Introduction to Emerging Technologies

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Chapter 1

1.1 Evolution of Technologies

- Emerging technology is a term generally used to describe a new technology
- It is reserved for technologies that are creating or are expected to create significant social or economic effects
- List of some currently available emerged technologies
  - Artificial Intelligence
  - Blockchain
  - Augmented Reality and Virtual Reality
  - Cloud Computing
  - Angular and React
  - DevOps
  - Internet of Things (IoT)
  - Intelligent Apps (I-Apps)
  - Big Data
  - Robotic Processor Automation (RPA)

1.1.1 Introduction to the Industrial Revolution (IR)

- period of major industrialization and innovation that took place
- late 1700s and early 1800s
- society shifts from using tools to make products to use new sources of energy, such as coal
- manufacturing of goods moved from small shops and homes to large factories.
- The revolution started in England
- Some industrial revolutions changed the world
  - The steam engine
  - The age of science and mass production, and
  - Digital technology
  - Smart and autonomous systems

1.1.2 The Most Important Inventions of the Industrial Revolution

- Transportation: The Steam Engine, The Railroad, The Diesel Engine, The Airplane
- Communication.: The Telegraph. The Transatlantic Cable. The Phonograph. The Telephone
- Industry: The Cotton Gin. The Sewing Machine. Electric Lights

1.1.3 Historical Background (IR 1.0, IR 2.0, IR 3.0)

- European countries industrialized after England: Belgium, France, and the German states.
- final cause of the Industrial Revolution was the effects created by the Agricultural Revolution : increase in food production

- The four type of industries:
    1. Primary industry: involves getting raw materials e.g. mining, farming, and fishing.
    2. Secondary industry: manufacturing e.g. making cars and steel.
    3. Tertiary industries: provide a service e.g. teaching and nursing.
    4. Quaternary industry: research and development industries e.g. IT.

1.1.3.1 Industrial Revolution (IR 1.0)

- first coined in the 1760s
- transition to new manufacturing processes
- From: hand production ☞ machines
- increasing use of steam power

1.1.3.2 Industrial Revolution (IR 2.0)

- began somewhere in the 1870s
- known as the Technological Revolution
- widespread adoption of pre-existing technological systems such as telegraph and railroad
- new technological systems introduced - electrical power

1.1.3.3 Industrial Revolution (IR 3.0)

- began from the late 1950s.
- known as Digital Revolution
- transition from mechanical and analog electronic technology ☞ to digital electronics

- Mass production and widespread use of digital logic circuits: computer, hand phones and the Internet.

1.1.3.4 Industrial Revolution (IR 4.0)

- Present day
- advancements in various technologies such as robotics, Internet of Things, additive manufacturing and autonomous vehicles
- technologies mentioned above are what you call: cyber physical systems:
  - ➢ mechanism that is controlled or monitored by computer-based algorithms
  - ➢ tightly integrated with the Internet and its users.
  - ➢ E.g : Computer Numerical Control (CNC) machines.
- Another major breakthrough that is associated with IR 4.0 is the adoption of Artificial Intelligence (AI)

1.2 Role of Data for Emerging Technologies

- Data is
  - ✓ strategic asset
  - ✓ determines the future of science, technology, the economy, and possibly everything

- ✓ It presents enormous challenges that in turn bring incredible innovation and economic opportunities

1.3 Enabling devices and network (Programmable devices)

- In digital electronic systems, there are four basic kinds of devices:
  1. Memory - store random information
  2. Microprocessors - execute software instructions
  3. Logic - provide specific functions e.g: signal processing, timing and control operations
  4. Networks - collection of computers, servers & other devices connected to one another to allow the sharing of data e.g: Internet
- Programmable devices
  - ✓ Chips

- ✓ Incorporate field programmable logic devices (FPGAs), complex programmable logic devices (CPLD) and programmable logic devices (PLD).
- ✓ Computer is programmable device

1.3.1 List of some Programmable devices

- Lattice Semiconductor's ECP3
- Achronix Speedster SPD60 e.t.c

Service Enabling Devices (SEDs)

- Modems
- Conferencing equipment
- Traditional channel service unit (CSU) e.t.c

1.4 Human to Machine Interaction (HMI)

✓ communication and interaction between a human and a machine via a user interface

✓ HCI (human-computer interaction)

- study of how people interact with computers
- consists of three parts:

1. the user
2. the computer
3. the ways they work together

- The goal of HCI is to improve the interaction between users and computers

1.4.1 Disciplines Contributing to Human-Computer Interaction (HCI)

- Cognitive psychology
- Computer science
- Linguistics

1.5 Future Trends in Emerging Technologies

1.5.1 Emerging technology trends in 2019

- ✓ 5G Networks
- ✓ Artificial Intelligence (AI)
- ✓ Autonomous Devices
- ✓ Blockchain e.t.c

1.5.2 Some emerging technologies that will shape the future of you and your business

- Chatbots
- Virtual/augmented reality
- Blockchain
- Ephemeral Apps and
- Artificial Intelligence are already shaping your life whether you like it or not

Emerging Technologies chapter 2

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Chapter 2: Data Science

2.1. An Overview of Data Science

- Data science
  - ➢ multi-disciplinary field that uses scientific methods, processes, algorithms, and systems to extract knowledge and insights from structured, semi-structured and unstructured data.
  - ➢ is much more than simply analyzing data.
  - ➢ one of the most promising and in-demand career paths for skilled professionals
- Data scientists need to be
  - ➢ curious and result-oriented
  - ➢ have exceptional industry-specific knowledge
  - ➢ communication skills
  - ➢ strong quantitative background in statistics and linear algebra
  - ➢ programming knowledge focus on Data:
    - ✓ warehousing
    - ✓ mining
    - ✓ modeling

2.1.1. What are data and information?

❖ Data

- unprocessed facts and figures
- represented with the help of characters

❖ information
- processed/ interpreted data
- base for decisions and actions

2.1.2. Data Processing Cycle

- Data processing: re-structuring or re-ordering of data
- Data processing consists three steps
    1. Input
    2. Processing
    3. Output

2.3 Data types and their representation

2.3.1. Data types from Computer programming perspective

- data type is simply an attribute of data that tells the compiler or interpreter how the programmer intends to use the data.
- Common data types include:
    - Booleans(bool)- is used to represent restricted to one of two values: true or false
    - Characters(char)- is used to store a single character
    - Floating-point numbers(float)- is used to store real numbers
    - Alphanumeric strings(string)- used to store a combination of characters and numbers
- data type defines:
    - ✓ operations that can be done on the data
    - ✓ meaning of the data
    - ✓ the way values of that type can be stored

2.3.2. Data types from Data Analytics perspective

- there are three common types of data types/ structures:
  1. Structured Data
     - ➢ adheres to a pre-defined data model
     - ➢ straightforward to analyze
     - ➢ conforms to a tabular format with rows and columns
     - ➢ Example: Excel files or SQL databases
  2. Semi-structured Data
     - ➢ also known as a self-describing structure
     - ➢ form of structured data that does not conform with the formal structure of data models: relational databases, tables
     - ➢ contains tags or other markers
     - ➢ Example: JSON and XML
  3. Unstructured Data
     - ➢ information that either does not have a predefined data model or is not organized in a pre-defined manner
     - ➢ typically text-heavy
     - ➢ Examples: audio, video files, No-SQL databases

Metadata – Data about Data

- ➢ this is not a separate data structure
- ➢ provides additional information about a specific set of data
- ➢ Example metadata provides fields for dates and locations for a photograph taken

2.4. Data value Chain

- describe the information flow within a big data system

I. Data Acquisition

- ✓ process of gathering, filtering, and cleaning data before it is put in a data warehouse or any other storage

- ✓ major big data challenges in terms of infrastructure requirements

II. Data Analysis
- ✓ making the raw data acquired amenable to use in decision-making as well as domain-specific usage.
- ✓ Involves: exploring, transforming, and modeling data

III. Data Curation
- ✓ the active management of data over its life cycle to ensure it meets the necessary data quality requirements for its effective usage
- ✓ ensuring that data are trustworthy, discoverable, accessible, reusable and fit their purpose

IV. Data Storage
- ✓ It is the persistence and management of data in a scalable way that satisfies the needs of applications that require fast access to the data
- ✓ NoSQL technologies present a wide range of solutions based on alternative data models.

V. Data Usage
- ✓ It covers the data-driven business activities that need access to data, its analysis, and the tools needed to integrate the data analysis within the business activity

2.5. Basic concepts of big data

- a blanket term for the non-traditional strategies and technologies needed to gather, organize, process, and gather insights from large datasets
- data that exceeds the computing power or storage of a single computer

2.5.1. What Is Big Data?

- large and complex data that it becomes difficult to process using on-hand database management tools or traditional data processing applications.
- Large dataset
- Big data is characterized by 3V and more:
    1. Volume - large
    2. Velocity - live streaming or in motion
    3. Variety - In many different forms from diverse sources
    4. Veracity - trust the data? How accurate is it?

2.5.2. Clustered Computing and Hadoop Ecosystem

2.5.2.1. Clustered Computing

- Big data clustering software combines the resources of many smaller machines
- provide a number of benefits:
    - ✓ Resource Pooling - Combining the available storage, CPU, and memory
    - ✓ High Availability - provide varying levels of fault tolerance and availability guarantees
    - ✓ Easy Scalability - easy to scale horizontally by adding additional machines

2.5.2.2. Hadoop and its Ecosystem

- It Is an open-source framework allows for the distributed processing of large datasets across clusters of computers
- four key characteristics of Hadoop are:
    1. Economical
    2. Reliable - stores copies of the data on different machines and is resistant to hardware failure.
    3. Scalable - easily scalable both, horizontally and vertically
    4. Flexible - you can store as much structured and unstructured data as you need

- Hadoop has an ecosystem that has evolved from its four core components:
  - ✓ data management – e.g Zookeeper
  - ✓ access – e.g PIG, HIVE
  - ✓ processing – e.g YARN
  - ✓ storage – e.g HDFS
- It is continuously growing to meet the needs of Big Data

2.5.3. Big Data Life Cycle with Hadoop

2.5.3.1. Ingesting data into the system

- data is ingested or transferred to Hadoop from various sources

2.5.3.2. Processing the data in storage

- data is stored and processed

2.5.3.3. Computing and analyzing data

- data is analyzed by processing frameworks

2.5.3.4. Visualizing the results

- analyzed data can be accessed by users

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Chapter Four: Internet of Things (IoT)

4.1. Overview of IoT

- important features of IoT:
  - **AI**
    - IoT essentially makes virtually anything "smart" with the power of data collection, artificial intelligence algorithms, and networks
  - **Connectivity**
    - IoT networking - networks between its system devices
    - Networks are smaller and cheaper scale while still being practical
  - **Sensor**
    - transform IoT from a standard passive network of devices into an active system capable of real-world integration
  - **Active Engagement**
    - active content, product, or service engagement
  - **Small Devices**
    - Devices have become smaller, cheaper, and more powerful over time

- purpose-built small devices to deliver its precision, scalability, and versatility

4.1.1. What is IoT?

- IoT is the networking of smart objects, huge number of devices intelligently communicating in the presence of internet protocol that cannot be directly operated by human beings
- smart objects have some constraints such as limited bandwidth, power, and processing accessibility for achieving interoperability among smart objects
- IoT is a framework of all things that have a representation in the presence of the internet in such a way that new applications and services enable the interaction in the physical and virtual world in the form of Machine-to-Machine (M2M) communication in the cloud.

IoT= Services+ Data+ Networks + Sensors

Generally

- IoT is the network of physical objects or "things" embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data
- IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction

- IoT is a network of devices that can sense, accumulate and transfer data over the internet without any human intervention
- Simply stated, the Internet of Things consists of any device with an on/off switch connected to the Internet
- IoT systems allow users to achieve deeper automation, analysis, and integration within a system
- IoT utilizes existing and emerging technology for sensing, networking, and robotics. IoT exploits recent advances in software, falling hardware prices, and modern attitudes towards technology

4.1.2. History of IoT

Development necessary component for developing the Internet of Things:

- ✓ first radio voice transmission took place on June 3, 1900
- ✓ development of computers began in the 1950s
- ✓ The Internet, itself a significant component of the IoT, started out as part of DARPA in 1962 and evolved into ARPANET in 1969
- ✓ Global Positioning Satellites (GPS) became a reality in early 1993, Satellites and landlines provide basic communications for much of the IoT
- ✓ IPV6's remarkably intelligent decision to increase address space
  - The Internet of Things, as a concept, wasn't officially named until 1999. One of the first examples of an Internet of Things is from the early 1980s and was a Coca Cola machine
  - By the year 2013, the Internet of Things had evolved into a system using multiple technologies

- Kevin Ashton, the Executive Director of Auto-ID Labs at MIT, was the first to describe the Internet of Things, during his 1999 speech.
- Kevin Ashton stated that Radio Frequency Identification (RFID) was a prerequisite for the Internet of Things. He concluded if all devices were "tagged," computers could manage, track, and inventory them
- To some extent, the tagging of things has been achieved through technologies such as digital watermarking, barcodes, and QR codes

4.1.3. IoT – Advantages

1. **Improved Customer Engagement**
   - ✓ to achieve richer and more effective engagement with audiences.
2. **Technology Optimization**
   - ✓ aid in more potent improvements to technology
   - ✓ IoT unlocks a world of critical functional and field data
3. **Reduced Waste**
   - ✓ IoT provides real-world information leading to the more effective management of resources
4. **Enhanced Data Collection**
   - ✓ It allows an accurate picture of everything

4.1.4. IoT – Disadvantages

1) potential that a hacker could steal confidential information
2) likelihood of every connected corruption due to a bug in the system
3) difficult for devices from different manufacturers to communicate with each other

4) millions of IoT devices; collecting and managing the data from all those devices will be challenging.

4.1.5. Challenges of IoT

- list of some its major issues:

a. Security

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

b. Privacy

- ✓ sophistication of IoT provides substantial personal data in extreme detail without the user's active participation.

c. Complexity

- ✓ complicated in terms of design, deployment, and maintenance

d. Flexibility

- ✓ Concern about IoT system to integrate easily with another because of several conflicting or locking systems

e. Compliance

- ✓ Its complexity makes the issue of compliance seem incredibly challenging

4.2. How does it work?

4.2.1. Architecture of IoT

- IoT device consists of hardware, software, network connectivity, and sensors
- four major components:

1. Sensing Layer

- It identify any phenomena in the devices' peripheral and obtain data from the real world
- It is consists of several sensors
- Sensors in IoT devices are usually integrated through sensor hubs
  - ➢ sensor hub: a common connection point for multiple sensors that accumulate and forward sensor data to the processing unit of a device
  - ➢ Actuators: intervene to change the physical conditions that generate the data.
    - ✓ Example: actuator might shut off a power supply, adjust airflow valve
- Sensors in IoT devices can be classified into three:

A. Motion Sensors

- measure the change in motion as well as the orientation of the devices
- two types of motions
  - linear motion - refers to the linear displacement of an IoT device
  - angular motion - rotational displacement of the device

B. Environmental Sensors

- sense the change in environmental parameters in the device's peripheral
- such as Light sensors, Pressure sensors, etc

- It help the devices to take autonomous decisions according to the changes of a device's peripheral

C.Position sensors

- deal with the physical position and location of the device
- The two common position sensors
  - Magnetic sensors - used as digital compass and help to fix the orientation of the device display
  - Global Positioning System (GPS) - for navigation purposes

2. Network Layer

- Act as a communication channel to transfer data, collected in the sensing layer, to other connected devices
- allow data flow between other devices within the same network
- implemented by using diverse communication technologies (e.g., Wi-Fi, Bluetooth, etc.)

3. Data Processing Layer

- takes data collected in the sensing layer and analyses the data to make decisions based on the result
- In some IoT devices it also saves the result of the previous analysis to improve the user experience
- It may share the result of data processing with other connected devices via the network layer

4. Application Layer

- implements and presents the results of the data processing layer to accomplish disparate applications of IoT devices
- It is user-centric layer that executes various tasks for the users
- Example: smart transportation, smart home, personal care, etc

4.2.2. Devices and Networks

- Every device talks to other related devices in an environment to automate home and industrial tasks, and to communicate usable sensor data to users, businesses and other interested parties
- devices can be categorized into three main groups: consumer, enterprise and industrial
  - Consumer connected devices - smart TVs, smart speakers, toys, wearables, smart appliances
  - industrial and enterprise IoT devices - smart meters, commercial security systems, smart city technologies
- IoT network typically includes a number of devices with constrained resources (power, processing, memory, among others) and some of those devices may be massively deployed over large areas whereas others may be deployed in hard-to-reach areas
- The efficient management of IoT networks requires considering both the constraints of low power IoT devices and the deployment complexity of the underlying communication infrastructure

- IoT landscape is depicted by an increasing number of connected devices characterized by their heterogeneity and the presence of resources constrained networks.
- Developing an IoT network management solution is not an easy task because of the intrinsic constraints of IoT networks (architecture, technologies, physical layer)
  - ✓ it is necessary to take into account several elements such as scalability, interoperability, energy efficiency, topology control, Quality of Service (QoS), fault tolerance, and security
- M4DN.IoT (Management for Device and Network in the Internet of Things)
  - ✓ It Is **platform** for IoT networks and devices management
  - ✓ integrates and controls the individual functionalities of the devices in an IoT network as well as the status and characteristics of the network
  - ✓ defines a management structure in two scopes
    - ➢ local management - the platform runs in the same environment as the devices
    - ➢ remote management – the platform controls the devices in different networks
  - ✓ structure of the platform is **expandable**, allowing the addition of new types of network devices or applications
  - ✓ the platform provides standard web services, such as device discovery, data storage, and user authorities, which are basic requirements for creating IoT applications

4.3. IoT Tools and Platforms

IoT Platform

- **KAA**
  - Manage an unlimited number of connected devices
  - Set up cross-device interoperability
  - Perform real-time device monitoring
  - Perform remote device provisioning and configuration
  - Collect and analyze sensor data
  - Analyze user behavior and deliver targeted notifications
  - Create cloud services for smart products
- **SiteWhere**
  - Run any number of IoT applications on a single SiteWhere instance
  - Spring delivers the core configuration framework
  - Add devices through self-registration
  - Integrates with third-party integration frameworks such as Mule any point
  - Default database storage is MongoDB
  - Eclipse Californium for CoAP messaging
  - InfluxDB for event data storage
  - Grafana to visualize SiteWhere data
- **ThingSpeak**
  - Collect data in private channels
  - Share data with public channels
  - MATLAB analytics and visualizations

- Alerts
- Event scheduling
- App integrations
- Worldwide community

➢ **DeviceHive**

- Directly integrate with Alexa
- Visualization dashboard of your choice
- It supports Big data solutions such as ElasticSearch, Apache Spark, Cassandra and Kafka for real-time and batch processing
- Connect any device
- It comes with Apache Spark and Spark Streaming support.
- Supports libraries written in various programming languages, including Android and iOS libraries
- It allows running batch analytics and machine learning on top of your device data

➢ **Zetta**

- Supports a wide range of hacker boards
- Zetta allows you to assemble smartphone apps, device apps, and cloud apps

➢ **ThingsBoard**

- Real-time data visualization and remote device control
- Customizable rules, plugins, widgets and transport implementations
- Allows monitoring client-side and provision server-side device attributes.
- Support multi-tenant installations out-of-the-box.

- Supports transport encryption for both MQTT and HTTP(s) protocols.

4.4. Applications of IoT

- **Agriculture**
  - indoor planting
    - ✓ monitoring and management of micro-climate conditions
  - outside planting
    - ✓ sense soil moisture and nutrients, in conjunction with weather data
    - ✓ better control smart irrigation and fertilizer systems
    - ✓ prevents wasting a precious resource
- **Consumer Use**
  - ✓ in the form of wearables and smart homes
  - ✓ make life easier
  - Wearables – Fitbit, smartphones, smart watches, health monitors
  - Smart homes
    - house is at peak comfort
    - Security is made more accessible
      - ✓ Ability to control to control appliances
      - ✓ activating a smart lock
- **Healthcare**
  - ✓ wearable IoT devices let hospitals monitor their patients' health at home
  - ✓ In hospitals, smart beds
  - ✓ Putting IoT sensors on critical equipment means fewer breakdowns and increased reliability

- sensors can also determine if a patient has fallen or is suffering a heart attack

❖ **Insurance**

- ✓ Insurance companies can offer their policyholders discounts for IoT wearables such as Fitbit
- ✓ By employing fitness tracking, the insurer can offer customized policies and encourage healthier habits, which in the long run benefits everyone, insurer, and customer alike.

❖ **Manufacturing**

- ✓ RFID and GPS technology can help a manufacturer track a product from its start to its placement in the destination store, the whole supply chain
- ✓ Sensors attached to factory equipment can help identify bottlenecks in the production line, thereby reducing lost time and waste
- ✓ track the performance of the machine, predicting when the unit will require maintenance, thereby preventing costly breakdowns

❖ **Retail**

- ✓ Online and in-store shopping sales figures can control warehouse automation and robotics, information gleaned from IoT sensors; Much of this relies on RFIDs
- ✓ IoT can help analyze mall traffic so that stores located in malls can make the necessary adjustments that enhance the customer's shopping experience while reducing overhead
- ✓ IoT helps retailers target customers based on past purchases
- ✓ a retailer could craft a personalized promotion for their loyal customers

❖ **Transportation**

- ✓ The GPS is being utilized to help transportation companies plot faster and more efficient routes for trucks hauling freight, thereby speeding up delivery times
- ✓ city planners can also use that data to help determine traffic patterns, parking space demand, and road construction and maintenance

❖ **Utilities**

- ✓ IoT sensors can be employed to monitor environmental conditions such as humidity, temperature, and lighting
- ✓ The information provided by IoT sensors can aid in the creation of algorithms that regulate energy usage and make the appropriate adjustments
- ✓ With IoT-driven environmental control, businesses and private residences can experience significant energy savings
- ✓ On a larger scale, data gathered by the Internet of Things can be used to help run municipal power grids more efficiently
- ✓ sensors can help pinpoint outages faster, thereby increasing the response time of repair crews and decreasing blackout times

4.4.1. IoT Based Smart Home

- Smart Home initiative allows subscribers to remotely manage and monitor different home devices from anywhere via smartphones or over the web with no physical distance limitations
- These “smart” devices have the potential to share information with each other given the permanent availability to access the broadband internet connection

- **Remote Control Appliances**:
  - ✓ Switching on and off remotely appliances
  - ✓ avoid accidents and save energy
- **Weather**:
  - ✓ Displays outdoor weather conditions with the ability to transmit data over long distances
- **Smart Home Appliances**:
  - ✓ Refrigerators - telling what's inside, food that's about to expire and with all the information available on a smartphone app
  - ✓ Washing machines - monitor the laundry remotely
  - ✓ Kitchen - allowing remotely adjustable temperature control and monitoring the oven's self-cleaning feature
- **Safety Monitoring**:
  - ✓ cameras, and home alarm systems
- **Intrusion Detection Systems**:
  - ✓ Detection of window and door openings and violations to prevent intruders
- **Energy and Water Use**:
  - ✓ Energy and water supply consumption monitoring to obtain advice on how to save cost and resources, & many more

4.3.2. IoT Based Smart City

✓ In cities, the development of smart grids, data analytics, and autonomous vehicles will provide an intelligent platform to deliver innovations in

- energy management

- traffic management
- security

➢ **Structural Health:**
- ✓ Monitoring of vibrations and material conditions in buildings, bridges and historical monuments

➢ **Lightning:**
- ✓ intelligent and weather adaptive lighting in street lights

➢ **Safety:**
- ✓ Digital video monitoring
- ✓ fire control management
- ✓ public announcement systems

➢ **Transportation:**
- ✓ Smart Roads and Intelligent High-ways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.

➢ **Smart Parking:**
- ✓ Real-time monitoring of parking spaces
- ✓ residents able to identify and reserve the closest available spaces

➢ **Waste Management:**
- ✓ Detection of rubbish levels in containers to optimize the trash collection routes
- ✓ Garbage cans and recycle bins with RFID tags allow the sanitation staff to see when garbage has been put out

4.3.3. IoT Based Smart Farming

- **Green Houses:**
  - ✓ Control micro-climate conditions to maximize the production of fruits and vegetables and its quality
- **Compost:**
  - ✓ Control of humidity and temperature levels in alfalfa, hay, straw, etc
  - ✓ prevent fungus and other microbial contaminants
- **Animal Farming/Tracking:**
  - ✓ Location and identification of animals grazing
  - ✓ Study of ventilation and air quality in farms
  - ✓ detection of harmful gases from excrements
- **Offspring Care:**
  - ✓ Control of growing conditions of the offspring in animal farms to ensure its survival and health
- **Field Monitoring:**
  - ✓ Reducing spoilage and crop waste