AMRITA VISHWA VIDYAPEETHAM
DEEMED TO BE UNIVERSITY

22AIE204
COMPUTER NETWORKS

NETWORK ACCESS LAYER

- **Internet of Things (IoT)**

Internet of Things(IoT)

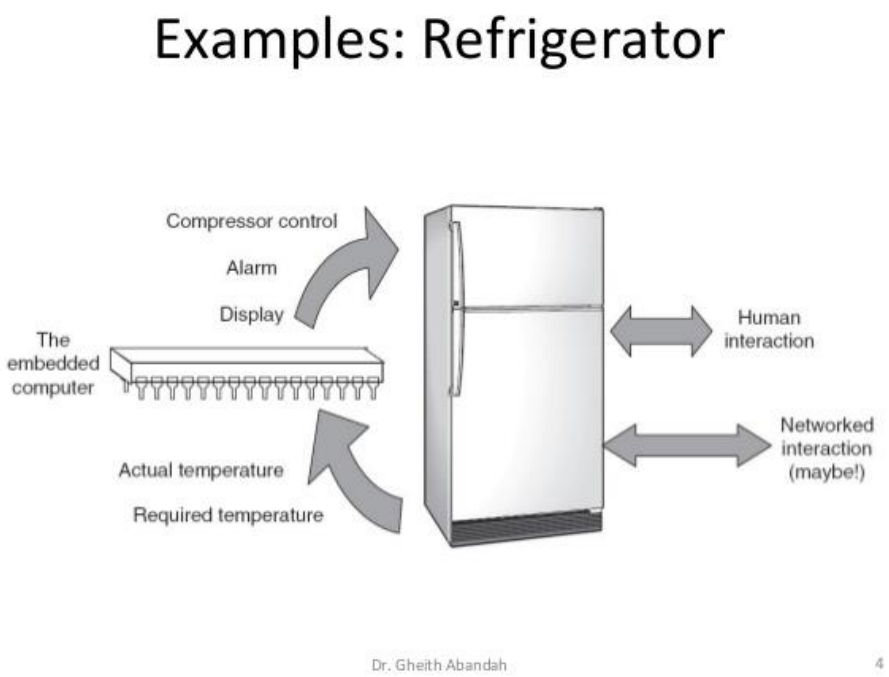
- Understanding of the term Internet of Things
- Global Problem Solving using IoT
- Building Blocks of IoT
- IoT Systems in the Real World
- Modeling IoT systems

Introduction

- What is IoT ? (Internet of Things)
- In simple terms it's a 'thing' which has some intelligence and network connectivity

Internet of Things

- Let's take an example
- Refrigerator is a 'thing'



- Now we add some computational intelligence to the Refrigerator like a Microcontroller which is hidden inside i.e an Embedded System
- Next we add Internet Connectivity – i.e it can connect to a network and use resources which are not local
- All of this put together gives us an '**IoT Device**'

IoT Example - Refrigerator

- Traditional Refrigerator - Keeps things cold
- 'Intelligent' Refrigerator
  - Tells you if the door is open
  - Tells you if you are low on butter, milk etc
  - Tells you if water filter needs to be replaced
- Enhanced functionality, not networked.
- Can be implemented with local sensors and processing

- IoT Refrigerator
  - Computational Intelligence + Network connectivity
  - Orders items if stock is low
  - Suggests where prices are low
  - Can anticipate meals and orders ingredients
- Greatly enhanced functionality – Internet required

IoT for Societal Benefits

- IoT devices can be of a great benefit to the society by helping people, it makes life easier for people.
- For instance :-
- Remote Health Monitoring – Fitness Tracker, Wearables
  - Fewer doctor visits
  - Beneficial in areas which are hard to access
- Disaster Monitoring Systems – Floods, Landslide etc
- Disability – Automated wheelchairs, IoT Refrigerator
- Wearables for better healthcare & monitoring pandemic
  - Enables people to be more independent
  - Helps assist in day to day activities
- Enables people to stay connected
  - Global Interactions possible
  - Low – cost

Internet of Things(IoT)

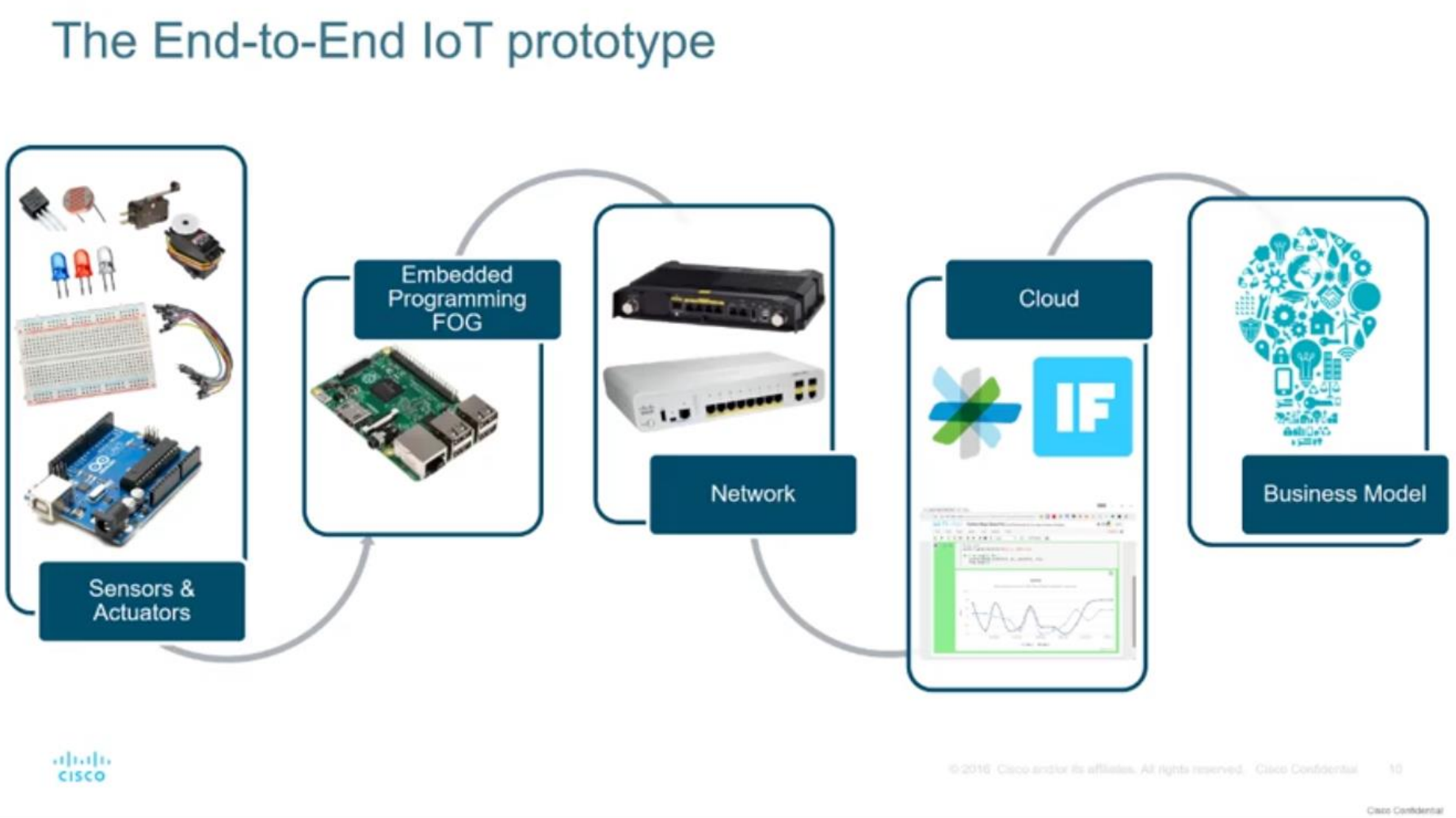
- Understanding of the term Internet of Things
- Global Problem Solving using IoT
- Building Blocks of IoT
- IoT Systems in the Real World
- Create your own IoT systems

Become a global problem solver

- Investigate real world social or environmental problems
- Global problems include air pollution, climate change, poverty, hunger, disease, gender inequality, healthcare and access to water and sanitation, etc
- In 2015, 189 world leaders at UN adopted 17 SDGs

Reference: Cisco Netacad course on Connected IoT devices

End-to-End IoT Prototype



Reference: Cisco Netacad course on Connected IoT devices

Empower your skill set ☺

IoT Multidisciplinary Skillset

A Multidisciplinary Digital Foundation

Electronics
Programming
Networking
Data Analytics

Cybersecurity
Problem solving
Design thinking
Soft skills

cisco

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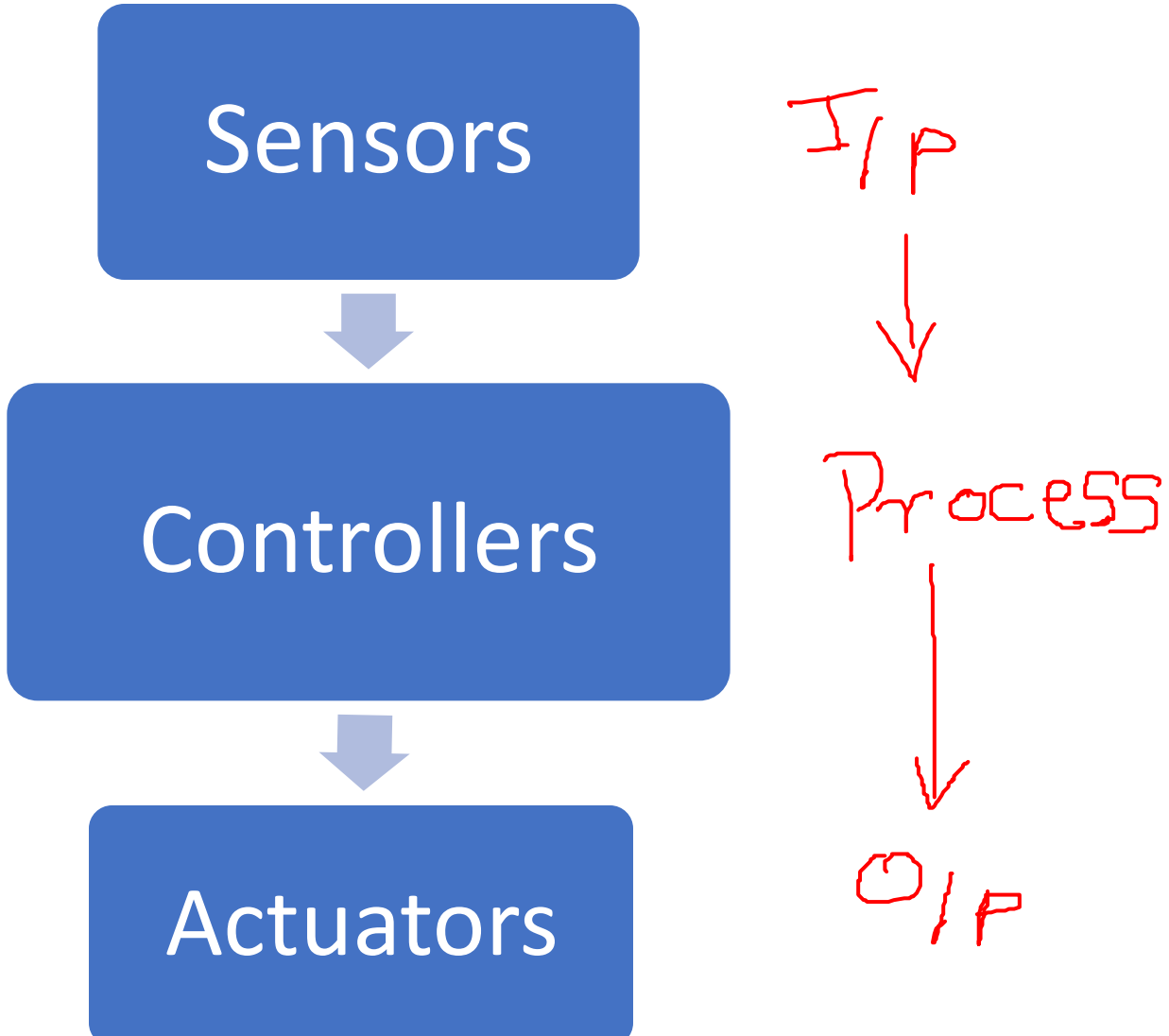
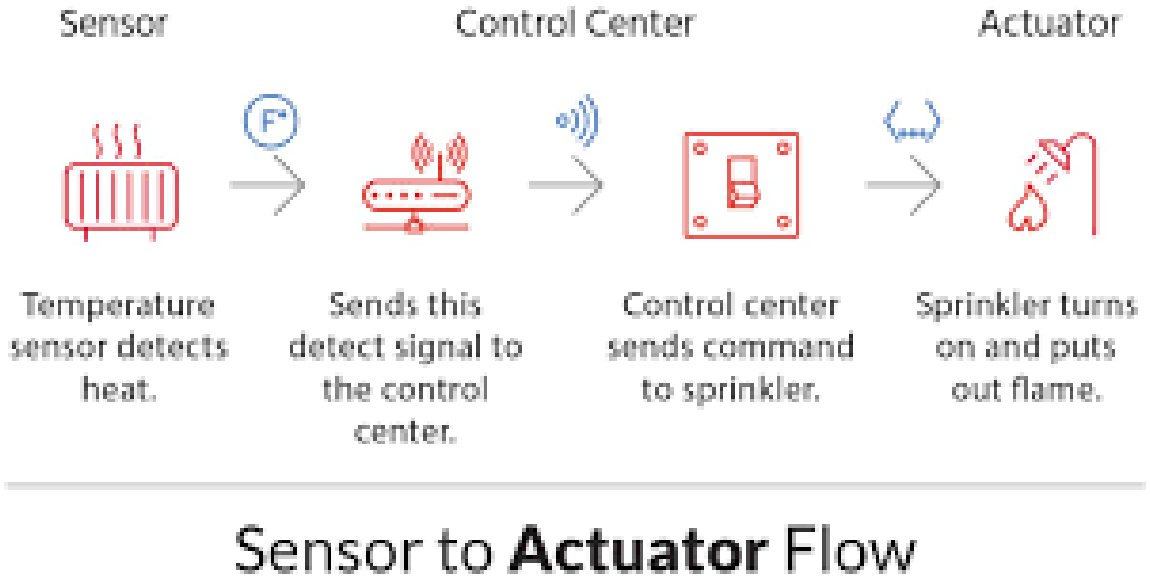
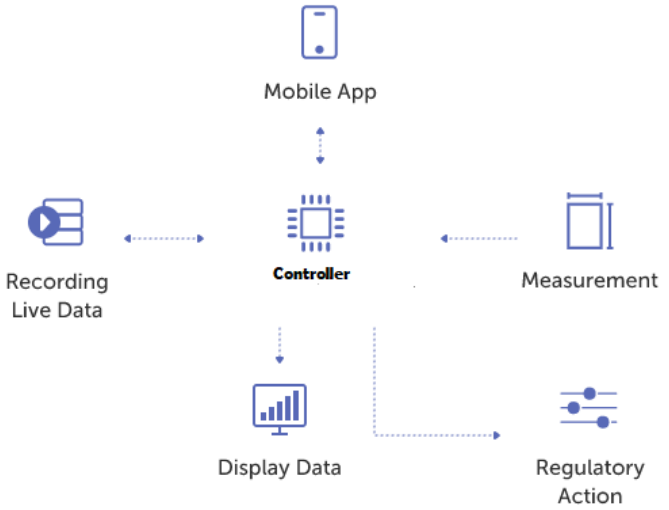
Building Blocks of an IoT System



Sensors and Actuators in IoT work flow

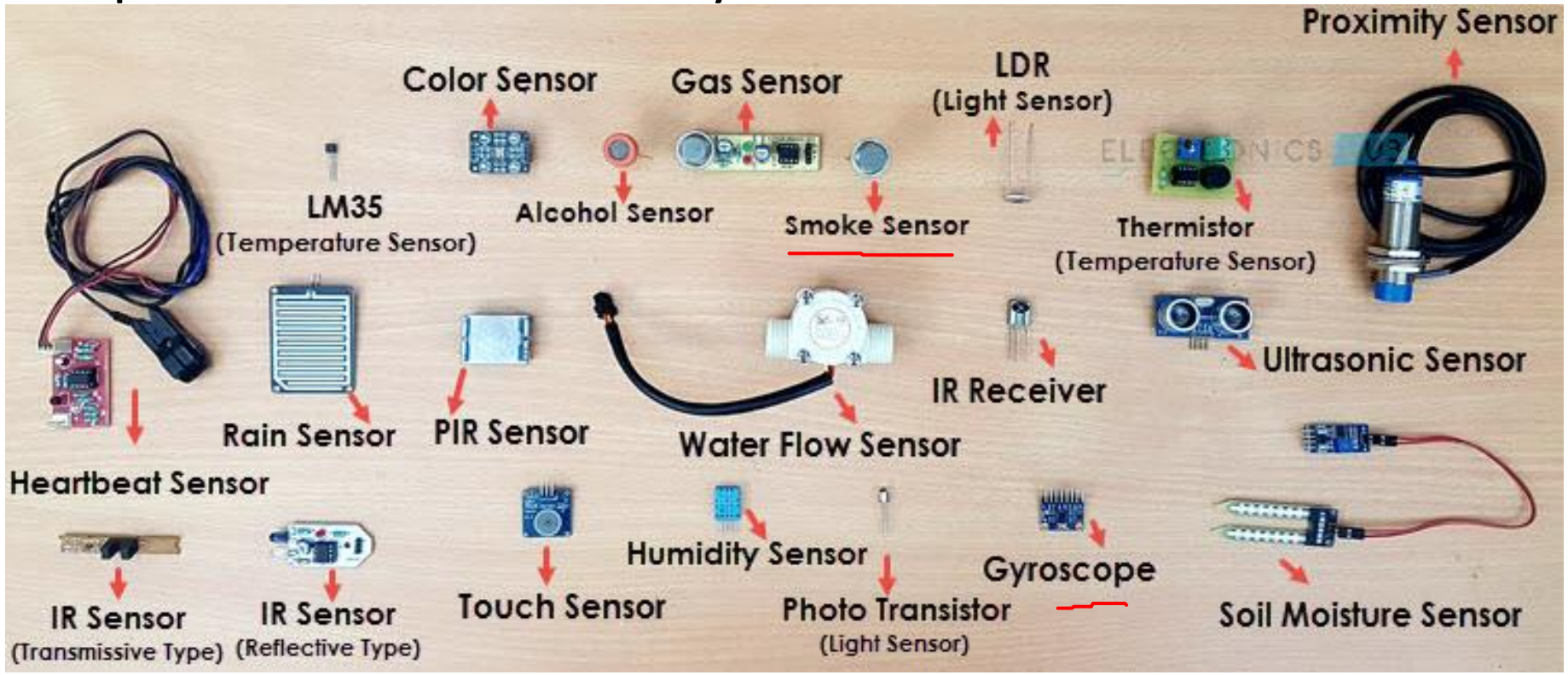
- **Sensors:** Input to the Embedded System
- **Actuators:** Output to the Embedded System
- **Controllers:** Responsible for collecting data from sensors and providing network connectivity. Has ability to make decisions





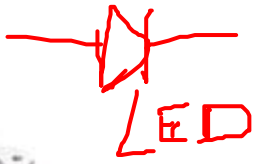
Sensors

- A sensor is a device that can be used to measure a physical property by detecting some type of information from the physical world.
- Input to the Embedded System



Actuators

- An actuator is a basic motor that can be used to create a movement in the environment
- can be responsible for transforming an electrical signal into physical ***output***.



DC Motor

DC Gear Motor

RC Servo motor

Stepper motor

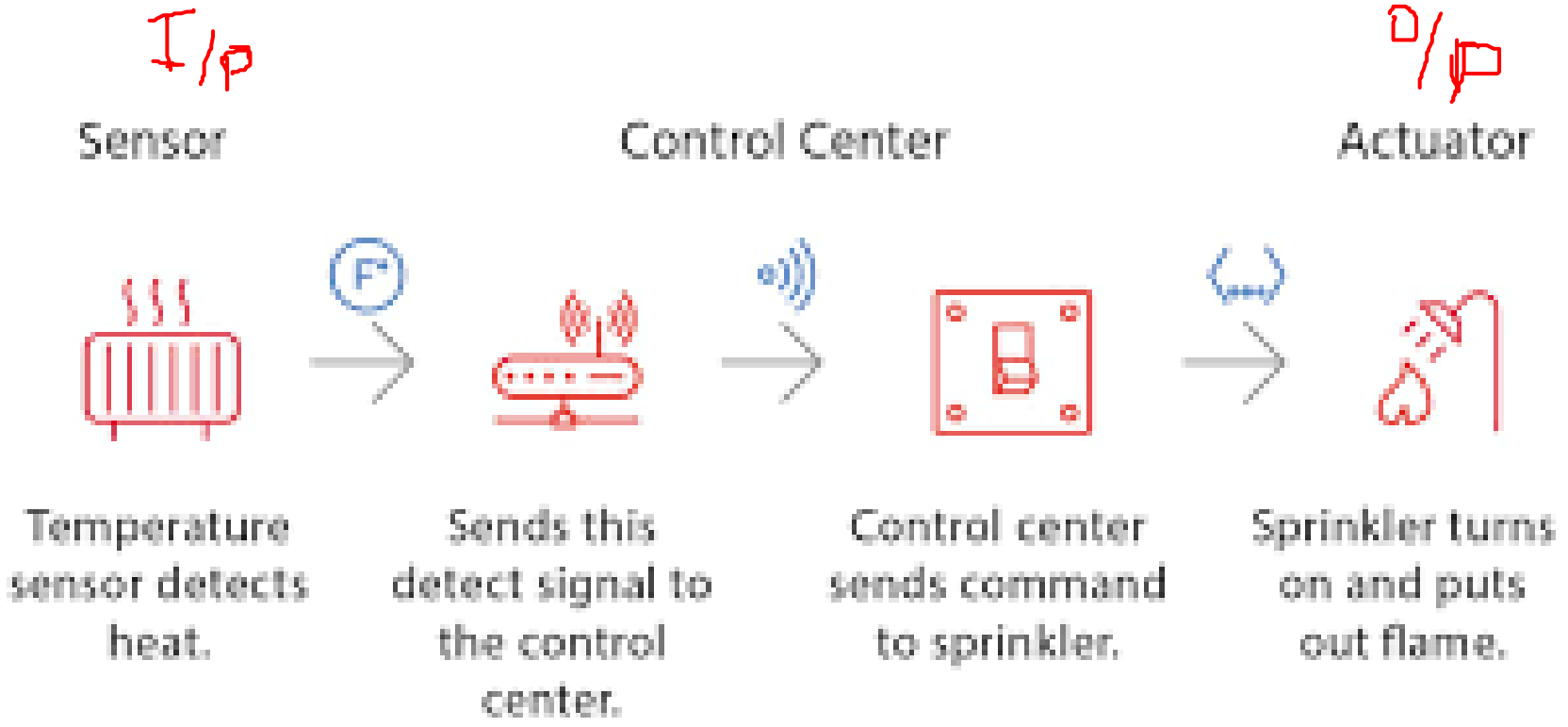
BLDC Motor

Smart Servo motors

Harmonic drives

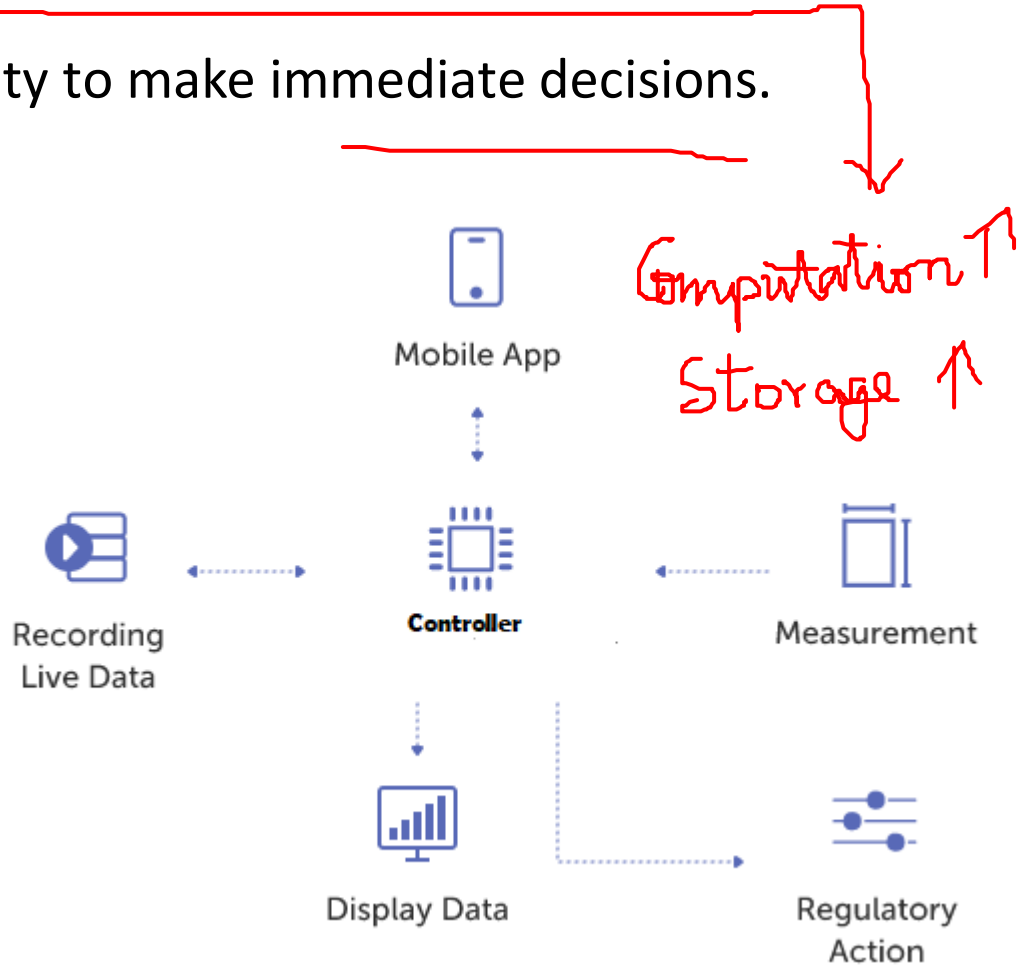
Linear electric actuator

Sensors and Actuators in IoT Flow



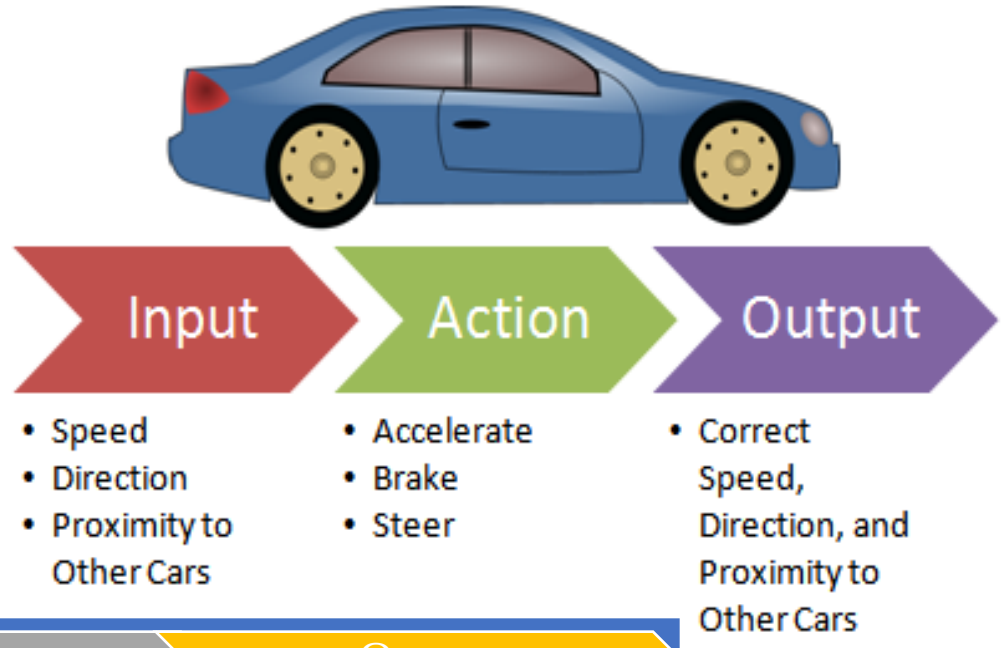
Controllers

- Responsible for collecting data from sensors and providing network connectivity.
- Controllers may have the ability to make immediate decisions.
- May also send data to remote and more powerful computer for analysis
- Arduino/TM4C controller takes less power – to acquire data
- Raspberry Pi Controller – more power- good to process data



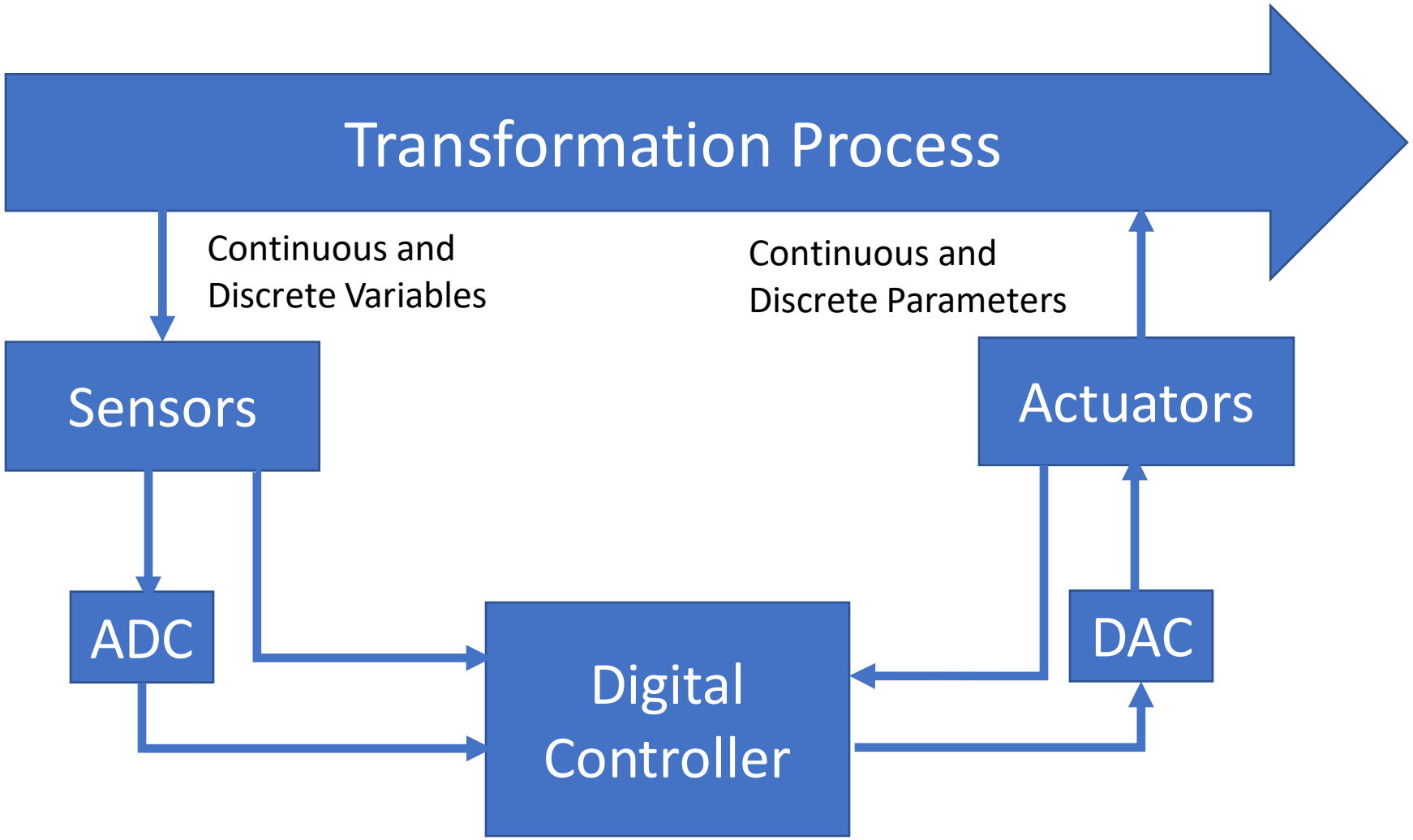
Processes in Controlled System

- Processes
  - A process is a series of steps or actions taken to achieve a desired result by the consumer of the process.
  - Observe the **Laundry process** given below



Input	Action	Output
Dirty clothes	Sort them by color	Sorted clothes
Sorted clothes and laundry detergent	Put clothes and detergent in the washer and start the washer	Clean and wet clothes
Wet clothes	Put wet clothes in the dryer	Clean and dry clothes
Clean and dry clothes	Fold and put the clean and dry clothes away	Clean laundry

Process and Controller



IoT Technologies

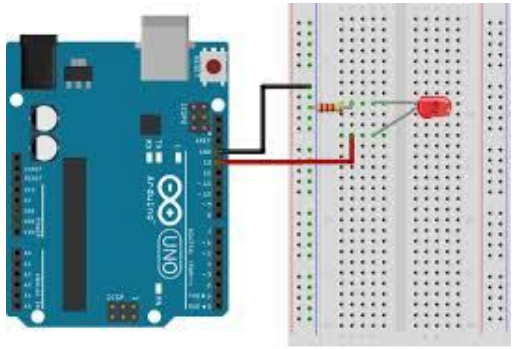
- Identification using EPC- Electronic Product Codes, uCode – Ubiquitous codes
- Communication – 5G, 6G
- Aggregation -related services summarize data
- Collaborative aware Services obtain data to make decision and response
- Ubiquitous services = services anytime, anywhere and for anyone

TABLE II
BUILDING BLOCKS AND TECHNOLOGIES OF THE IOT

IoT Elements		Samples
Identification	**Naming**	EPC, uCode
	Addressing	IPv4, IPv6
Sensing		Smart Sensors, Wearable sensing devices, Embedded sensors, Actuators, RFID tag
Communication		RFID, NFC, UWB, Bluetooth, BLE, IEEE 802.15.4, Z-Wave, WiFi, WiFiDirect, , LTE-A
Computation	**Hardware**	SmartThings, Arduino, Phidgets, Intel Galileo, Raspberry Pi, Gadgeteer, BeagleBone, Cubieboard, Smart Phones
	Software	OS (Contiki, TinyOS, LiteOS, Riot OS, Android); Cloud (Nimbits, Hadoop, etc.)
Service		Identity-related (shipping), Information Aggregation (smart grid), Collaborative-Aware (smart home), Ubiquitous (smart city)
Semantic		RDF, OWL, EXI

Reference: Al-Fuqaha, Ala, et al. "Internet of things: A survey on enabling technologies, protocols, and applications." *IEEE communications surveys & tutorials* 17.4 (2015): 2347-2376. (Cited: 5020)

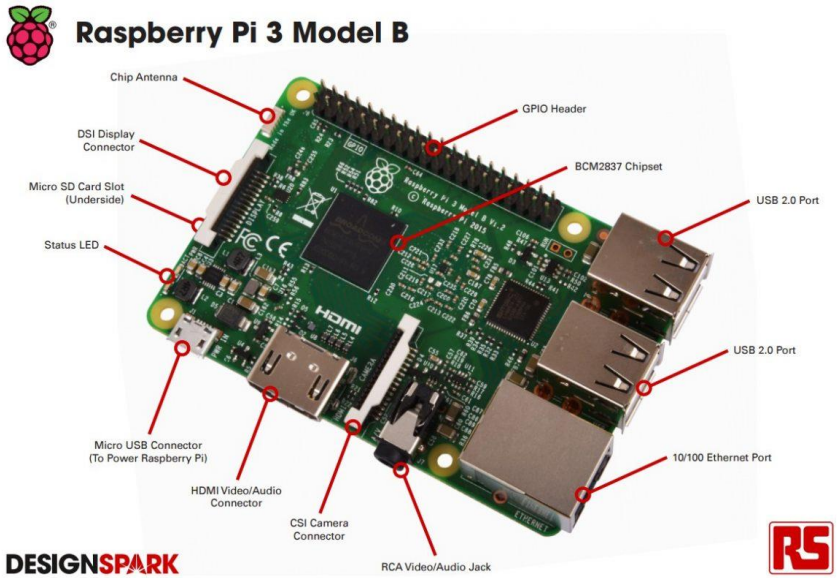
Hardware - Arduino



- The Arduino is a microcontroller for prototyping.
- Arduino IDE is Free, downloadable software used to interact with the Arduino board
- Programs written using the Arduino IDE are called sketches and are saved with the file extension of .ino.
- Arduino sketch keywords can be divided in three main category types: structures, values (variables and constants), and functions.
- Building a Circuit
  - A simple circuit can be created by Connecting electronic components (LED, resistor, and jumper wires) in series along a row on the breadboard, Connecting the power source to the lower red and black jumper wires.

Reference: Al-Fuqaha, Ala, et al. "Internet of things: A survey on enabling technologies, protocols, and applications." *IEEE communications surveys & tutorials* 17.4 (2015): 2347-2376. (Cited: 5020)

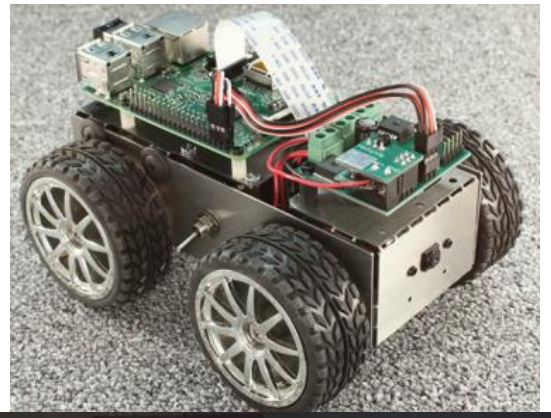
Raspberry Pi



- Programs are used in IoT to provide logic and intelligence to the devices. A programmer can create code to allow an IoT device to perform tasks such as monitoring, communicating to others, data processing and more.
- The Raspberry Pi runs Raspbian, a modified version of the open source and wide-spread Linux operating system.
- The Raspberry Pi supports many different programming languages including Blockly, a visual programming language, designed to help beginners learn how to program.

Reference: Al-Fuqaha, Ala, et al. "Internet of things: A survey on enabling technologies, protocols, and applications." *IEEE communications surveys & tutorials* 17.4 (2015): 2347-2376. (Cited: 5020)

Uses of Raspberry Pi



- Artificial Raspberry Pi Pancreas
  - Dana Lewis and her husband used a Raspberry Pi to build an artificial pancreas.
  - It was possible due to the Pi's small size and low power requirements.
- 4Borg Pi Robot
  - PiBorg is an affordable robot kit built around a Raspberry Pi.
  - It is both fun and educational.
- Controlling the Arduino Through the Pi
  - While the Pi is powerful, it may not be the best option for all projects.
  - The Pi doesn't include analog GPIO pins.
  - The Pi is **not** real-time.
  - The Pi's power requirements and size may be too large, depending on the application.
  - To adjust to these limitations, an Arduino may be used

Reference: Al-Fuqaha, Ala, et al. "Internet of things: A survey on enabling technologies, protocols, and applications." *IEEE communications surveys & tutorials* 17.4 (2015): 2347-2376. (Cited: 5020)

Internet of Things(IoT)

- Understanding of the term Internet of Things
- Global Problem Solving using IoT
- Building Blocks of IoT
- Explore a collaborative aware IoT system – Explore Smart Home
- Data Link and Network Connections => Role of network in IoT system
- IoT Systems in the Real World

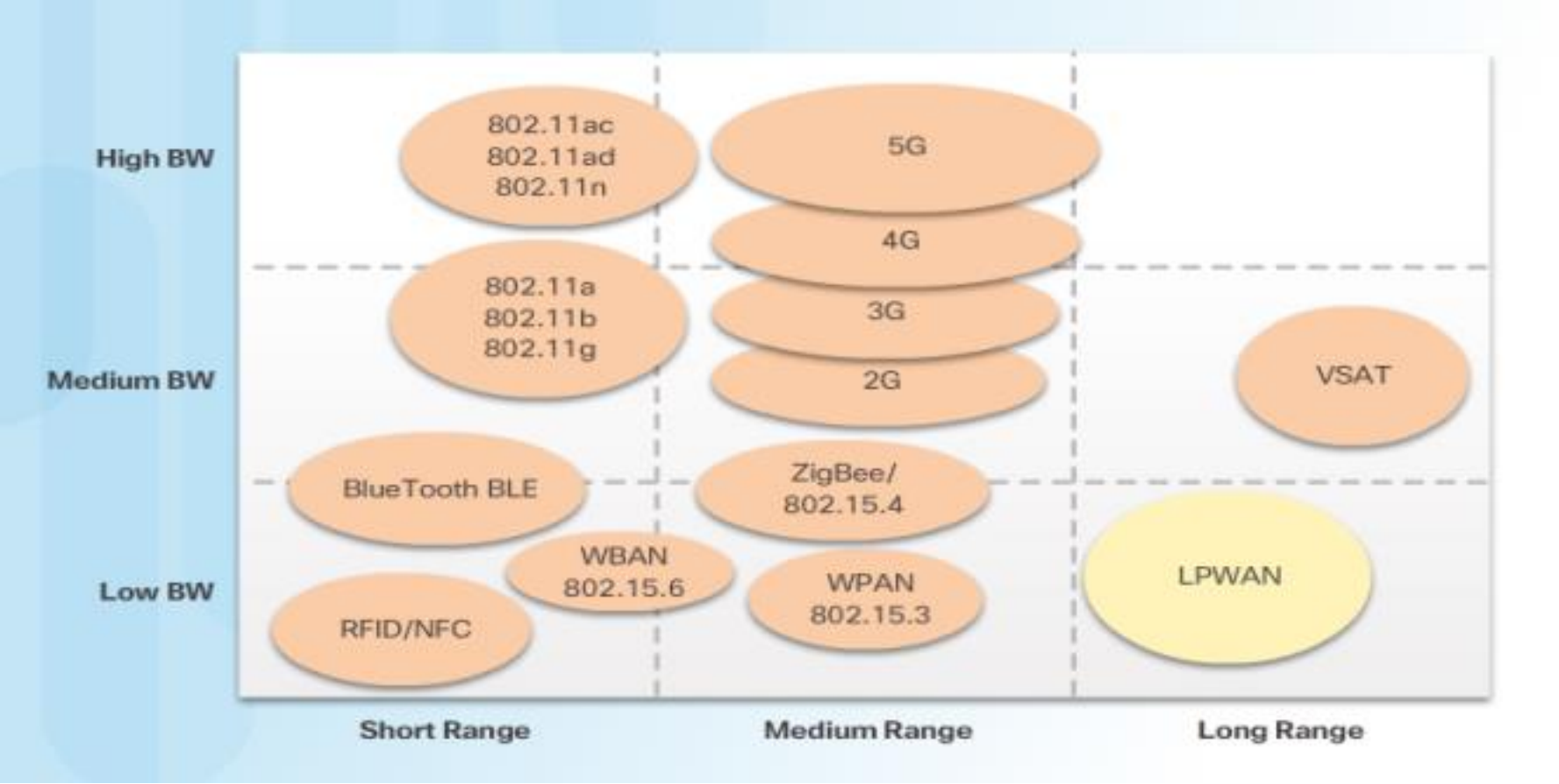
Role of Network in IoT system

- PAN , LAN and WAN
  - LAN used to connect machines in the factory plant
  - Low PowerWide Area Networks (LPWAN) for use in the IOT
- IoT Protocols
  - IoT Devices are often embedded devices designed to work in sub-optimal conditions.
  - These devices require specialized protocols to function with low power and limited connectivity.
  - IoT devices use CoAP (Constrained Application Protocol) and MQTT (Message Queuing Telemetry Transport).

Reference: Cisco Netacad course on Connected IoT devices

Role of Wireless Technologies

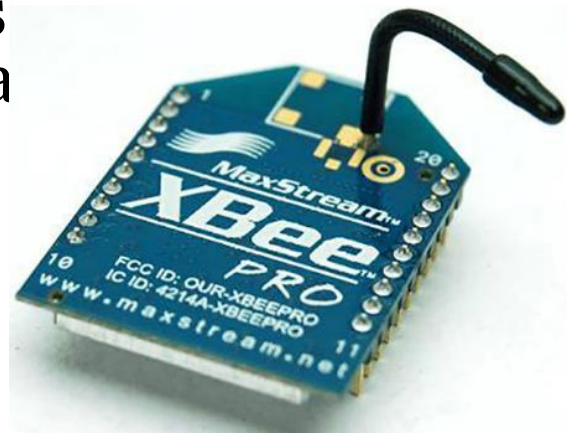
- New protocols created/updated to support diverse IoT devices: ZigBee, Bluetooth, 4G/5G, LoRaWAN
- Protocols created for short, medium, and wide ranges



Reference: Cisco Netacad course on Connected IoT devices

ZigBee

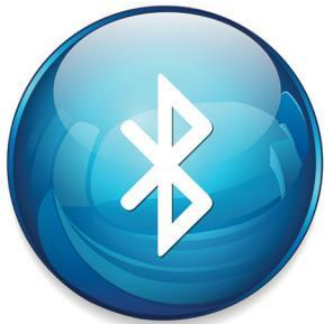
- A low-energy, low-power, low-data rate wireless protocol specification used to create personal area networks
- Areas of utilization: home automation, medical device data collection, and other low-power low-bandwidth needs
- 250 kbps transfer rate best suited for intermittent data transmissions
- ZigBee version 1.2 has a number of serious and exploitable security vulnerabilities Most of these protocol design flaws rela to attempts to make it easier for the end-user to add a ZigBee device to the ZigBee network



Reference: Cisco Netacad course on Connected IoT devices

Bluetooth

- Wireless protocol used for data communication over short distances (PAN)
- Supported by almost all mobile devices and accessories - the defacto standard for audio between mobile devices.
- Bluetooth Low Energy (BLE) - very popular because of the smartphone industry and new applications in healthcare, fitness, and beacons.
  - operates in the 2.4 GHz ISM band
  - Has a very fast connection rate (milliseconds) and a very high data rate (1 Mbps).
  - The BLE device then goes into “sleep mode” until a connection is reestablished -lengthens the battery life for several years.
- Beacons use BLE technology - positioned on buildings, in coffee shops, and on light posts to provide location services.



Reference: Cisco Netacad course on Connected IoT devices

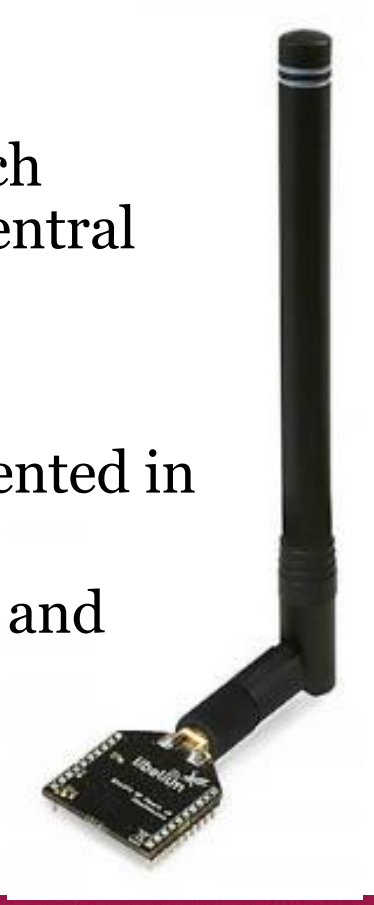
4G/5G

- Cellular-based data networks designed to take advantage of communications over large geographic areas
- High mobility bandwidth (trains and cars) of 4G system is 100 Mbps
- Low mobility (pedestrians and stationary users) of 4G systems is 1 Gbps
- 4G provides support for voice, IP telephony, mobile Internet access, video calling, gaming services, cloud computing, high-definition mobile TV, and mobile 3D TV.
- Long Term Evolution (LTE) and WiMAX (IEEE 802.16e) are two popular 4G systems.
- LTE 4G technology release 13e includes the standardization of NarrowBand IoT (NB-IoT) - an LPWAN technology.
- Next Generation Mobile Networks Alliance defining the standards and requirements for 5G

Reference: Cisco Netacad course on Connected IoT devices

LoRaWAN

- Wireless technology designed to provide wireless WAN connections to power constricted devices.
- targets key requirements of the Internet of Things such as secure bi-directional communication, mobility and localization services.
- Architecture is often an extended star topology in which gateways relay messages between end-devices and a central network server is located in the backend.
- Data rates range from 0.3 kbps to 50 kbps
- Security is built into the LoRaWAN standard, implemented in a multi-layer encryption scheme.
  - Unique keys are used in the Application, Network, and Device layers.

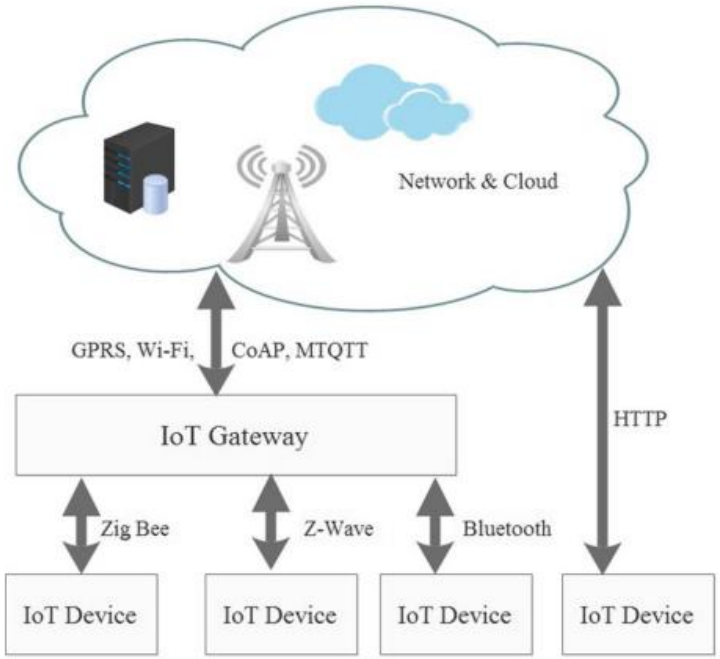


Reference: Cisco Netacad course on Connected IoT devices

IoT Protocol Stack

- Sobin, C. C. "A survey on architecture, protocols and challenges in iot." *Wireless Personal Communications* 112.3 (2020): 1383-1429.

Example of IoT gateway



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Software and hardware components of IoT

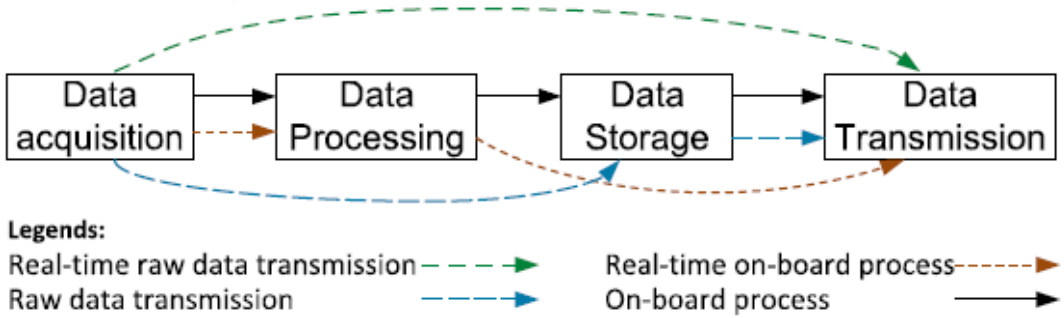


Figure 2: General stages of IoT applications

Reference:

Samie, Farzad, Lars Bauer, and Jörg Henkel. "IoT technologies for embedded computing: A survey." *2016 International Conference on Hardware/Software Codesign and System Synthesis (CODES+ ISSS)*. IEEE, 2016.

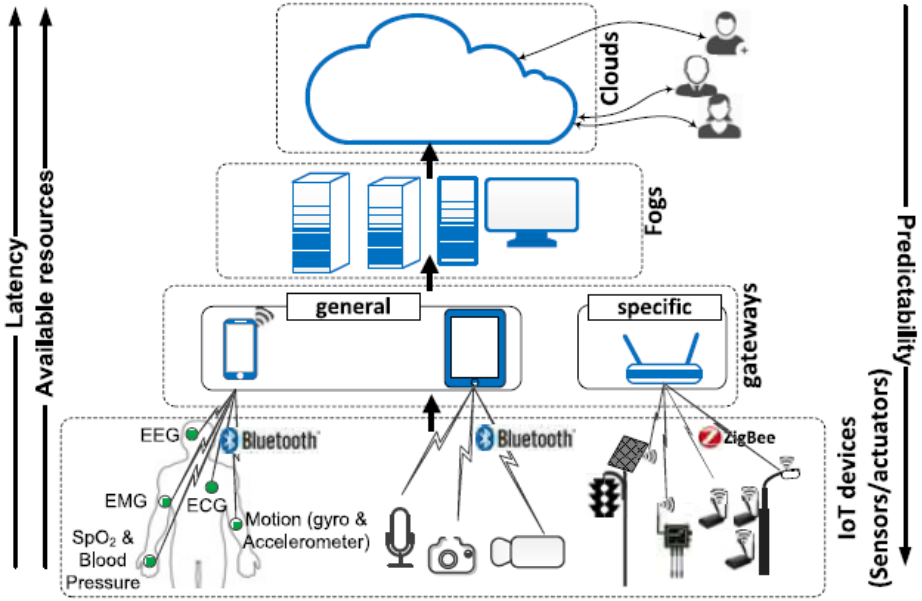


Figure 4: Different computation layers. The available resources (e.g. memory, processing power) and networking latency increase from bottom to top.

Cloud Computing Model

- On-demand access to a shared pool of configurable computing resources.
- Resources can be made available quickly with minimal management effort.
- Cloud service providers use data centers for their cloud services and cloud-based resources.
- “Pay-as-you-go” model treats computing and storage expenses as a utility.
- Enables access to organizational data and applications anywhere and at any time
- Reduces cost for equipment, energy, physical plant requirements, and personnel training needs
- Cloud services offered: Infrastructure as a Service (IaaS), Platform and mobile Platform as a Service (PaaS) (mPaaS), Software as a Service (SaaS)

Reference: Cisco Netacad course on Connected IoT devices

Cloud Services

- Cloud customers have access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort.
- Extends functionality of an IoT system: data processing and storage done in the cloud instead of in the IoT devices.
- Data and resources - always available to any device in the system as long as the device has Internet connectivity
- Cloud service providers are also very serious about security, ensuring customer data is kept safe and secure..
- Examples of cloud services: Amazon AWS, IFTTT, Zapier, Built.io, Cisco Spark

Reference: Cisco Netacad course on Connected IoT devices

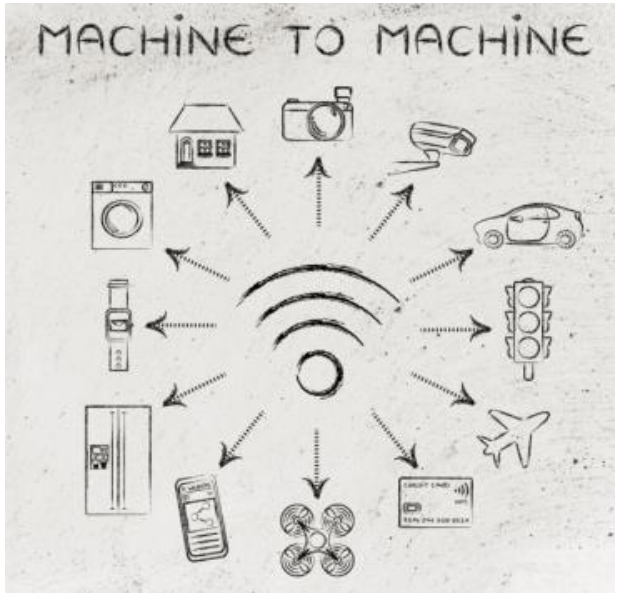
Fog Computing

- Distributed computing infrastructure closer to the network edge. Edge devices run applications locally and make immediate decisions
- Reduces the data burden on networks as raw data not sent over network connections.

Reference: Cisco Netacad course on Connected IoT devices

Fog Computing Model

- Enhances security - keeping sensitive data from being transported beyond the edge where it is needed.
- Fog applications monitor or analyze real-time data from network-connected things and then take action such as locking a door, changing equipment settings, applying the brakes on a train, zooming in with a video camera
- The action can involve machine-to-machine (M2M) communications and machine-to-people (M2P) interaction
- Cisco predicts that 40% of IoT-created data will be processed in the fog by 2022



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Namah Shivaya