years	3-8 years	3-5 years
Terminal cost	Very low	Low	Low-medium
Network cost	Very low	Medium	Medium
Data Rate	Up to 10 Mbps	Up to 100 Kbps	Up to 200 Kbps

RPMA – Overview

- **Random Phase Multiple Access (RPMA) technology is a low-power, wide-area channel access method used exclusively for machine-to-machine (M2M) communication**
  - Uses the popular 2.4 GHz band
  - Offer extreme coverage and High capacity
  - Allows handover (channel change) with Excellent link capacity

- **RPMA is a Direct Sequence Spread Spectrum (DSSS) using**
- Convolutional channel coding, gold codes for spreading
- 1 MHz bandwidth
- TDD frame with power control in both open and Closed Loop Power Control

TDD frame

RPMA – Development

2008

RPMA was developed by On-Ramp Wireless to provide connectivity to oil and gas actors

September 2015

it was renamed Ingenu, and targets to extend its technology to the IoT and M2M market

2016

RPMA was implemented in many places
Austin, Dallas/Ft. worth, Hostton,TX,Phenix,AZ, ….

2017

RPMA will be introduced in many others countries: Los Angeles, San Franscisco-West Bay,CA,Washington,DC, Baltimore,MD, Kanasas City

EnOcean

- **Ultra low power radio technology based on miniaturized power converters**
  - Power is generated by harvesting energy from motion, light or temperature (e.g. pressure on a switch or by photovoltaic cell)
  - These power sources are sufficient to power each module to transmit wirelessly and have battery-free information.

- **Frequencies:**
  - 868 MHz for Europe and 315 MHz for the USA

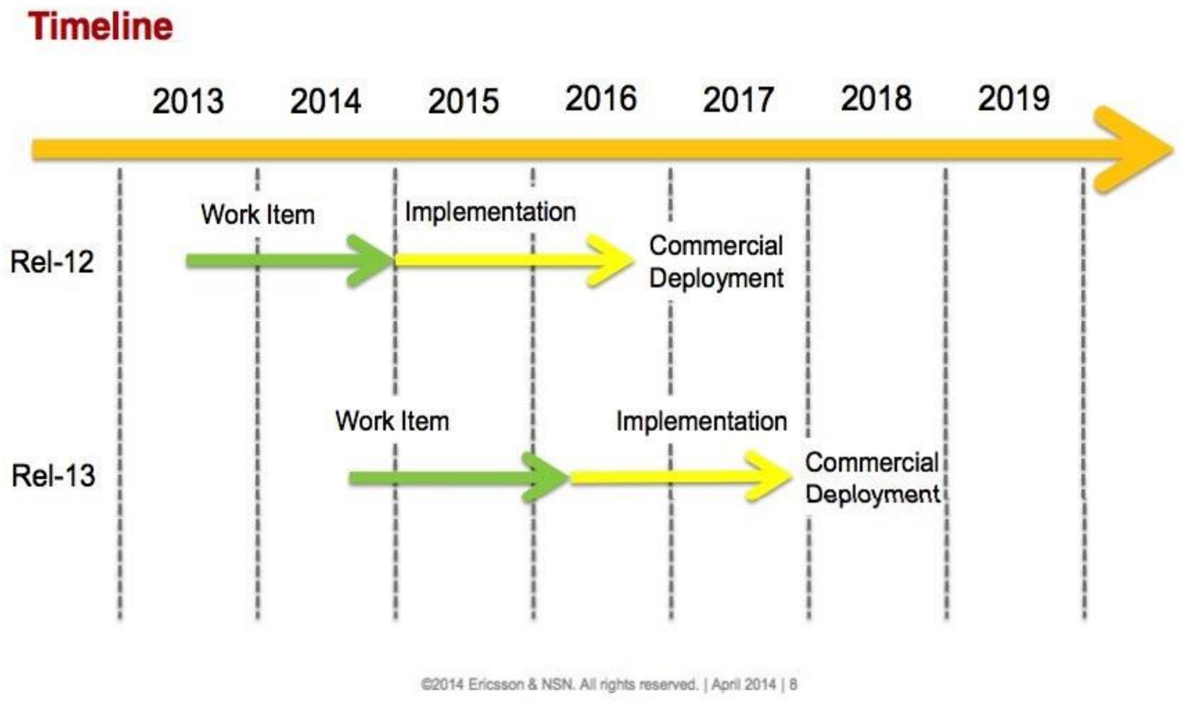
- **EnOcean Alliance**
  - By 2014 = more than 300 members (Texas, Leviton, Osram, Sauter, Somfy, Wago, Yamaha ...)

ZWave

- Low power radio protocol
- Home automation (lighting, heating, ...) applications
- Low-throughput: 9 and 40 kbps
- Battery-operated or electrically powered
- Frequency range: 868 MHz in Europe, 908 MHz in the US
- Range: about 50 m (more outdoor, less indoor)
- Mesh architecture possible to increase the coverage
- Access method type CSMA / CA
- **Z-Wave Alliance:** more than 100 manufacturers

LTE-M – (Long Term Evolution for Machines)

- Evolution of LTE optimized for IoT
- Low power consumption and autonomous
- Easy Deployment
- Interoperability with existing LTE networks
- Coverage upto 11 Km
- Max Throughput ≤ 1 Mbps



- ✓ First released in Rel.1 in 2 Q4 2014
- ✓ Optimization in Rel.13
- ✓ Specifications completed in Q1 2016
- ✓ Available since 2017

LTE to LTE-M

3GPP Releases	8 (Cat.4)	8 (Cat. 1)	12 (Cat.0) LTE-M	13 (Cat. 1,4 MHz) LTE-M
Downlink peak rate (Mbps)	150	10	1	1
Uplink peak rate (Mbps)	50	5	1	1
Number of antennas (MIMO)	2	2	1	1
Duplex Mode	Full	Full	Half	Half
UE receive bandwidth (MHz)	20	20	20	1.4
UE Transmit power (dBm)	23	23	23	20

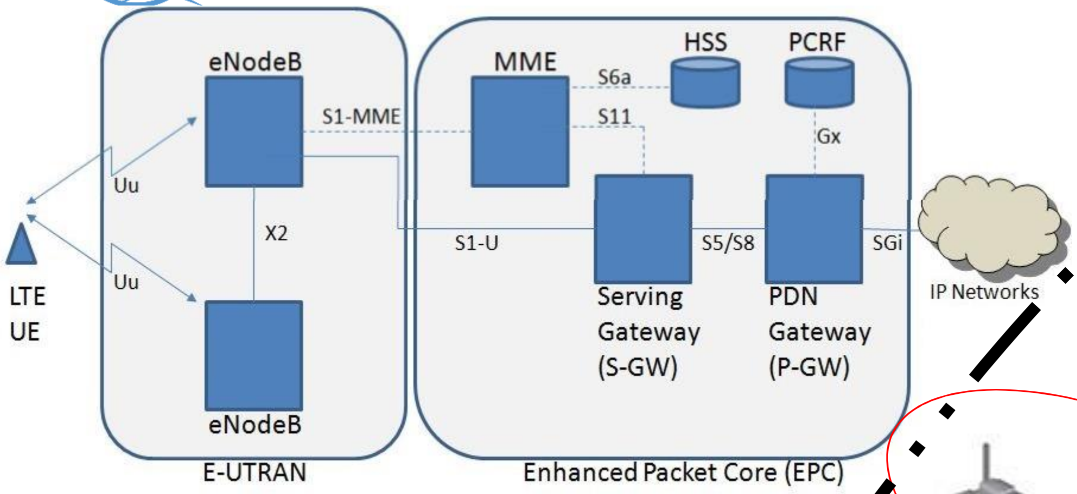
Release 12

- New category of UE ("Cat-0"): lower complexity and low cost devices
- Half duplex FDD operation allowed
- Single receiver
- Lower data rate requirement (Max: 1 Mbps)

Release 13

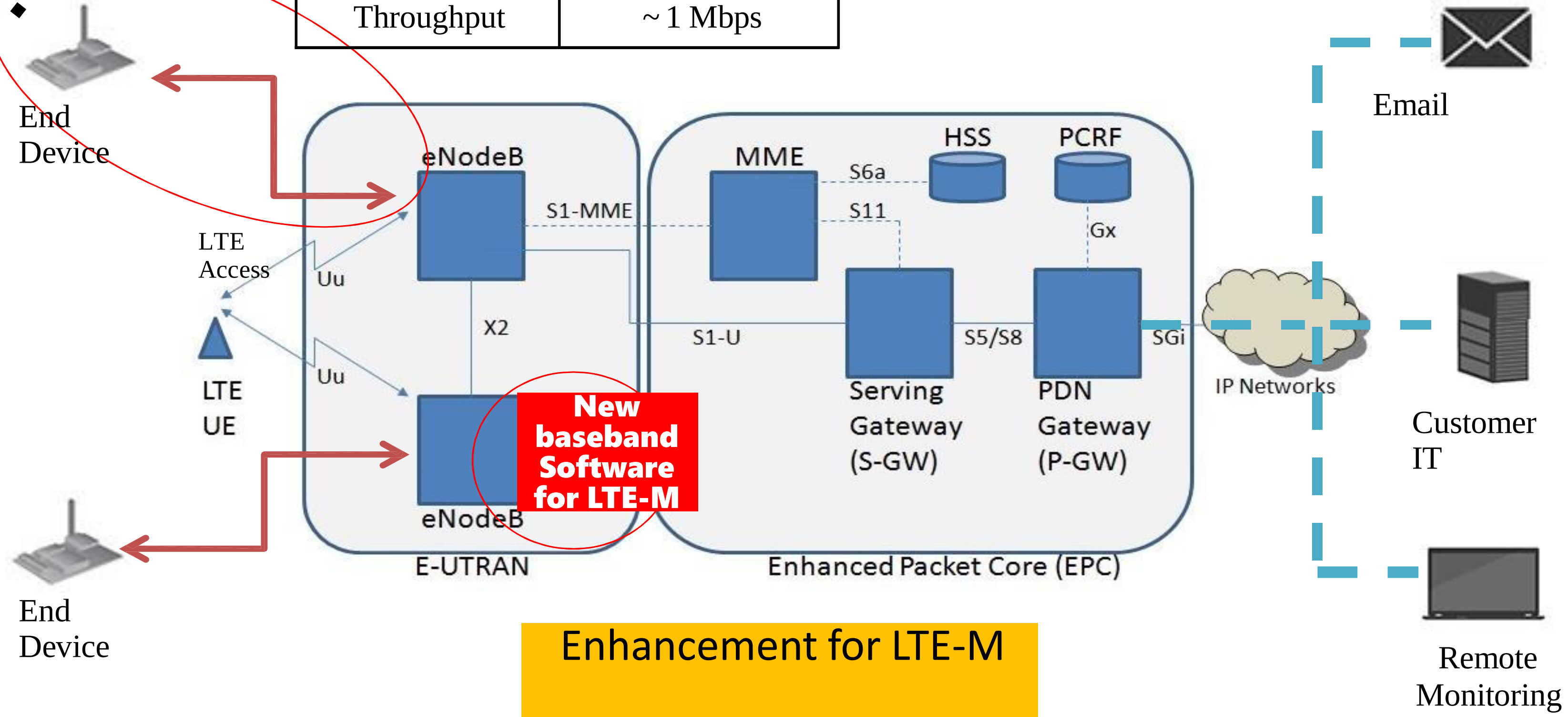
- Reduced receive bandwidth to 1.4 MHz
- Lower device power class of 20 dBm
- 15dB additional link budget: better coverage
- More energy efficient because of its extended discontinuous repetition cycle (eDRX)

LTE to LTE-M - Architecture



Present LTE Architecture

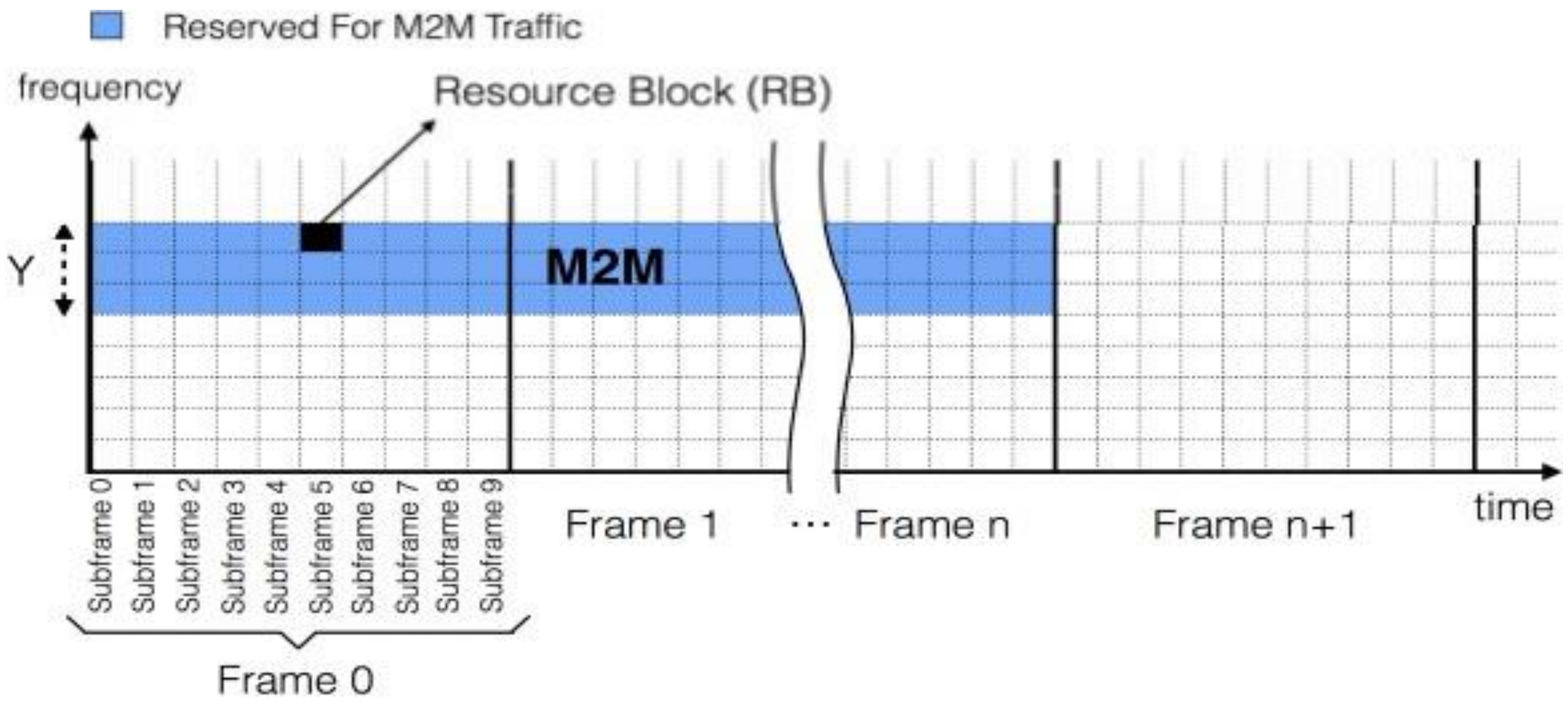
Frequency Band	Narrow Band
Access	LTE-M
Range	~ 11 Km
Throughput	~ 1 Mbps



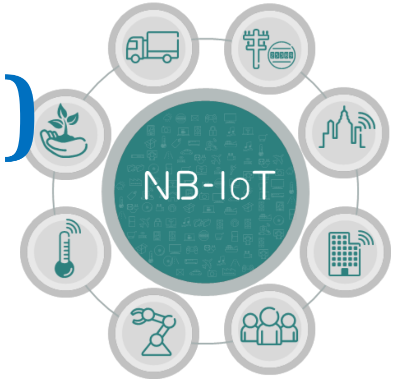
Enhancement for LTE-M

LTE-M

- Licensed Spectrum
- Frequency Bands: 700-900 MHz for LTE
- Some resource blocks are allocated to IoT on LTE bands



NB-IoT (Narrowband – Internet of Things)



Date	Event
April 2014	Narrowband proposal to Connected Living
May 2014	3GPP ‘Cellular IoT’ Study Item
March 2015	GSMA Mobile IoT created
August 2015	3GPP alignment on single standard
November 2015	1st ive pre-standard NB-IOT message NB-IoT
Jun 2015	Full 3GPP Standard Released
2017+	Commercial rollout

A GLOBAL INITIATIVE

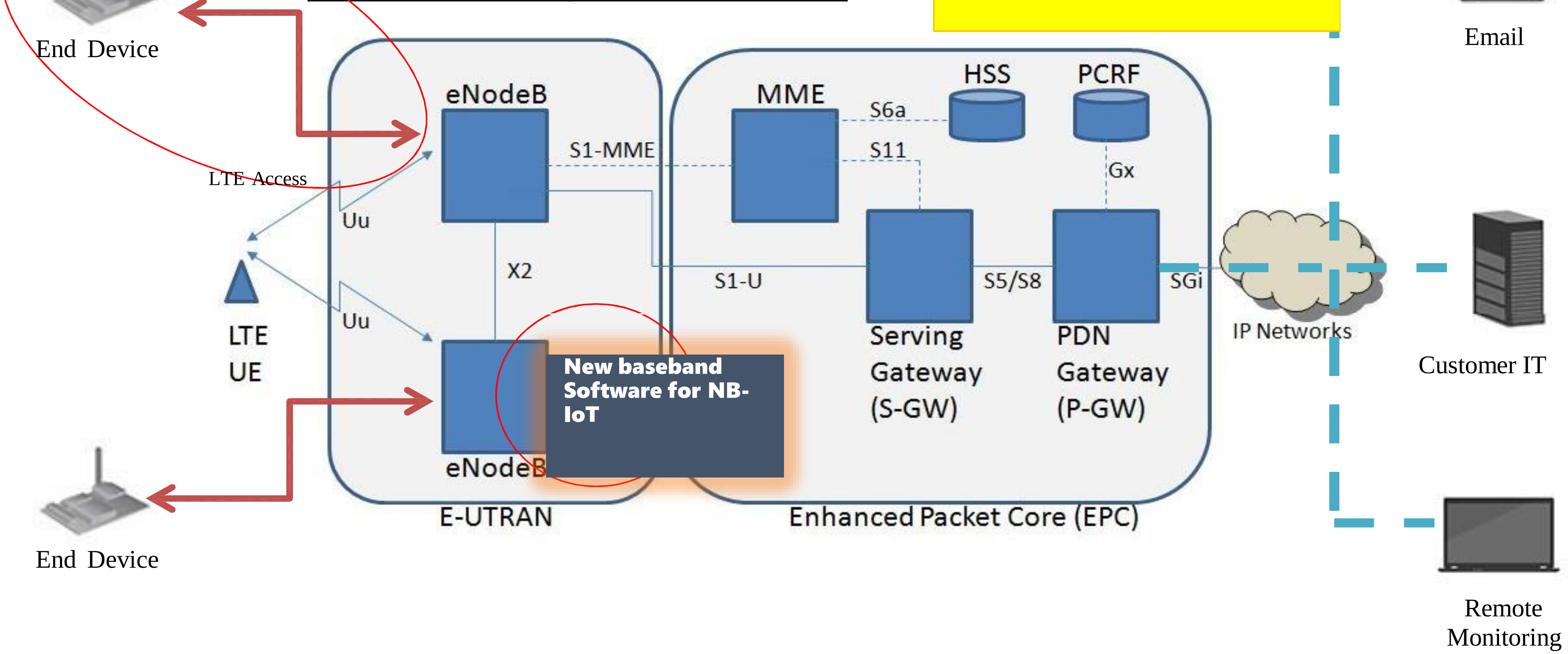
NB-IoT

- **Uses LTE design extensively** e.g. DL: FDMA, UL: SC-FDMA
- **Lower cost** than eMTC (Narrow band: supports 180 KHz channel)
- **Extended coverage:** 164 dB maximum coupling loss or link budget (at least for standalone) in comparison to GPRS link budget of 144dB and LTE of 142.7 dB
- **Low Receiver sensitivity** = -141 dBm
- **Long battery life**: 10 years with 5 Watt Hour battery (depending on traffic and coverage needs)
- **Support for massive number of devices**: at least 50.000 per cell
- **3 modes of operation:**
  - **Stand-alone**: *stand-alone carrier, e.g. spectrum currently used by GERAN (GSM Edge Radio Access Network) systems as a replacement of one or more GSM carriers*
  - **Guard band:** *unused resource blocks within a LTE carrier's guard-band*
  - **In-band:** *resource blocks within a normal LTE carrier*

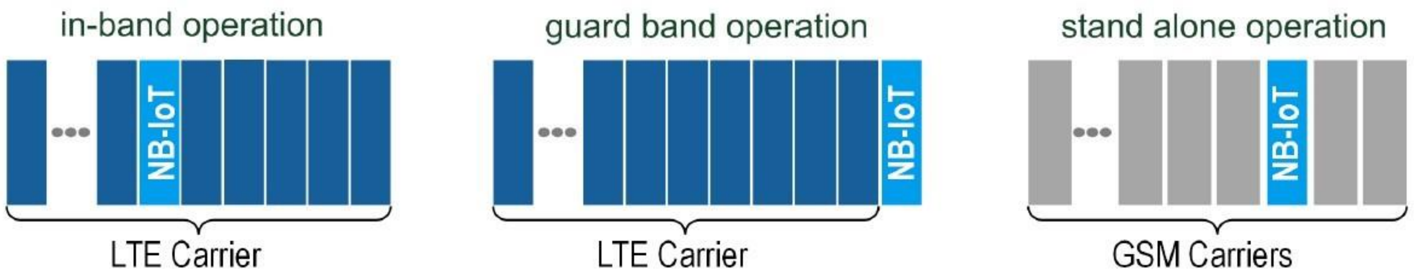
NB-IoT - Architecture

Frequency Band	Ultra Narrow Band
Range	~ 11 Km
Throughput	~ 150 Kbps

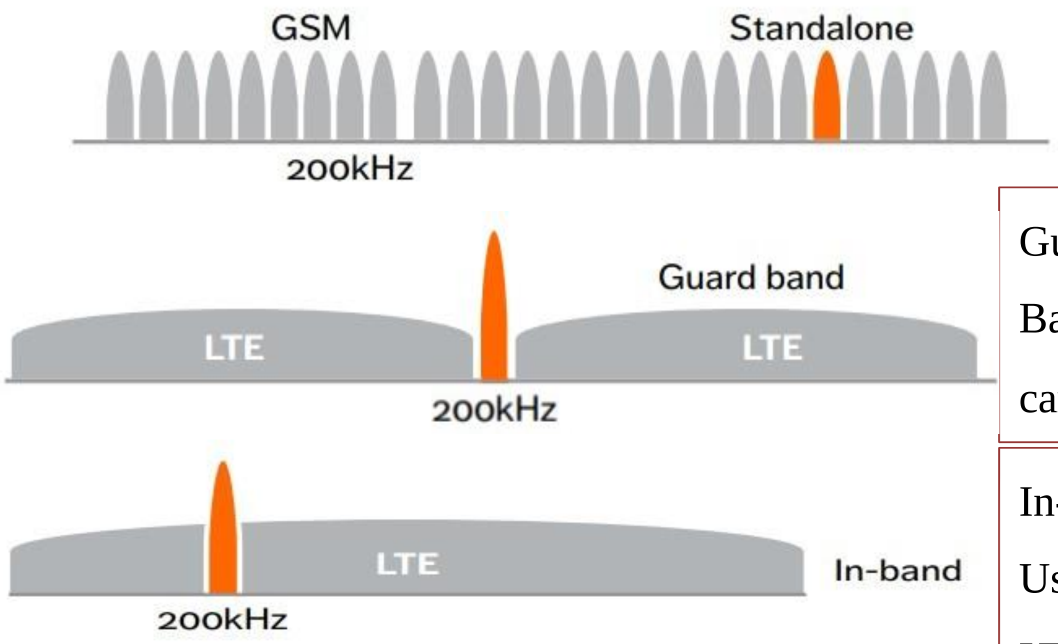
HD-FDD
p/2 BPSK, p/4 QPSK Class 3 (23 dBm) Class 5 (20 dBm)



NB-IoT – Spectrum & Access



Designed with a number of deployment options for licensed GSM , WCDMA or LTE spectrum to achieve efficiency



Stand-alone operation

Dedicated spectrum.

Ex.: By re-farming GSM channels

Guard band operation

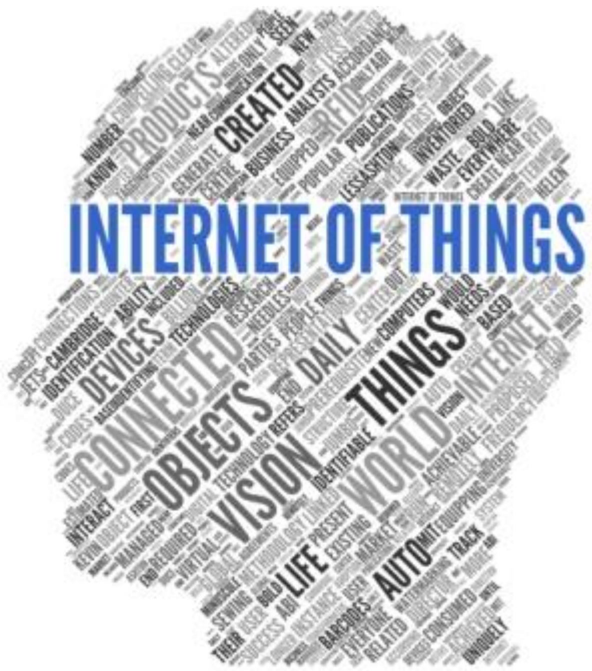
Based on the unused RB within a LTE carrier's guard-band

In-band operation

Using resource blocks within a normal LTE carrier

Future Issues of IoT

- Data Ownership
- Rights around derivative use of data
- Dynamic decision rights (change in consent)
- Consumer awareness
- Privacy rights
- Cybersecurity
- Liability (decision made by AI: health, transportation)
- curacy
- Public profit sharing
- Preventing oligopolies (Large tech companies taking over)
- Fairness (Some may not be able to afford)
- Disposal of electronic waste



Source: Dr. Shoumen Datta of Massachusetts Institute of Technology (MIT)

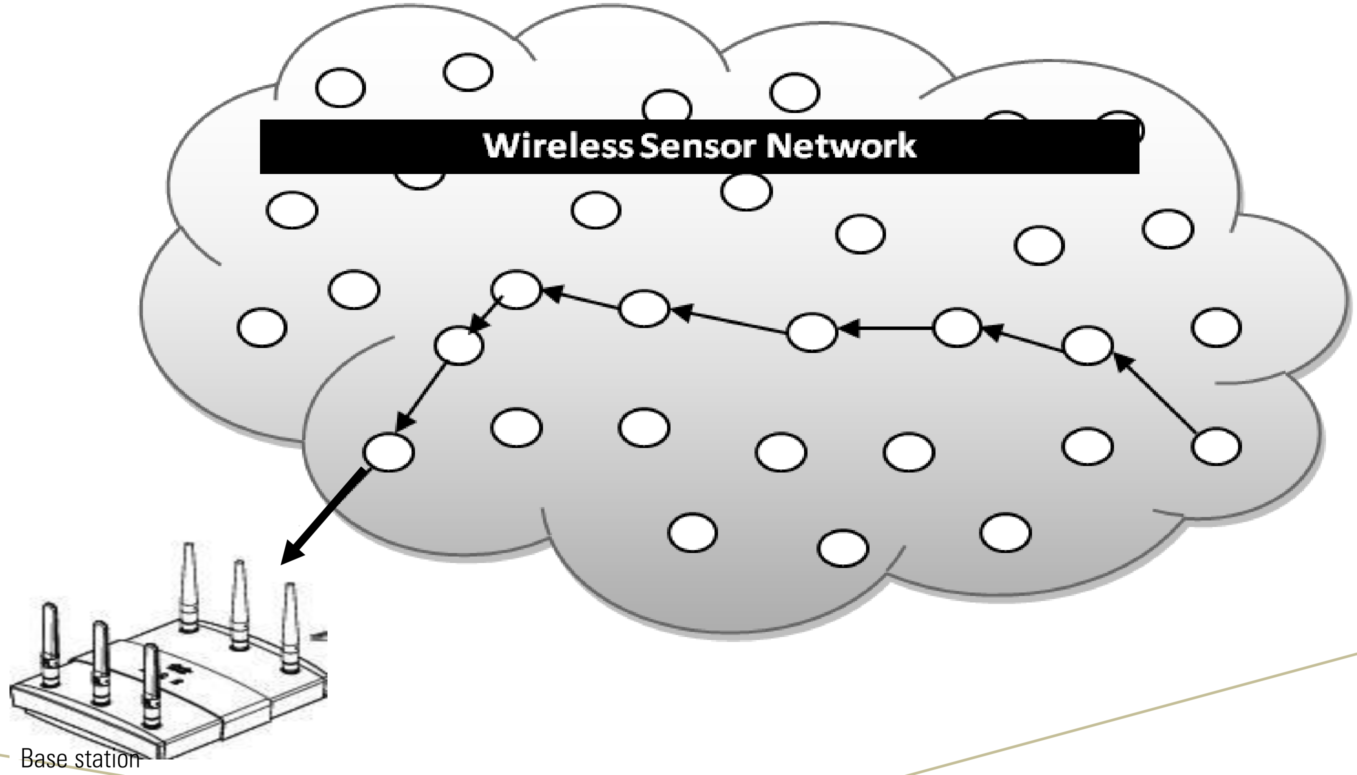
WIRELESS SENSOR NETWORKS

LECTURE – 5

DR. SK WIJAYASEKARA

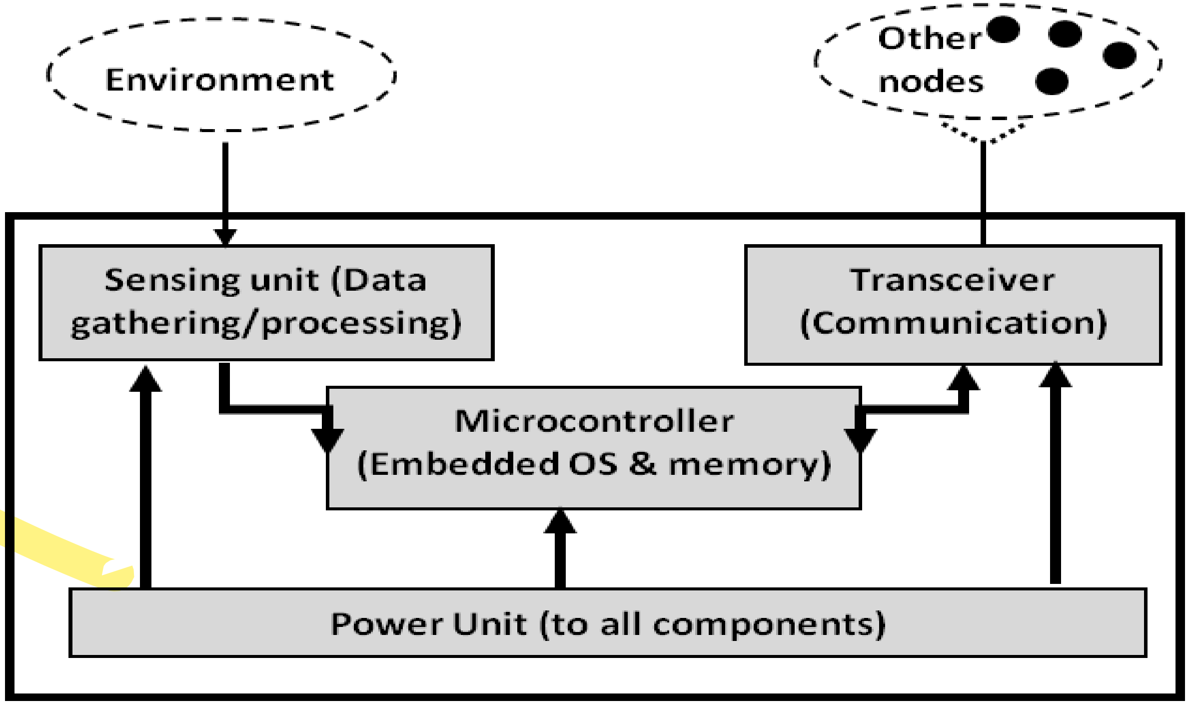
WIRELESS SENSOR NETWORKS (WSNS)

A sensor network is a wireless network that consists of thousands of very small nodes called *sensors*.



WSNS CONT.

- WSN Sensors are equipped with sensing, limited computation, and wireless communication capabilities.



- Wireless Sensor Networks are networks that consists of sensors which are distributed in an ad hoc manner.

- These sensors work with each other to sense some physical phenomenon and then the information gathered is processed to get relevant results.

- Wireless sensor networks consists of protocols and algorithms with self-organizing capabilities.

COMPARISON WITH AD HOC NETWORKS

- Wireless sensor networks mainly use broadcast communication while ad hoc networks use point-to-point communication.
- Unlike ad hoc networks wireless sensor networks are limited by sensors limited power, energy and computational capability.
- Sensor nodes may not have global ID because of the large amount of overhead and large number of sensors.

WSNS APPLICATIONS

- WSNs have many advantages over traditional networking techniques.

- They have an ever-increasing number of applications, such as infrastructure protection and security, surveillance, health-care, environment monitoring, food safety, intelligent transportation, and smart energy.

WSNS APPLICATIONS

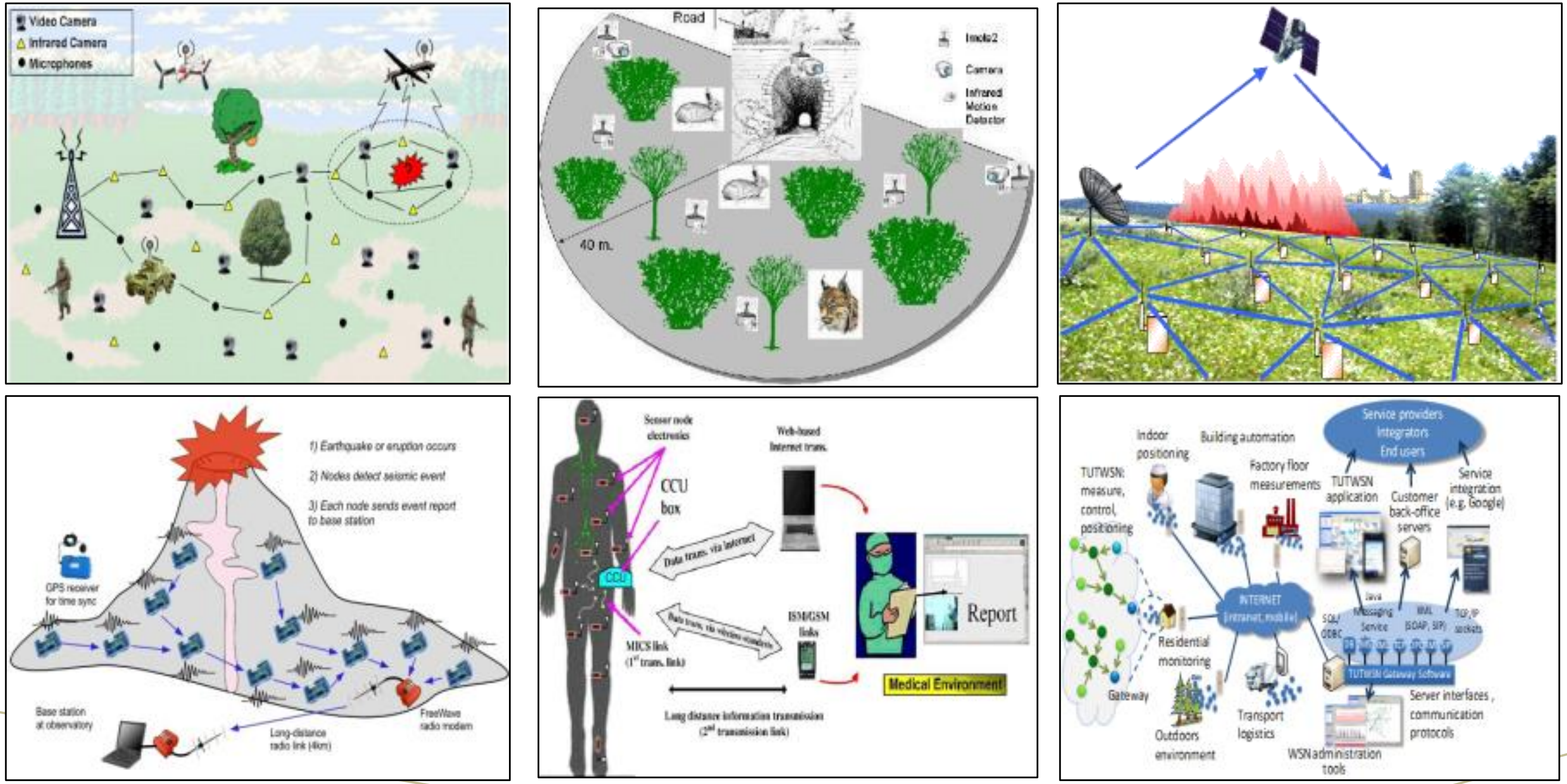


Figure 3: WSNs Applications

APPLICATIONS OF WIRELESS SENSOR NETWORKS

The applications can be divided in three categories:

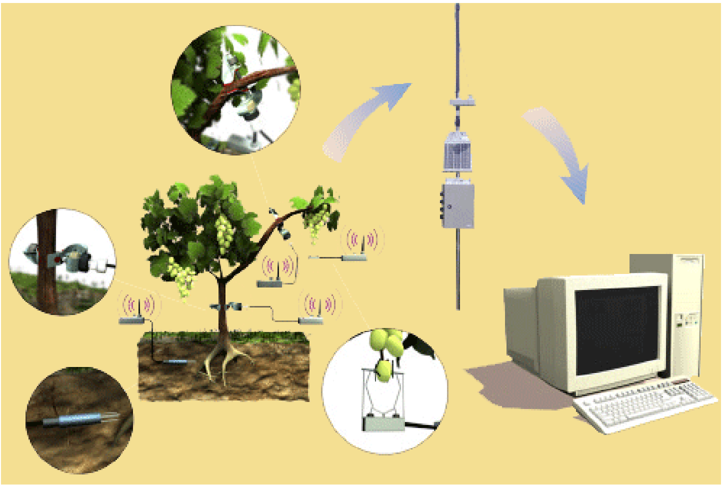
1. Monitoring of objects.
2. Monitoring of an area.
3. Monitoring of both area and objects.

MONITORING AREA

- Environmental and Habitat Monitoring
- Precision Agriculture
- Indoor Climate Control
- Military Surveillance
- Treaty Verification
- Intelligent Alarms

EXAMPLE: PRECISION AGRICULTURE

- Precision agriculture aims at making cultural operations more efficient, while reducing environmental impact.
- The information collected from sensors is used to evaluate optimum sowing density, estimate fertilizers and other inputs needs, and to more accurately predict crop yields.



MONITORING OBJECTS

- Structural Monitoring
- Eco-physiology
- Condition-based Maintenance
- Medical Diagnostics
- Urban terrain mapping

MONITORING INTERACTIONS BETWEEN OBJECTS AND SPACE

- Wildlife Habitats
- Disaster Management
- Emergency Response
- Ubiquitous Computing
- Asset Tracking
- Health Care
- Manufacturing Process Flows

CHARACTERISTICS OF WIRELESS SENSOR NETWORKS

- Wireless Sensor Networks mainly consists of **sensors**. Sensors are -
  - low power
  - limited memory
  - energy constrained due to their small size.
- Wireless networks can also be deployed in **extreme environmental** conditions and may be prone to enemy attacks.
- Although deployed in an ad hoc manner they need to be **self organized** and **self healing** and can face constant reconfiguration.

DESIGN CHALLENGES

- **Heterogeneity**
  - The devices deployed maybe of various types and need to collaborate with each other.
- **Distributed Processing**
  - The algorithms need to be centralized as the processing is carried out on different nodes.
- **Low Bandwidth Communication**
  - The data should be transferred efficiently between sensors

CONTINUED..

- Large Scale Coordination
  - The sensors need to coordinate with each other to produce required results.
- Utilization of Sensors
  - The sensors should be utilized in a ways that produce the maximum performance and use less energy.
- Real Time Computation
  - The computation should be done quickly as new data is always being generated.

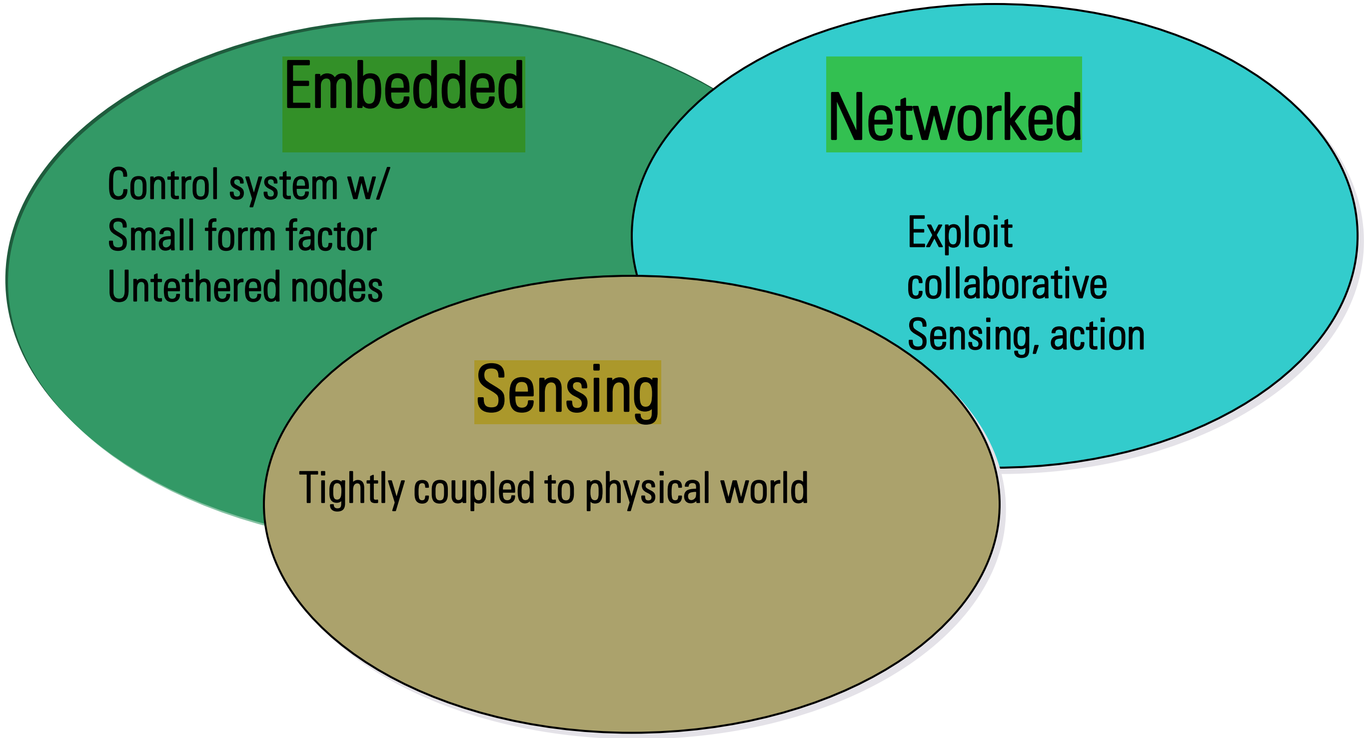
OPERATIONAL CHALLENGES OF WIRELESS SENSOR NETWORKS

- Energy Efficiency
- Limited storage and computation
- Low bandwidth and high error rates
- Errors are common
  - Wireless communication
  - Noisy measurements
  - Node failure are expected
- Scalability to a large number of sensor nodes
- Survivability in harsh environments
- Experiments are time- and space-intensive

Enabling Technologies

Embed numerous distributed devices to monitor and interact with physical world

Network devices to coordinate and perform higher-level tasks



Exploit spatially and temporally dense, in situ, sensing and actuation

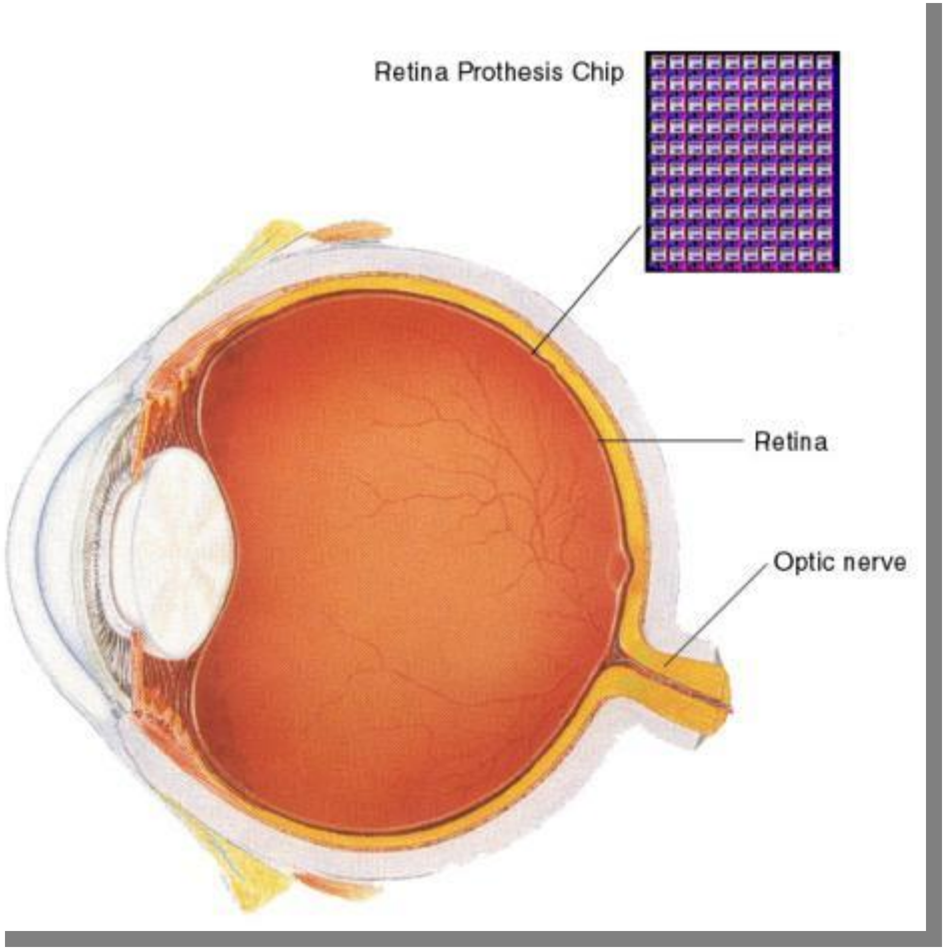
FUTURE OF WSN

SMART HOME / SMART OFFICE

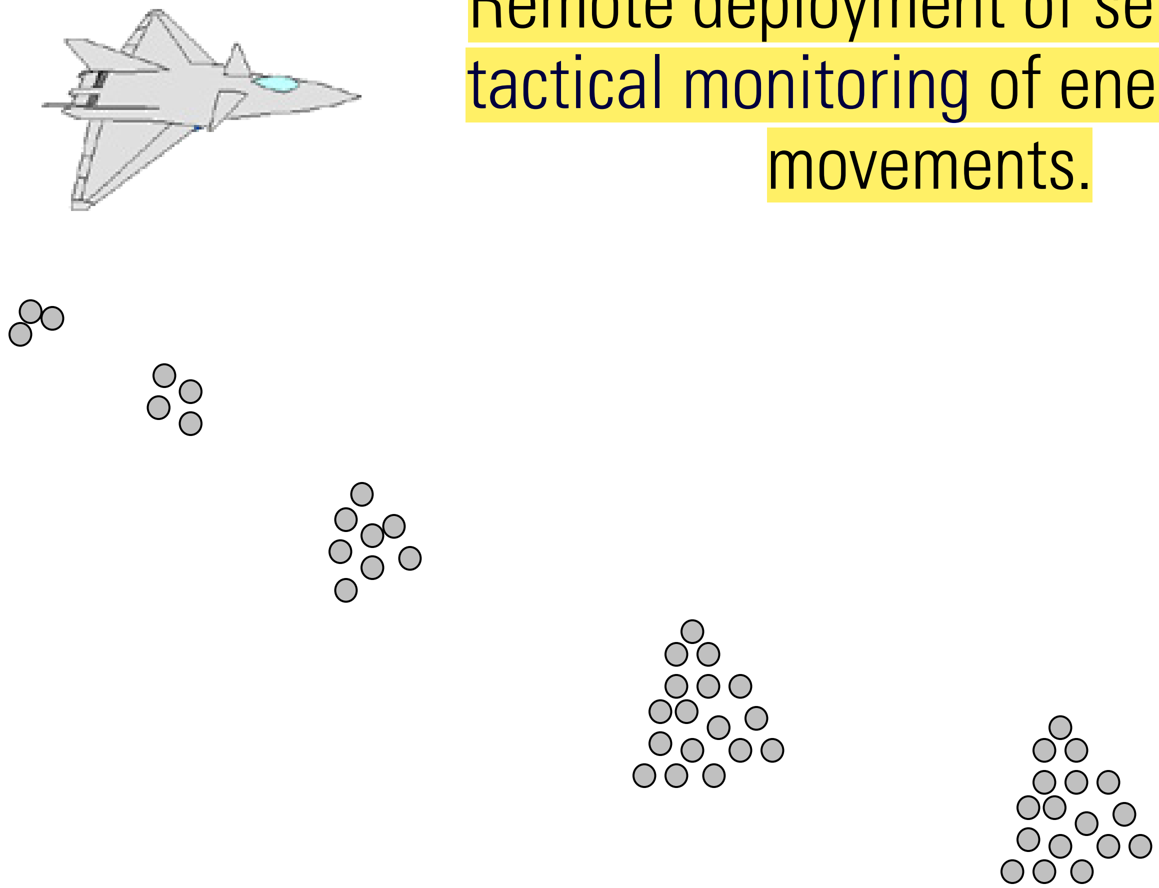
- Sensors controlling electrical devices in the house.
- Better lighting and heating in office buildings.
- The Pentagon building has used sensors extensively.

BIOMEDICAL / MEDICAL

- Health Monitors
  - Glucose
  - Heart rate
  - Cancer detection
- Chronic Diseases
  - Artificial retina
  - Cochlear implants
- Hospital Sensors
  - Monitor vital signs
  - Record anomalies



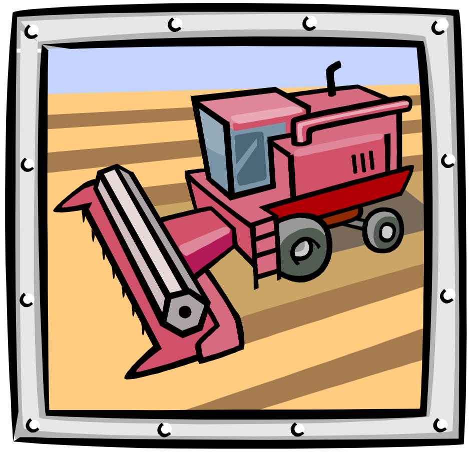
MILITARY



Remote deployment of sensors for tactical monitoring of enemy troop movements.

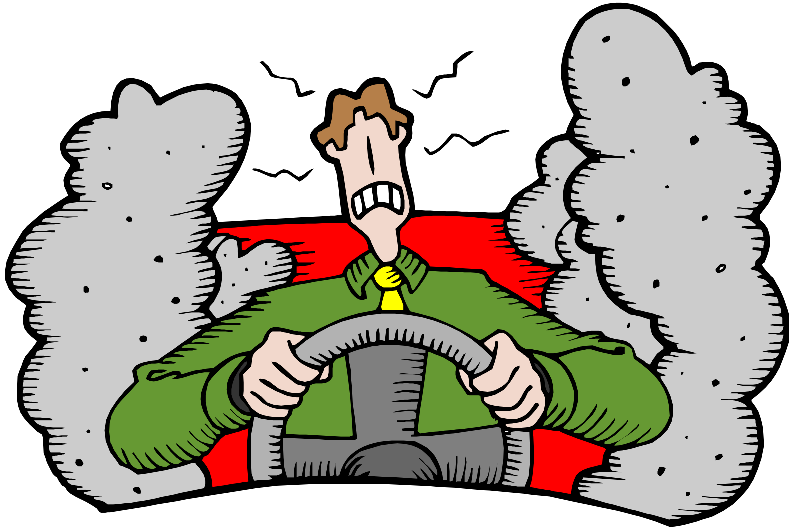
INDUSTRIAL & COMMERCIAL

- Numerous industrial and commercial applications:
  - Agricultural Crop Conditions
  - Inventory Tracking
  - In-Process Parts Tracking
  - Automated Problem Reporting
  - Theft Deterrent and Customer Tracing
  - Plant Equipment Maintenance Monitoring



TRAFFIC MANAGEMENT & MONITORING

- Future cars could use wireless sensors to:
  - Handle Accidents
  - Handle Thefts



✓Sensors embedded in the roads to:

- Monitor traffic flows
- Provide real-time route updates