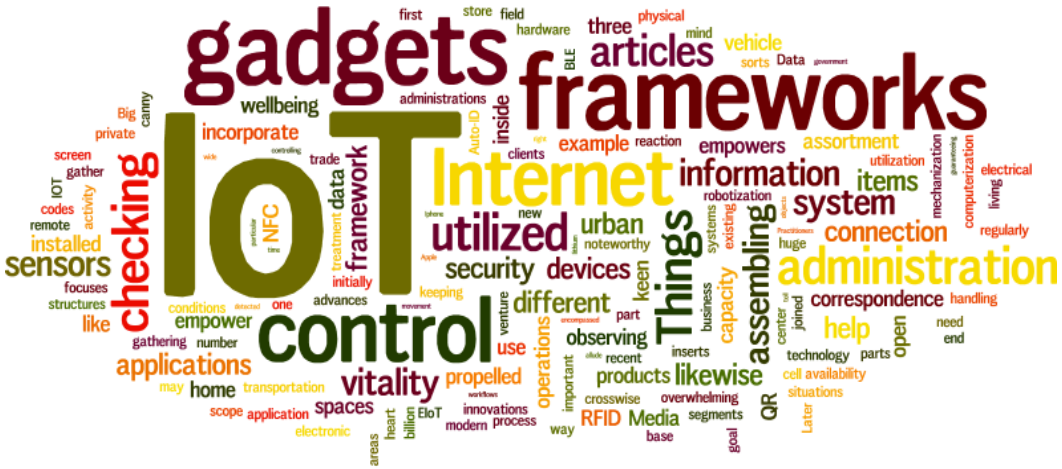
CS578: Internet of Things

IoT Ecosystem

Different components of IoT



Dr. Manas Khatua

Assistant Professor

Dept. of CSE, IIT Guwahati

E-mail: manaskhatua@iitg.ac.in

"Strength is Life, Weakness is Death." – **Swami Vivekananda**

IoT Ecosystem

IoT is **not just a technology**; it is **an enormous ecosystem!**

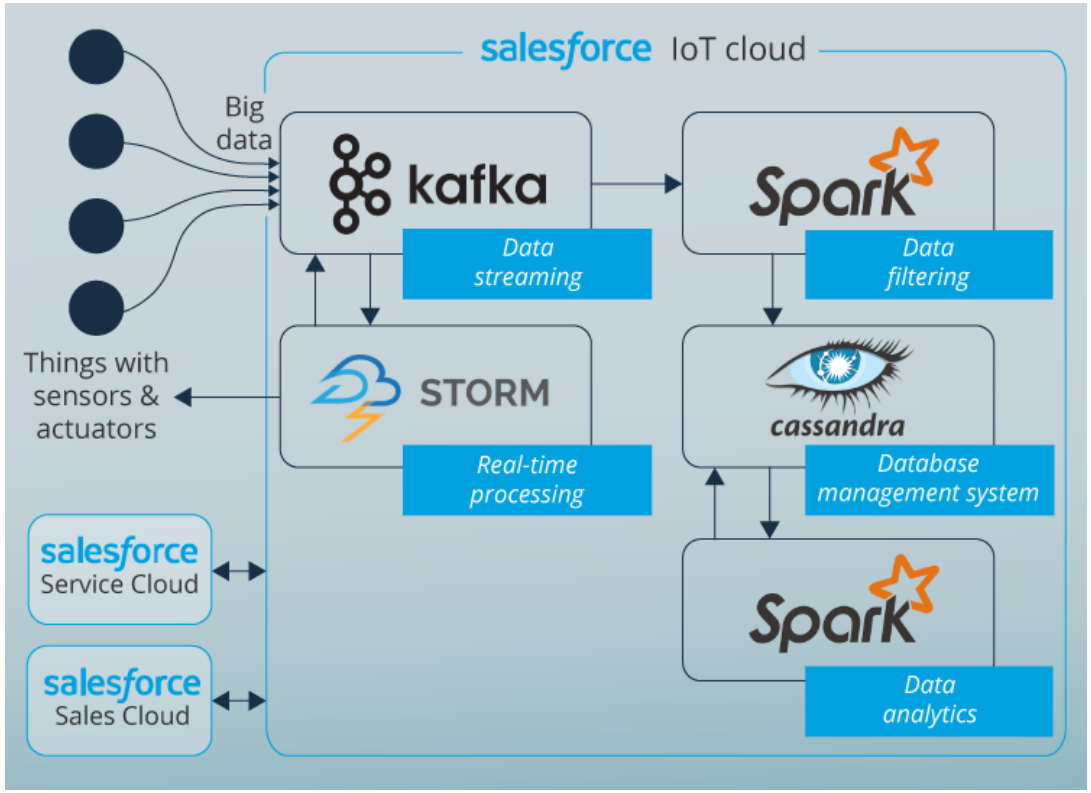
- Community components:
  - ✓ IoT Frameworks
    - Tools needed to design and implement IoT-based solutions and products
  - ✓ IoT Architectures
    - Graphical structure of the designed IoT-based solutions and products
  - ✓ IoT Core
    - Sensors & Actuators, microcontrollers, internet connectivity, service platform including security
  - ✓ IoT Gateway
    - It carries the responsibility to ensure bidirectional communication between IoT protocols and other networks
  - ✓ Cloud
    - Accepts, accumulates, maintains, stores, and process data in real time
  - ✓ Analytics
    - It indulges in conversion of data which results in meaningful suggestions and recommendations
  - ✓ User Interface / Visualization
    - Design sleek, visually appealing, interactive, and ease-of-use graphical user interface

IoT Framework

- Framework provides a development environment.
  - It provides appropriate infrastructure to design and implement the architecture
- IoT framework comprises of large number of components
  - sensors, sensor systems, gateways, mobile app, embedded controller, data management platform, analytical platform, and so on.
  - support interoperability among all devices, provides secure connectivity, reliability in data transfer, interface to 3rd party application to built on it, and so on.

Few IoT Framework	Few IoT Framework
RTI (Real-Time Innovations) Connext DDS	Cisco Ultra IoT
Salesforce IoT cloud	Azure IoT
Eclipse IoT	ThingWorx
GE (General Electronic) Predix	AWS IoT
Watson IoT	Kaa

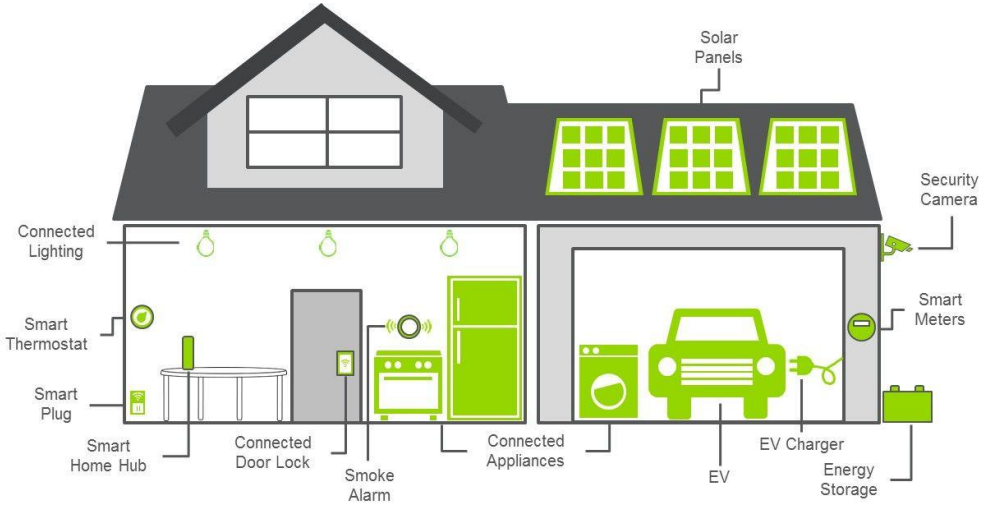
Salesforce IoT Cloud



- Salesforce IoT Framework
  - Combines IoT and big data
- A new data is sent to **Kafka**, where **Spark** is responsible to transmit it to **Cassandra** for further processing.
- Meanwhile, **Storm** analyses the dataset to formulate responses for current events
- The backbone of these technologies:
  - Salesforce's Heroku PaaS
  - AWS Cloud
  - Apache Technologies and Thunder event-processing engine

IoT Network Architecture

- At present, networks run the business
- It should never be built without careful planning



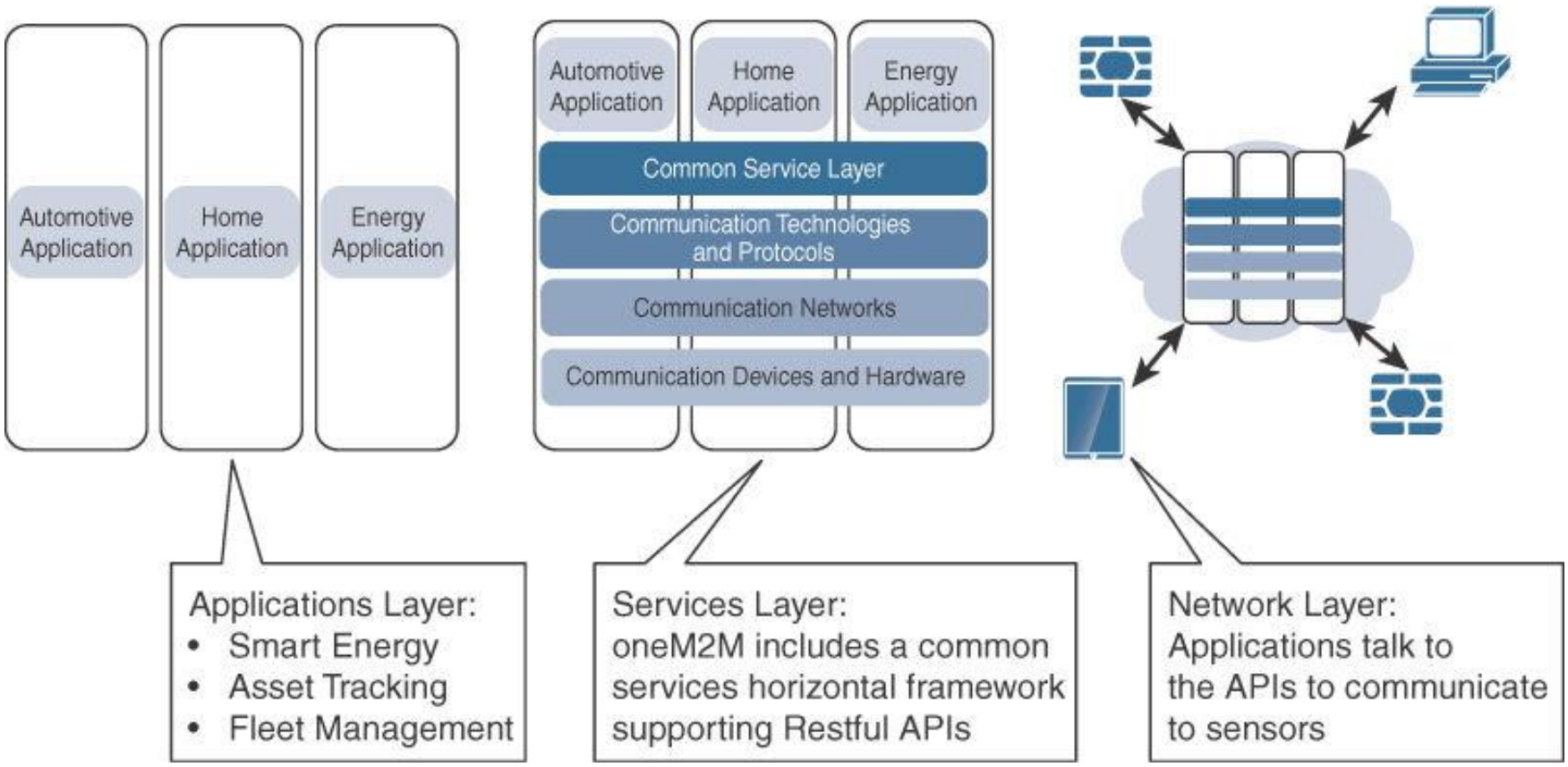
Driving forces:

- Scale
- Security
- Constrained devices
- Massive data
- Data analysis
- Support to legacy devices

- Architecture is how you design (i.e. graphical structure) your application or solution.
- The key difference between IT and IoT networks is the data

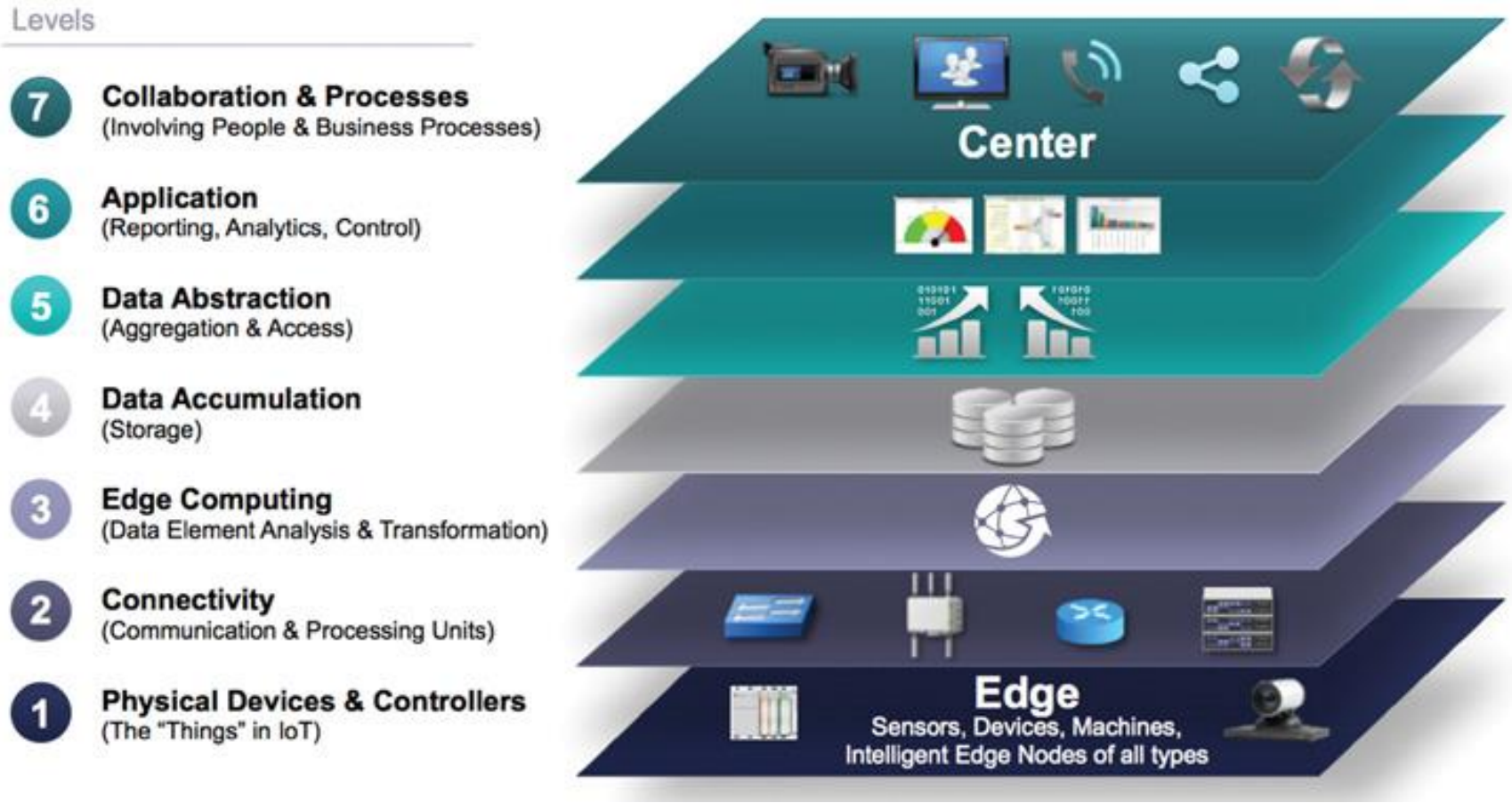
oneM2M IoT Architecture

- Proposed by European Telecommunications **S**tandards Institute (ETSI)
- Goal : to create a common services layer, which can be readily embedded in **field devices** to allow communication with application servers.



IoTWF Architecture

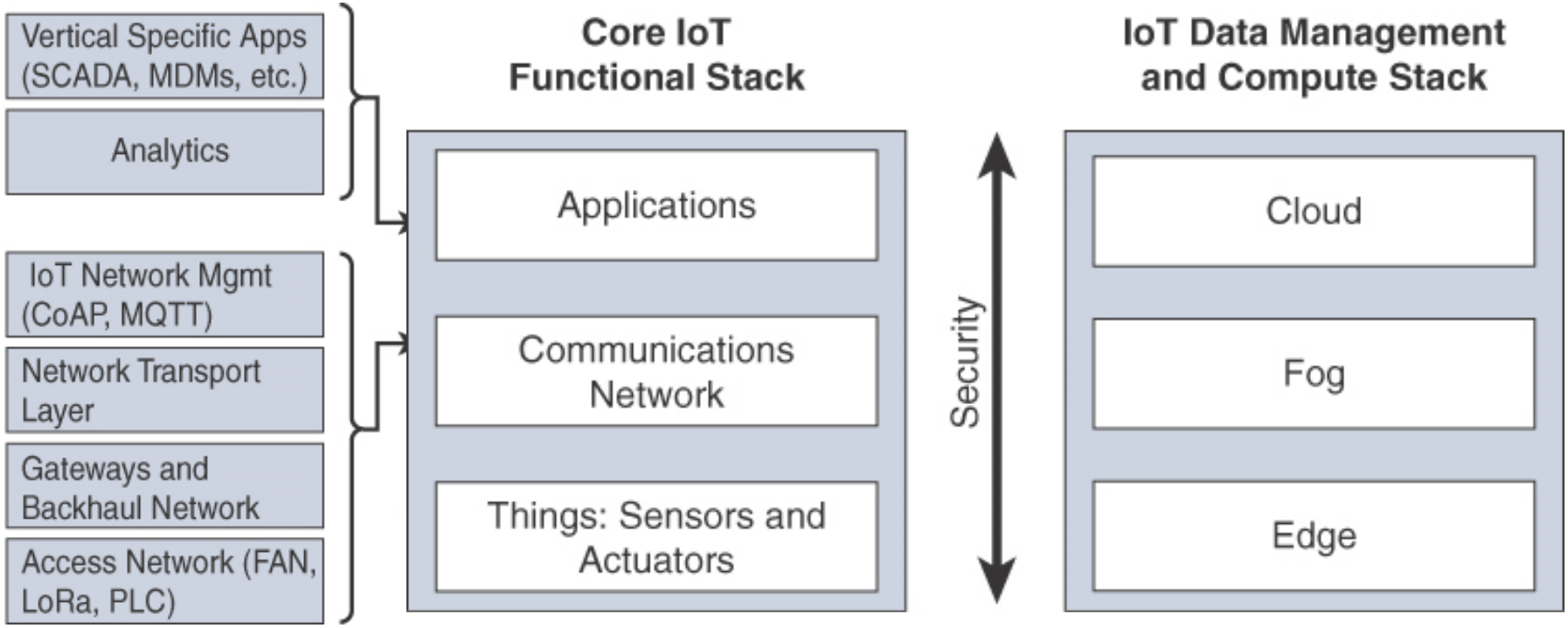
- IoTWF architectural committee (led by Cisco, IBM, Rockwell Automation, and others)
- way of visualizing IoT from a technical perspective



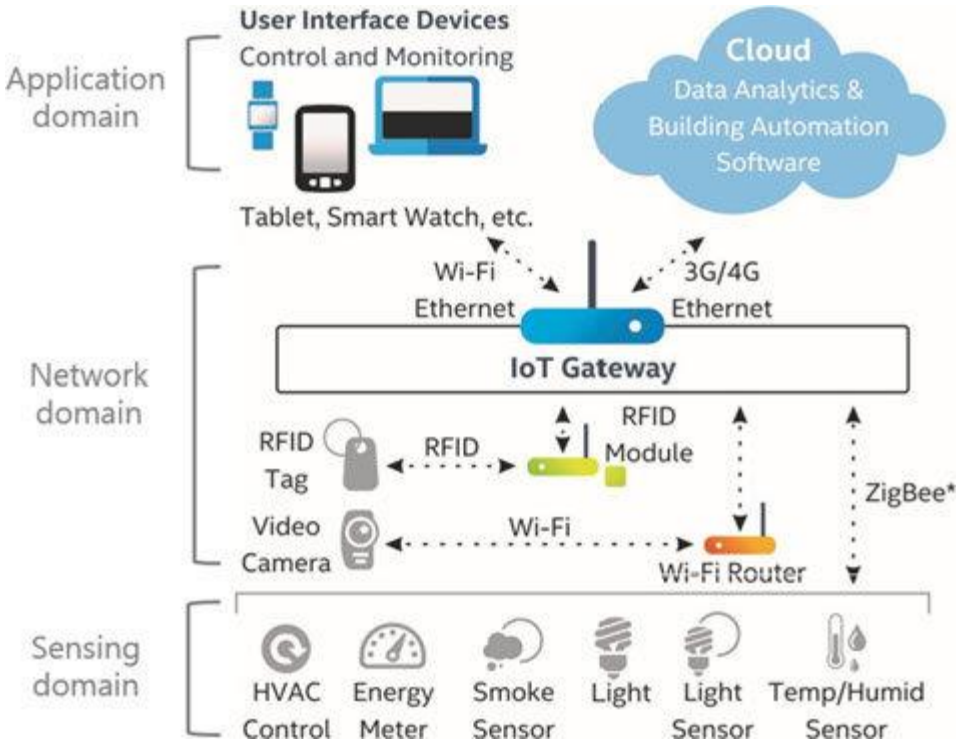
Simplified IoT Architecture

- It highlights the fundamental building blocks that are common to most IoT systems and which is intended to help in designing an IoT network.

- IoT architectural framework is presented as two parallel stacks
  - Core IoT Functional Stack
  - IoT Data Management and Compute Stack



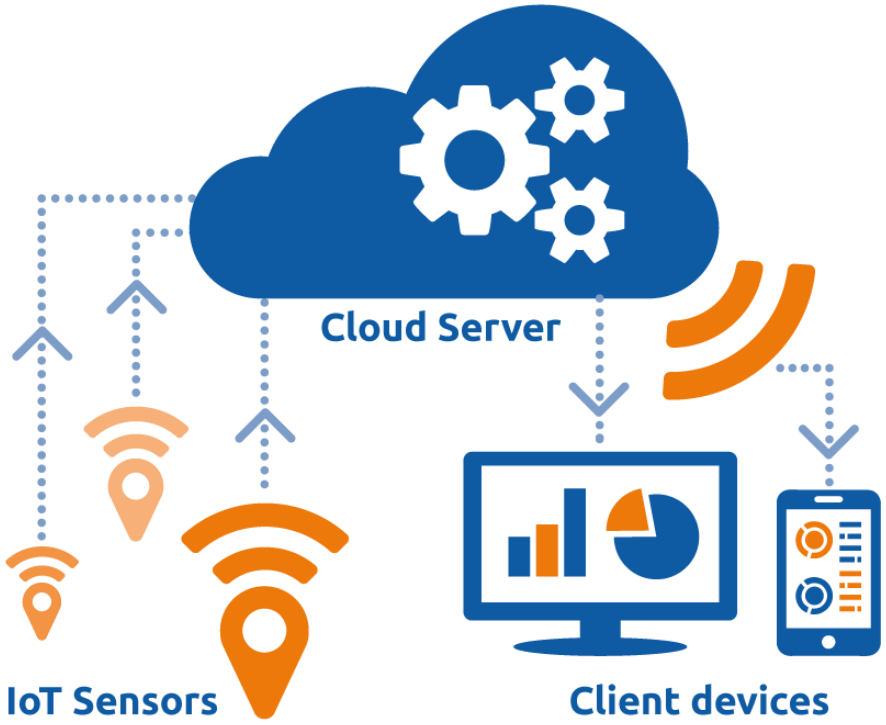
IoT Gateway



- It is a physical device or software program that serves as the connection point between the two different types of networks
- Provide bidirectional communication
  - Between IoT protocols and other networks
    - e.g. Zigbee <--> Ethernet
- Sometimes programmed to execute some processing operations
  - Edge computing
- It is necessary to maintain security to a certain extent
  - Can shield the entire IoT systems from any cyberattack

Source: B. Kang, D. Kim, H. Choo, "Internet of Everything: A Large-Scale Autonomic IoT Gateway", IEEE Transactions on Multi-scale Computing Systems, vol. 3, no. 3, 2017, pp. 206-214.

Cloud

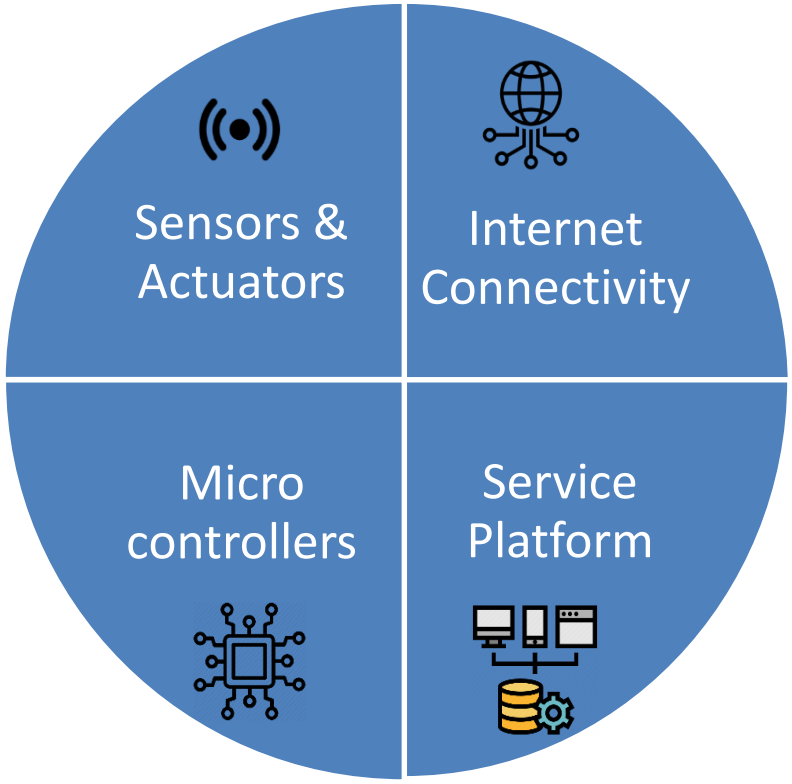


- IoT generates vast amount of Big Data;
- this in turn puts a huge strain on Internet Infrastructure.

- Cloud can facilitate to
  - Provide different services
  - Store huge amount of data
  - Process the data efficiently

- **Benefits of Cloud Platform in IoT**
  - Network Scalability
  - Data Mobility
  - Time to market
  - Security
  - Cost-effectiveness

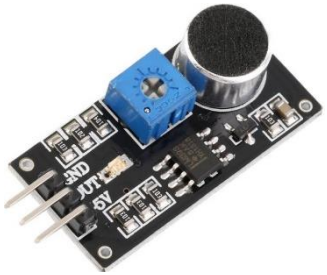
Core Components of IoT



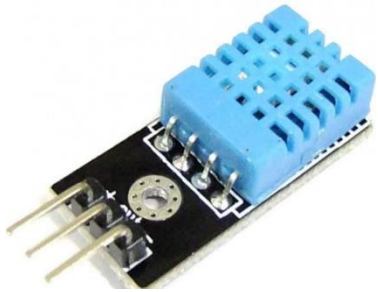
- Sensors - to gather data and events
- Actuators – responsible for moving and controlling a mechanism or system
- Microcontrollers - automatically controls sensors and actuators; makes them smart
- Internet connectivity – responsible for sharing gathered information and control command
- Service Platform – ability to deploy and manage the IoT devices and applications including data management, data analytics and all aspects of security

“Things” in IoT – Sensors

MQ135 - Air Quality Gas Sensor



Sound Detection Sensor



DHT11 - Temprature and Humidity Sensor

PIR Motion Detector Sensor

Pulse Sensor

LDR Light Sensor

Ultrasonic Distance Sensor

IR Sensor

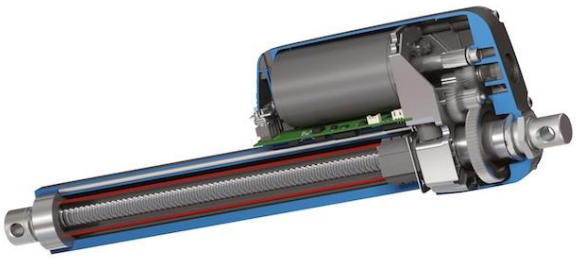
“Things” in IoT – Actuators

4 Channel 5V Relay

Servo Motor

DC Motor

Solenoid valve



Linear Actuators

LED

LCD

Connecting Smart Objects

Communication Criteria

- Range
- Frequency Bands
- Power Consumption
- Topology
- Constrained Devices
- Constrained-Node Networks

IoT Access Technologies

Comparison of Key Attributes

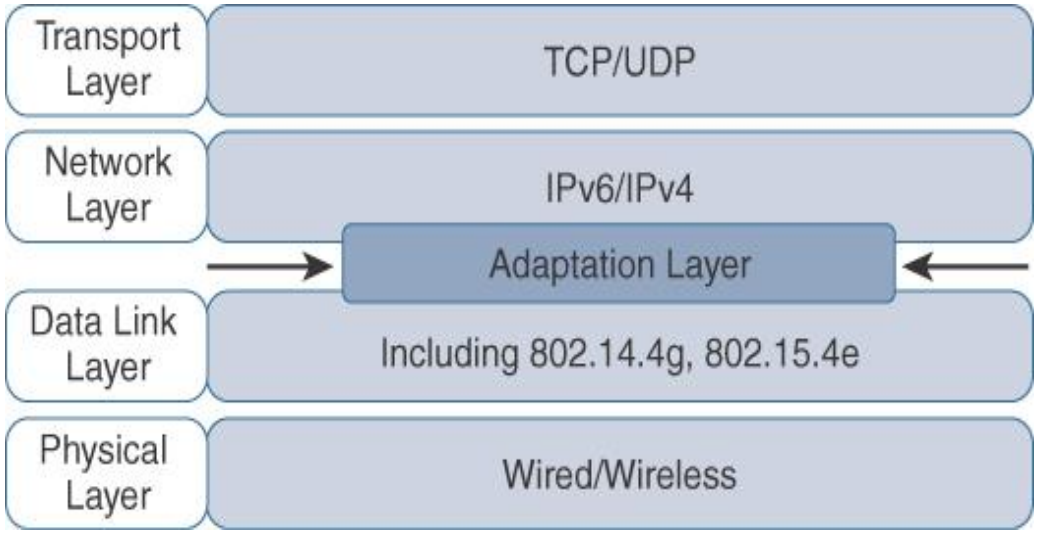
	WiFi	BLE	Thread	Sub-GHz: TI	Sigfox	Zigbee	LoRa
Max. Data throughput	72 Mbps	2 Mbps	250 Kbps	200 Kbps	100 bps	250 Kbps	50 Kbps
Range	100 m	750 m	100 m	4 km	25 km	130 m	10 km
Topology	Star	P2P/ Mesh	Mesh/ Star	Star	Star	Mesh/ Star	Star of Star
Frequency	2.4 GHz	2.4 GHz	2.4 GHz	Sub-GHz	Sub-GHz	2.4 GHz	Sub-1GHz
Power consumption	1 Year (AA battery)	Up to years on a coin-cell battery for limited range					Few Years (AA battery)
IP at the device node	Yes	No	Yes	No	No	No	No
Deployed Devices	AP	smart phones	No	No	No	No	No

Source: Nick Lethaby "Wireless Connectivity for the IoT: one size does not fit all", Texas Instruments, 2017

Utilizing IP for IoT

Key Advantages of IP

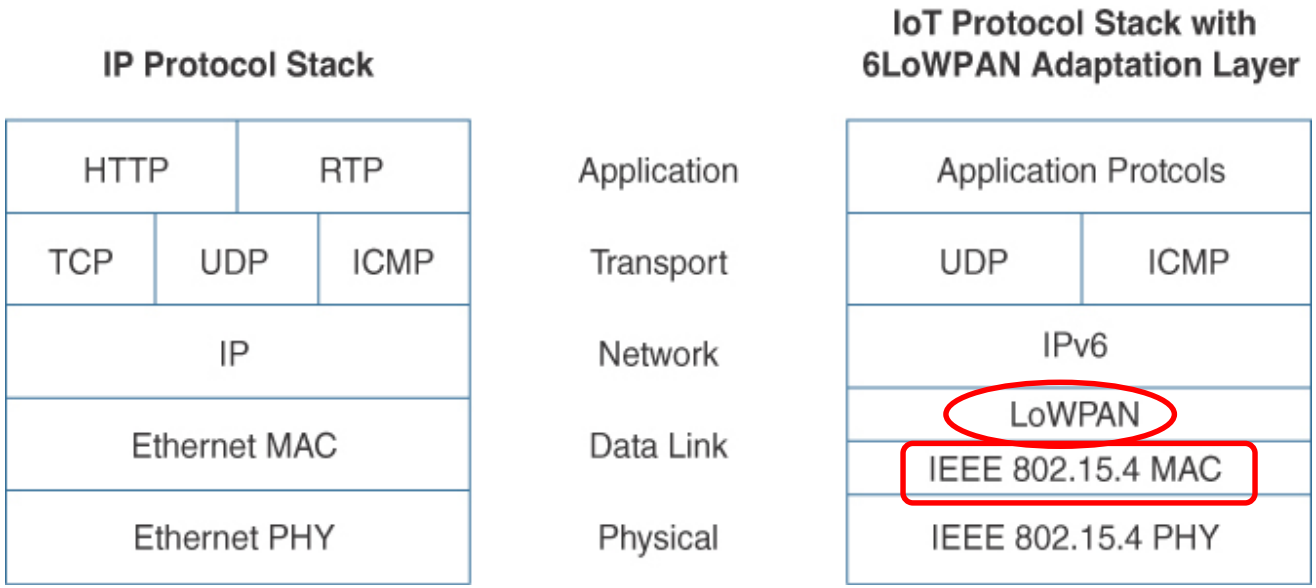
- Open and standard-based
- Versatile
- Ubiquitous
- Scalable
- Manageable
- Highly secure
- Stable and resilient



Need of optimization for

- Constrained Nodes
- Constrained Networks

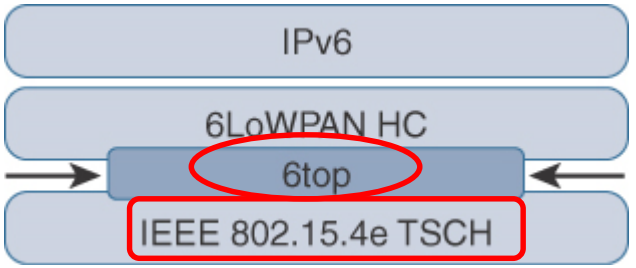
Modification in TCP/IP Stack



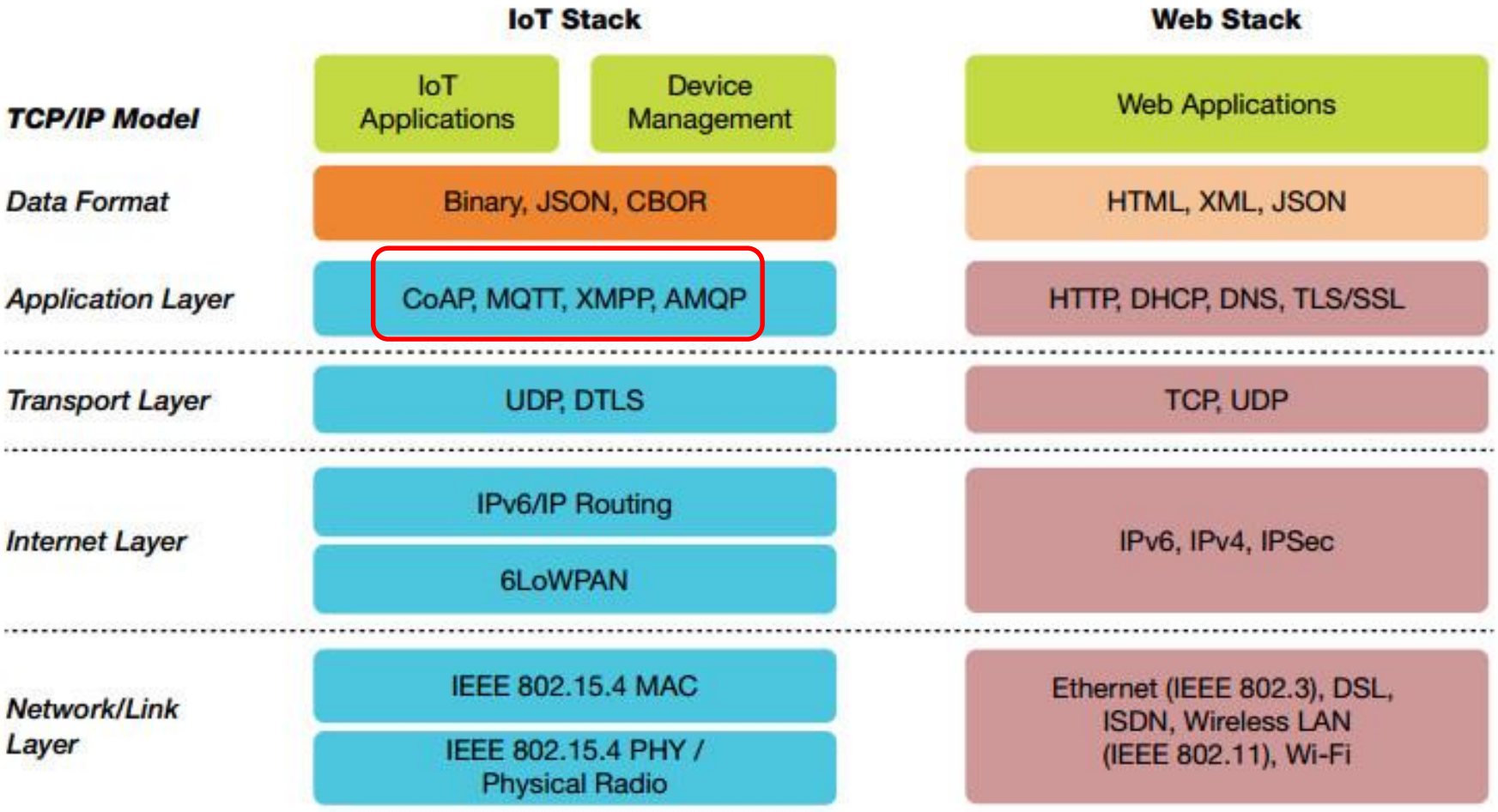
- WPAN: Wireless Personal Area Networks
- IEEE 802.15.4: Low-rate WPAN

- LoWPAN: Low-Power WPAN
- 6LoWPAN: IPv6 over LoWPAN
- TSCH: Time Synchronized Channel Hopping
- 6TiSCH: IPv6 over the TSCH mode of IEEE 802.15.4e
- 6top: 6TiSCH Operation Sublayer

In 6TiSCH IoT Network



Application Layer



6TiSCH Protocol Stack

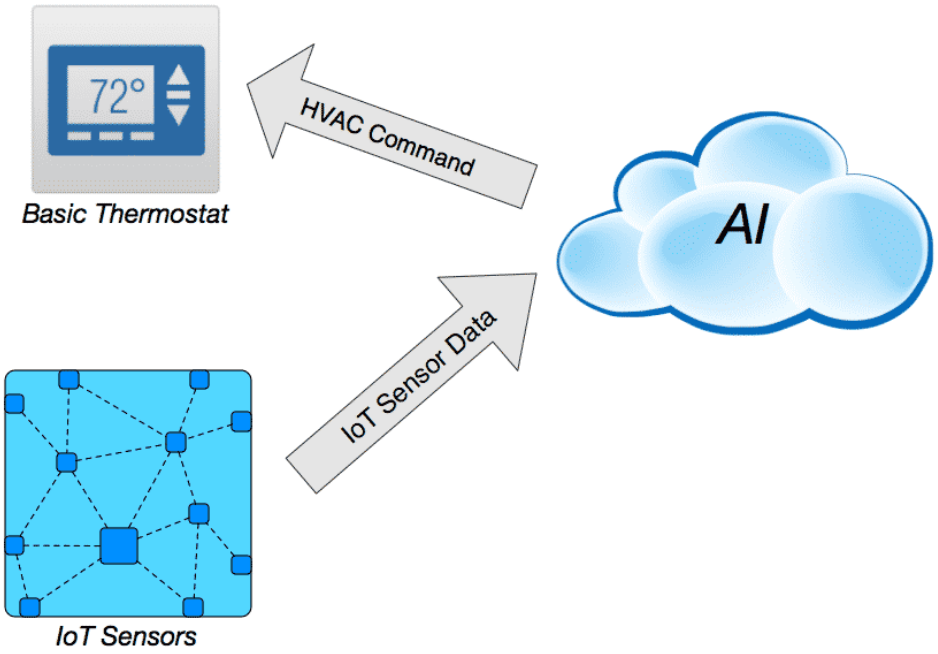
Application (CoAP)	**RFC8613**	(2019) *object security extension to CoAP*
	RFC7252	(2014) *base CoAP specification*
Routing (RPL)	**RFC6554**	(2012) *header format for routing header*
	RFC6553	(2012) *header format for RPL option*
	RFC6552	(2012) *Objective Function, RPL algorithm*
	RFC6550	(2012) *base RPL specification*
Adaptation (6LoWPAN)	**RFC8505**	(2018) neighbor discovery and registration
	RFC8138	(2017) *routing header* compression
	RFC8025	(2016) *mechanism for extending 6LoWPAN*
	RFC6282	(2011) *updated base 6LoWPAN* specification
	RFC4944	(2007) *base 6LoWPAN specification*
Scheduling (6TiSCH)	**draft-ietf-6tisch-msf**	(WIP) *distributed scheduling algorithm*
	RFC8480	(2018) *6P, distributed scheduling protocol*
	RFC8137	(2017) *container for 6P*
	draft-ietf-6tisch-minimal-security	(WIP) *security framework for 6TiSCH*
	RFC8180	(2017) *minimal 6TiSCH*
Physical layer	**IEEE802.15.4**	(2015) *2.4 GHz, 50-200 m range, 250 kbps, 127 byte frames*

AI for IoT

- AI focuses on putting human intelligence in machine
- It gives the ability to a machine/program to think and learn by itself

Use of AI in IoT:

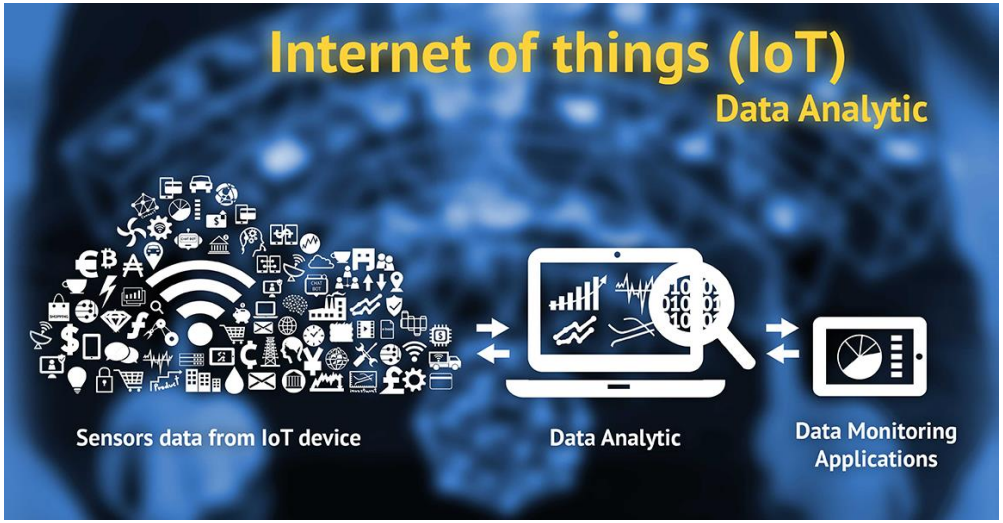
- Smart Home
  - Automated HVAC control
- Industrial IoT
  - Predictive maintenance
  - Optimized supply chain
- Farming
  - Smart farming
  - Interruption warning
- Self-driving Car
  - Mimic human driving on road
- Health
  - Auto-diagnosing any disease
  - Assistive healthcare



Data Analytics in IoT

"Data Analytics + IoT => Smart Business Solutions"

- The business value of IoT is not just in the ability to connect devices, but it comes from understanding the data these devices create.



Challenges:

- Huge Volume
- Unstructured data
- Changing data model
- Variety of data types

- IoT analytics is the application of data analysis tools and procedures to realize value from the huge volumes of data generated by connected IoT devices

Securing IoT

- Both the IoT manufacturers and their customers didn't care about the security !

Unauthorized access to IoT devices

Source:https://www.theguardian.com/technology/2016/oct/26/ddos-attack-dyn-mirai-botnet

Major cyber attack disrupts internet service across Europe and US;
October 26, 2016

Unauthorized access to IoT network

Source:http://metropolitan.fi/entry/ddos-attack-halts-heating-in-finland-amidst-winter

DDoS attack halts heating in Finland amidst winter;
November 7, 2016

Cont...

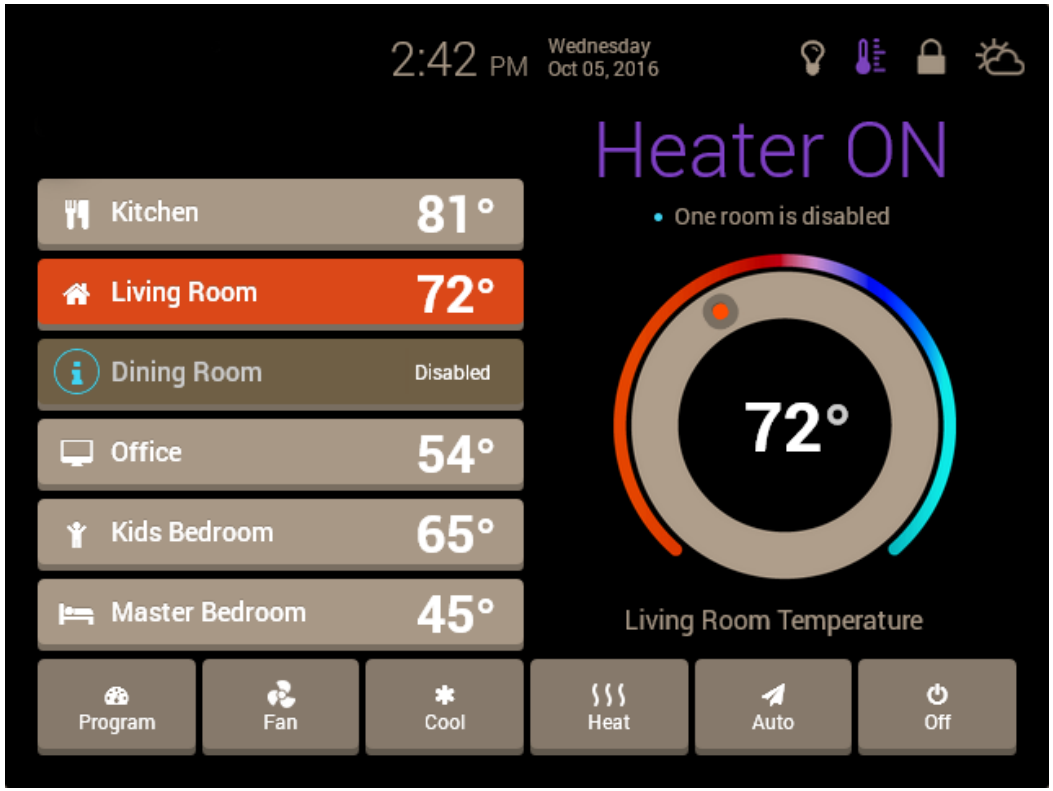
- US Military's Defense Advanced Research Projects Agency (DARPA) demonstrates hacking smart "Things"

Source: https://www.youtube.com/watch?v=7E1WsdODxu0

Source: https://www.youtube.com/watch?v=4oONdV5RYp8

User Interface

- Information made available to the end-users
- Users can actively check and act in for their IOT system



Source: https://data-flair.training/blogs/how-iot-works/

Important Characteristics:

- ✓ Sleek design
- ✓ Visually appealing
- ✓ Interactive UI
- ✓ Ease-of-use
- ✓ Handy

Lessons Learned

- ✓ What is IoT Ecosystem
- ✓ What are different components
- ✓ What is IoT Framework
- ✓ Sensors & Actuators
- ✓ IoT Architecture
- ✓ IoT Access Technologies
- ✓ IoT Gateway
- ✓ Use of Cloud in IoT
- ✓ Data Analytics in IoT
- ✓ AI for IoT
- ✓ Security in IoT
- ✓ User Interface for IoT

Thanks!

Figures and slide materials are taken from the following Books:

1. David Hanes *et al.*, "**IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things**", 1st Edition, 2018, Pearson India.

2. Mayur Ramgir, "**Internet of Things: Architecture, Implementation and Security**", 1st Edition, 2020, Pearson India.