UNIVERSITY OF ALBERTA

Master of Science in Internetworking

Capstone Project Report

On

'IoT Integration into the AI-enabled Enterprise Networks'

MINT 709 – CAPSTONE PROJECT

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Under the Supervision of

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DECLARATION

I, Rashi Midudula, hereby declare that the project work entitled "IoT Integration into the AI-enabled Enterprise Networks" in the Department of Computing Science, Master's in internetworking, University of Alberta, is based on my own work. The dissertation has not formed the basis for any degree, fellowship or similar title to the best of my knowledge.

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ABSTRACT

In recent years, the number of IoT devices has increased exponentially, evolving in virtually every domain, making businesses smarter and more efficient. This project will oversee various applications and use cases of IoT in enterprises and its evolution by aspects of Artificial Intelligence. Also, we explore the challenges of implementing IoT in an enterprise network. IoT is a concept where several sensors are connected to the internet with free data sharing and creating a mesh network so that applications get reverse benefits in almost every aspect of our lives. This IoT is currently trending in the IT industry but comes with several challenges; hence we need to plan the IoT applications and solutions carefully. Also, we look into how AI is catering for the needs of enterprises with IoT integrations.

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Chapter 1 Introduction

IoT and AI have bought fundamental changes to the current business landscape. The merger of AI and IoT technologies assists businesses in making informed decisions effectively and accurately. Here, IoT devices help businesses to accumulate huge amounts of data, and AI techniques help businesses to assimilate and evaluate this data [1]. Machine Learning, on the other hand, involves identifying the patterns and detecting the faults in the data collected by IoT devices. The objective of this project is to study and analyze the Internet of Things (IoT) and its evaluation, along with the challenges faced by its implementation in an enterprise network.

This project describes the detailed study and analysis of IoT and its protocols used in enterprises such as MQTT, CoAP, AMQP, and device Management TR-069, OMA and any challenges associated with them. This project also discusses the detailed study of Machine learning and Artificial intelligence, its usage of analyzing meaningful insights from data and applications of AI in creating new products and services or enchanting the existing ones. This project also outlines the current transformations of IoT in enterprise and the role of AI, along with the discussion on further research areas and examples of AI/IoT in action.

This project is done in three parts.

Section 1: A detailed study and analysis of various IoT protocols used in enterprises such as MQTT, CoAP, AMQP, and device Management TR-069, OMA and any challenges associated with them.

Section 2: A detailed study of Machine learning and Artificial intelligence and its usage of analysing meaningful insights from data. Applications of AI in creating new products and services or enchanting the existing ones

Section 3: An outline of current transformations of IoT in enterprise and the role of AI. It will also discuss further research areas and examples of AI/IoT in action.

SECTION I

Chapter 2 Internet of Things (IoT)

The Internet of Things (IoT), which is also referred to as the Internet of Objects and is an Industry 4.0 revolution as companies across the world are focusing on the integration and adoption of digital technologies and investing in the creation of disruptive innovation to enable them to sustain and go forward in the fast-evolving economic environment [1]. IoT refers to everyday objects that are locatable, recognizable, readable and addressable through information sensing devices that can be connected to the internet and controlled via the internet, irrespective of means of communication, including RFID, wide area networks, and wireless LAN) [1].

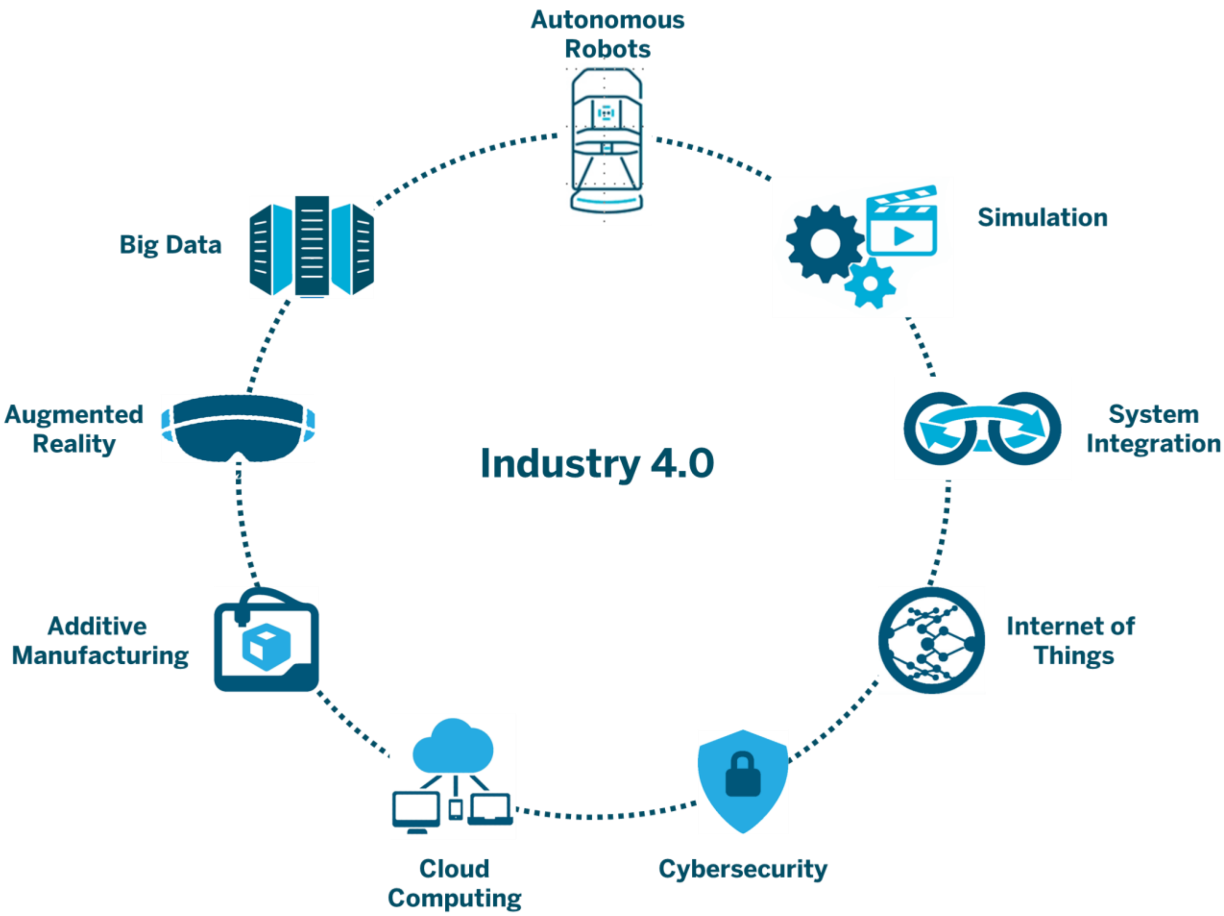


Figure 1 Industry 4.0

These everyday objects include not only the electronic devices that we use or the equipment and vehicles, but also the things that we do not even think about them as electronic at all, such as a chair, animal, clothing, water, tree etc.

IoT has the ability to change everything, not only how we use objects but also ourselves in using the objects [2]. Similar to the impact the Internet had on education, business, science, communication, humanity and government, IoT has the ability to create a great impact on the world. The Internet is one of the great inventions that humans have ever made that changed how we communicate with each other and exchange goods and services between countries. Today everything in this world is interconnected, making our lives better and better every single day [2].

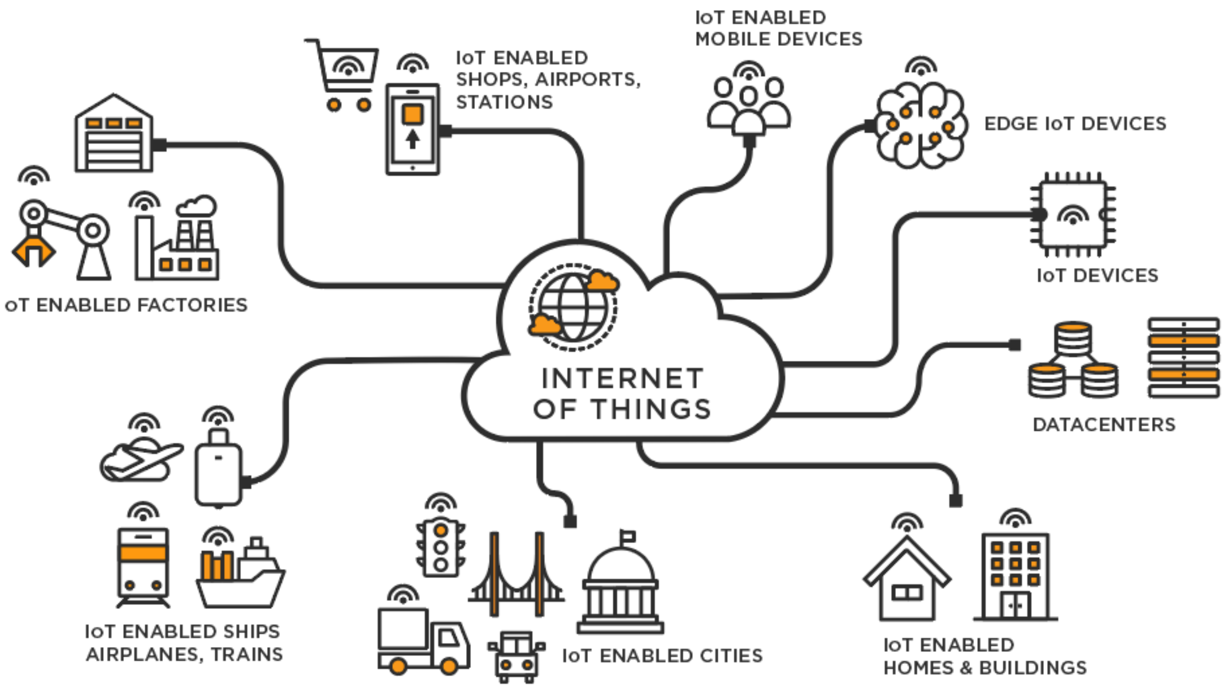


Figure 2 Internet of Things

IoT is the next evolution of the Internet with much greater abilities, including gathering, analyzing and distributing data that can be turned into information, knowledge and ultimately, wisdom. The essential abilities of IoT make it more important for the industry 4.0 revolution. Companies across the world are working on various IoT projects with the aim of closing the gap between rich and poor effective and improving the distribution of resources across the world that are in need of them, improving the understanding of the planet to make human beings less reactive and more proactive [3]. Though there are various barriers that resist the development of IoT, including the transition from IPv4 to IPv6, developing energy for numerous minute sensors used in IoT devices and having a common set of standards.

IoT also requires unconditional support and collaboration of governments, businesses, academia, and standards bodies to solve the above-mentioned challenges as well as to continue the IoT development progress. As IoT has been in the spotlight for the past decade, its applications in various industries will make it a disruptive technology of this century. In addition to the support and collaboration of various parties for the development of IoT, the positive attitude of people and society is very important to make it easier for companies to adopt IoT and develop IoT-enabled devices in the future [3].

Currently, businesses adopting IoT are changing their business models as well as changing their approach to the development of services and products. Enterprises, institutions, and governments are slowly understanding and identifying the potential benefits that can be obtained from the adoption of IoT and leading them to undertake strategies, initiatives and projects with the aim of developing IoT as well as getting profit from it [4].

Figure 3 IoT Devices

IoT-enabled objects or devices make themselves recognizable as they are connected to the internet. IoT-enabled devices obtain intelligence by enabling context-related decisions as they have the ability to communicate to other devices connected to the internet by themselves. IoT-enabled devices have the ability to access the information that is aggregated by other IoT-enabled things. The development of IoT is connected to the development of cloud computing. The emergence of cloud computing and internet transition towards IPv6 is really essential for successful transformation to address unlimited capacity. The main goal of IoT is to enable things to be connected and assessable anytime, from anywhere, any place with anything using a network and any service [4].

IoT devices are nothing but devices that have the ability to connect to the internet and are recognizable. For example, a water heater can be turned off and turned on automatically using the water heater application on the smartphone. Here, the water heater connects to the internet and works with the application designed especially for the device. The application can be downloaded on a smartphone, and using the application, the device can be operated from anywhere and anytime when connected to the internet [5].

2.1 History of IoT

Going back to history, the concept of IoT was first coined by a member of the Radio Frequency Identification (RFID) development community in the year 1999. With the growth of mobile devices, cloud computing, data analytics, and ubiquitous and embedded communication, IoT has become more relevant to the practical world [6]. The connected devices concept first emerged in the year 1832 when the first electromagnetic telegraph was designed. Through the transfer of electrical signals, the telegraph has enabled direct communication between two machines. Though IoT history has started with the invention of the internet, which is developed rapidly and came into usage over the next decades [7].

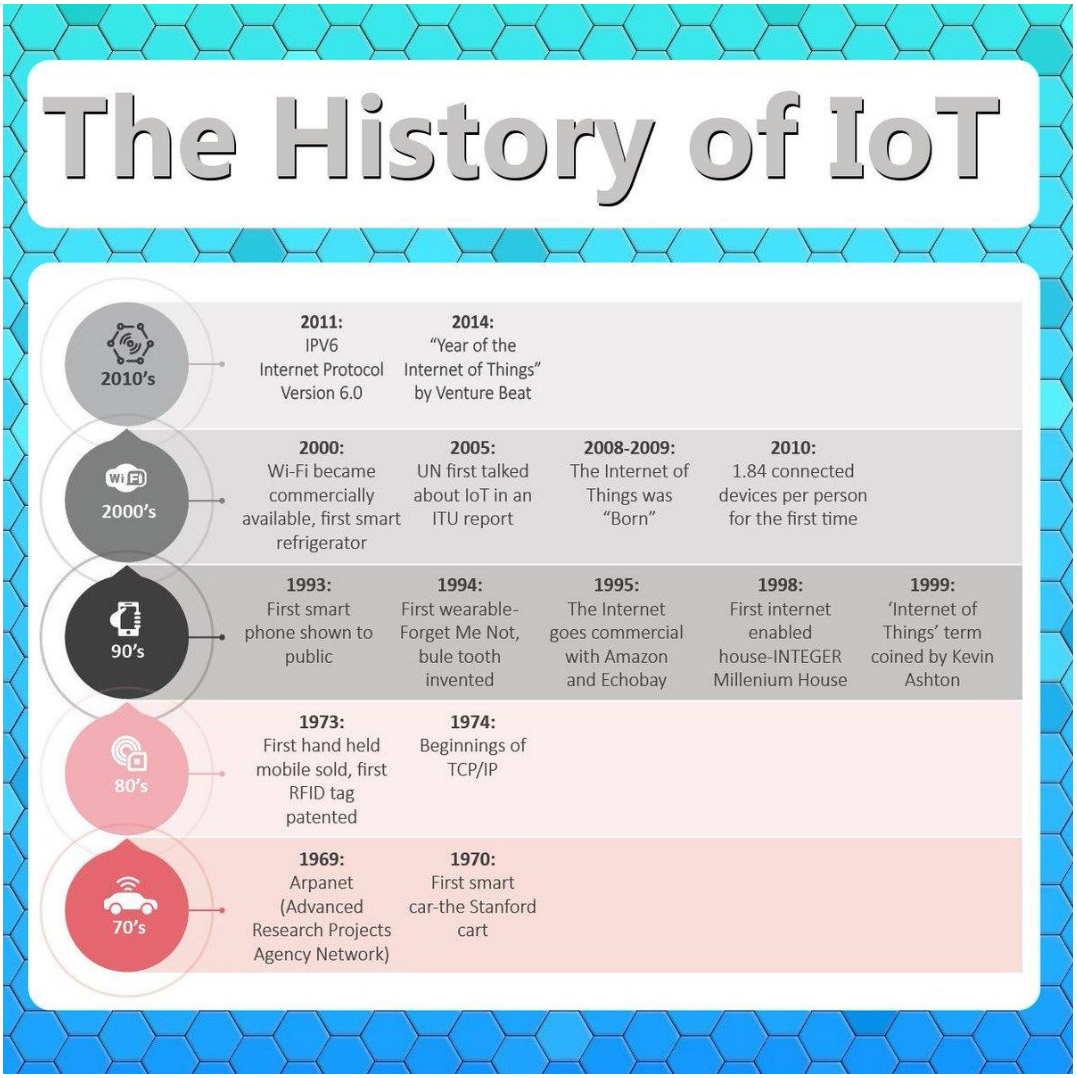


Figure 4 History of IoT

At the beginning of the 21st century, the term 'Internet of Things' was used extensively by the media communities, including Forbes, The Guardian, and the Boston Globe. The technological communities started to increase their interest in IoT technology steadily over the years, and that led to the first international conference on the IoT held in Switzerland in 2008, where representatives of 23 countries were involved in the discussion on sensor networks, short-range wireless communications and RFID [8].

After the first conference on the IoT in 2008, many companies across the world started to develop IoT enabled devices, and one of them is Smart Refrigerator by LG electronics, which allows users to make video calls as well as shop online. The IoT boom was supported by the launch of IPv6 publicly, which is central to IoT. IPv6 is a network layer protocol that provides a unique IP address that is necessary for the communication between internet-enabled devices [9]. Though the purpose of IPv4 and IPv6 is the same, the only difference between both is the address size of IP addresses. While IPv4 is a 32-bit address, IPv6 is a 128-bit hexadecimal address. When compared to IPv4, IPv6 provides a large address space, and it contains a simple header [9].

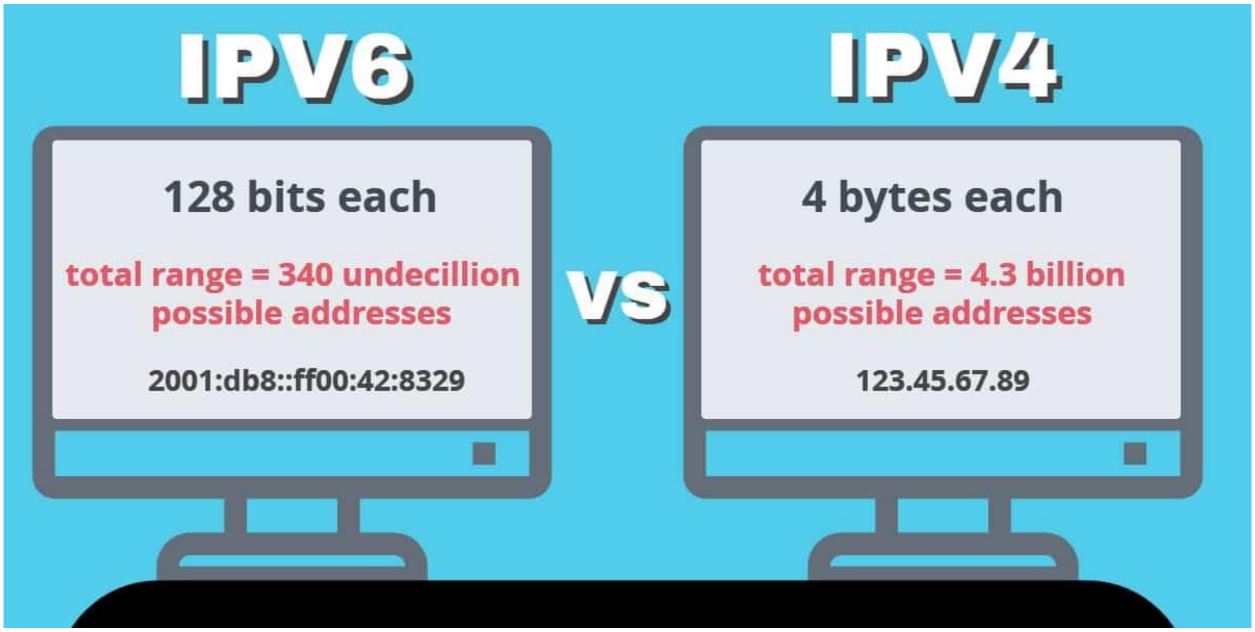


Figure 5 IPv6 vs IPv4

The launch of IPv6 increased the development of interconnected devices, and they have become commonplace in our everyday lives. Multinational technological companies like Cisco, Google, Samsung, General Motors and Apply are continuously focusing and putting their efforts into the production of IoT devices and sensors. Google has developed smart glasses and working on self-driving cards, and others are involved in developing interconnected thermostats and other interconnected devices.

Today every industry is coming forward to adopt IoT to create value for the customers. Today, IoT-enabled devices are increasingly used in healthcare, manufacturing, transportation, energy, oil, retail, agriculture and many more. The dramatic transformation clearly indicates the fact that the IoT revolution is right here, right now. Today, IoT platforms have a strong hold on the top trends every year, along with connected homes, virtual assistants and self-driving cars. In the next 5 to 10 years, IoT is expected to be adopted significantly, and the use of IoT enabled devices will reach 50% [10].

2.2 IoT Characteristics

The seven fundamental characteristics of IoT are connectivity, data, communication, action, ecosystem, intelligence and things.

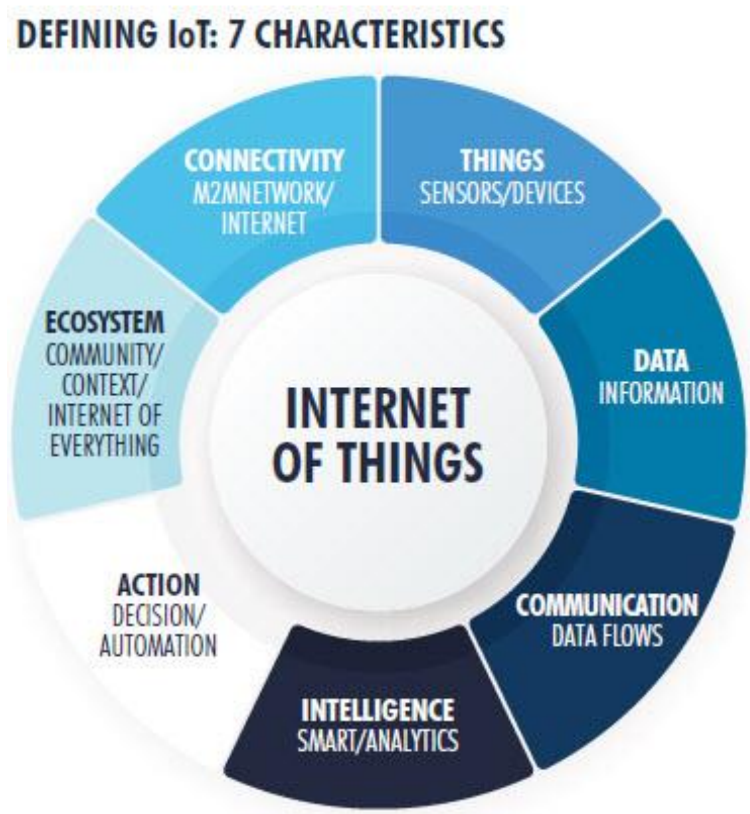


Figure 6 IoT Characteristics

2.2.1 Connectivity

Connectivity enables network compatibility. IoT devices consist of sensors, electronics, control systems and connected hardware, which helps in the creation of connectivity. With the global information and communication infrastructure, anything can be connected and interconnected with regard to the IoT. Connectivity is the most important characteristic of IoT. The seamless communication among the interrelated components of the IoT ecosystem it makes possible to execute any proper business use case [11]. IoT devices can be connected over Wi-Fi, Radio waves, Bluetooth and others. Various protocols of internet connectivity layers can be leveraged to maximize the efficiency of connectivity across IoT ecosystems and industries.

2.2.2 Things

Things in relation to IoT are devices that can be tagged or connected. The things are designed in a way that they can be connected, from sensors, household applications and smart cards to tagged livestock. These things generally consist of sensing materials, and sensors can be attached to items and devices.

2.2.3 Data

Data is an essential characteristic of IoT, and it is the first step towards intelligence and action.

2.2.4 Communication

When devices are designed to get connected, they can communicate data, and the data can be analyzed to take the required action. Communication between these connected devices can occur over shorter distances to very long-range distances [12].

2.2.5 Intelligence

The data generated by IoT devices are used to generate important business insights, and these insights are used to make important business decisions. The sensing capabilities in IoT devices and data gathered from big data analytics and artificial intelligence generates valuable insights.

2.2.6 Action

Action is the consequence of intelligence. The action could be a decision, manual action or an action regarding a phenomenon and automation.

2.2.7 Ecosystem

The IoT ecosystem is a broad network of interdependent and connected devices and technologies that are used by specialists in order to achieve a specific goal, such as the creation of a smart home. In the IoT ecosystem, the user is involved in using a smart device such as a tablet, smartphone or a sensor to send a request to the device for information over the network. The connected device responds and performs the given request or command to send information back to the user via a network [13]. The typical IoT ecosystem can be seen below, where the devices involved in sending and receiving data from the devices themselves in the environment that is connected via internet network and cloud computing.

2.3 IoT Architecture

There are different layers of technologies in IoT architecture that supports IoT. The IoT architecture serves to illustrate how various technologies in different layers relate to each other and to communicate the modularity and scalability of IoT deployments in different scenarios. There are totally four layers in IoT architecture they are Sensor layer, gateways and networks, the management service layer and the application layer [14]. The functionality of each layer in the IoT architecture is described below.

2.3.1 Smart device / Sensor layer (Perception layer)

The sensor layer is the lowest layer in the IoT architecture, and it consists of smart objects that are integrated with sensors. The sensor layer is also referred to as the physical layer or perception layer. The sensor layer consists of both sensors and actuators. Sensors in this layer involve in the collection of data from the environment and transform the data into meaningful information that is used for the analysis. The actuators involve in helping the study of change that is recorded by the sensors [15]. Establishing all the physical devices to capture the data is the most important basic step in IoT architecture. The sensors and actuators in the sensor layer carry out the sensing and actuating process.

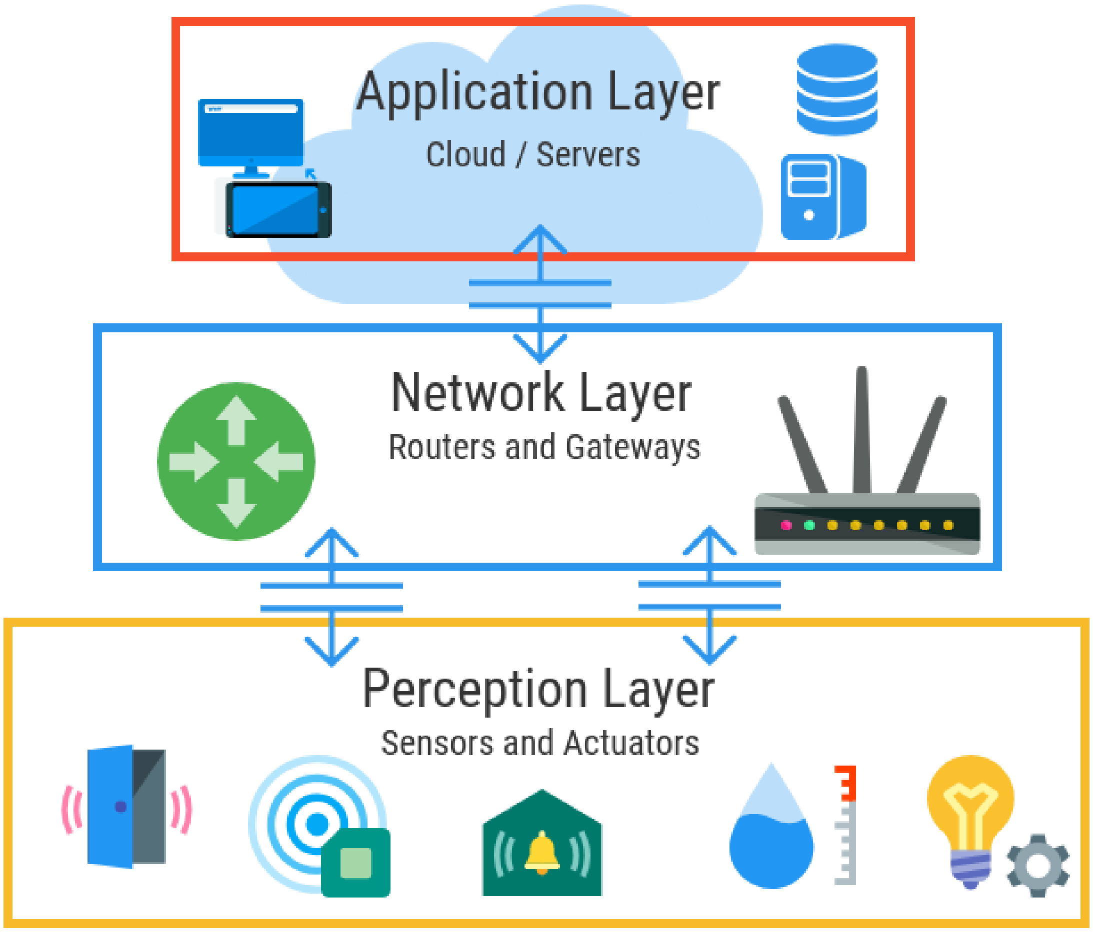


Figure 7 IoT Architecture

In this layer, the sensors involve in enabling the interconnection of the digital and physical worlds and allow the collection and processing of real-time information. In this layer, various types of sensors are used depending on the IoT device for different purposes. There are different sensors for different purposes, including measuring temperature, speed, altitude, air quality, flow, pressure, electricity, movement, humidity and others [15]. These sensors sometimes consist of a degree of memory that enables them to record certain measurements.

Sensors measure the physical properties, and then they are converted into signals. Most of the sensors used in the sensor layer of IoT architecture require connectivity to the sensor gateways. The connection could be a Wi-Fi connection, Ethernet connection, Local Area Network (LAN) connection or Personal Area Network (PAN) such as Ultra-Wideband (UWB, Bluetooth and ZigBee. For sensors that which not require connectivity, their connectivity will be provided using Wide Area Networks (WANs) such as LTE, 5G, GPRS and GSM [15].

2.3.2 Gateways and Networks or Network Layer

The next layer in the IoT architecture consists of gateways and networks. The data collected by sensors and actuators will be in analog form, and this analog data should be changed to digital data. In order to do that, a mechanism is required. The mechanism is created by using internet gateways. As sensors collect a massive volume of data, gateways and networks act as a medium to transport the data [16]. These gateways and networks are part of robust and high performance wireless or wired network infrastructure.

The networks that are currently being used are often associated with very different protocols that are used to support machine-to-machine (M2M) networks and their associated applications. In order to serve a wide range of IoT applications and services, such as context-aware applications, high-speed transactional services, etc., multiple networks with various access protocols and technologies are needed to work with each other in a configuration that is heterogeneous[16]. These networks can be in the form of hybrid, public or private models that are designed and built to support the communication requirements for security, bandwidth or latency.

2.3.3 Management Service Layer

The management service layer is the next layer in the IoT architecture that renders the processing of information possible through process modelling, security controls, analytics and management of devices. Business and process engines are the important features of the management service layer. IoT brings interaction and connection of systems and objects together, providing information in the form of contextual data or events such as traffic data, current location and temperature of goods [17]. Some events might require routing or filtering to post-processing systems that include a collection of periodic sensory data, while others might require immediate responses to the emergency situations such as patient's health conditions.

The rule engines in the management service layer involve in supporting the formulation of trigger interactive, decision logic and automated processes to enable a more effective responsive IoT system. For analytics, various tools related to analytics are used to extract relevant data from the huge volume of raw data that needs to be processed at higher speeds. Analytics like in-memory analytics involve in allow large volumes of data that need to be cached in random access memory (RAM) rather than storing it in the physical storage disks [18]. The advantages of in-memory analytics include reduction of data query time and augmenting the speeds of decision making. In addition to in-memory analytics, streaming analytics is another form of analytics that analyzes the data that is in motion, which is essential is to make decisions quickly in real-time.

The management service layer also consists of data management that will give the ability for IoT devices to manage the flow of data information. Through data management, information can be controlled, integrated and accessed. The applications in the higher layer of IoT architecture can be protected from the need to process unnecessary data and reduce the threat of disclosing private and confidential data from the data source.

Data anonymization, data synchronization and data integration are the data filtering techniques that are used to hide the details of information while providing the significant information that is required for the relevant applications. Data abstraction can be used to extract the information to offer a common business perspective of data in order to gain greater agility as well as reuse across domains [19]. The management service layer also provides security across the whole dimension of the IoT architecture, right from the physical layer to the application layer. Security ensures protection from unauthorized personnel accessing the system as well as prevents hacking, thus reducing the possibility of risks.

2.3.4 Application layer

The application layer is the final layer in the IoT architecture that involves managing all application processes based on the data or information that is obtained from the previous layer, i.e., the management service layer or middleware layer [19]. The application layer in the IoT architecture involves activating the alarm, sending emails, security systems, smartwatch, turning on or turning off a device, smart agriculture, smart cities, smart home, etc.

2.4 Benefits of IoT

The major benefits that come with the adoption of IoT include reduction in operational costs, helping gather useful and rich data, enhanced security measures, use of smart devices and achieving customer-centricity.

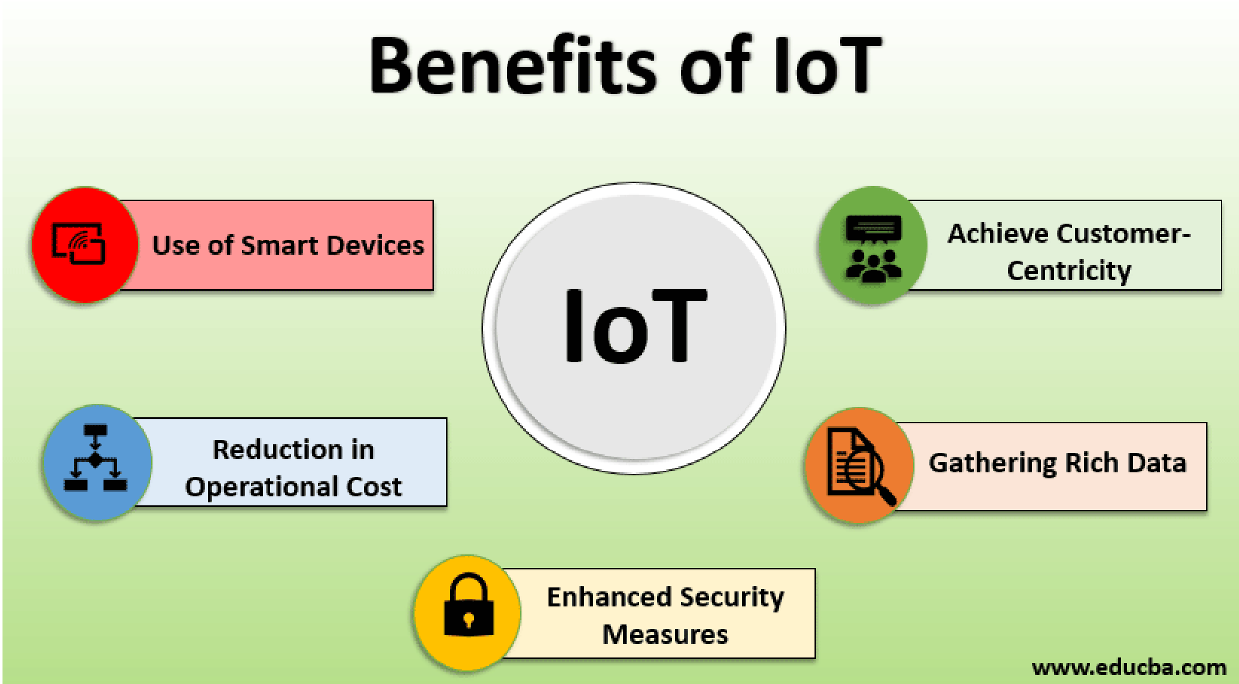


Figure 8 Benefits of IoT

2.4.1 Customer-Centricity

Customer satisfaction is one of the essential factors for any business or any organization which needs to be focused on. Customer satisfaction is directly proportional to customer experiences. If a customer had a bad experience with the service, then customer satisfaction is said to be very poor. Using advanced IoT technologies such as smart trackers or mobile card readers can enhance the customer experience [20]. Mobile card readers are one of the IoT technologies that help the customer to make transactions using the smartphone rather than using credit cards/debit cards every single time. IoT devices like smart trackers help organizations to monitor inventories and products. Organizations today are effectively using IoT to enhance customer experiences as well as to enhance business performance. Different IoT solutions have the ability to solve the issues of customers and thus help improve customer satisfaction levels.

2.4.2 Gathering Rich Data

Data is an important weapon for any organization today as it helps businesses to make better and more informed business decisions. Companies are using IoT devices to collect a huge amount of data related to customers, products and markets. The data obtained from IoT devices can be used to perform different analyses to get a deeper understanding of the customer behaviour and market to improve the product or service quality [20]. IoT applications in healthcare help track and monitor the health of the patient without physically diagnosing the patient. The data can be used to decide what can be done about the patient and choose better treatment options for better healthcare.

2.4.3 Enhanced Security Measures

The IoT provides additional security to businesses as well as to common people. Many cities are using IoT for additional security and surveillance and to help track any suspicious activities. In smart cities, IoT devices track and monitor the activities of people in public areas, and any suspicious activity identified can be managed without any further damage through immediate response [21]. Using the internet, security can be controlled from anywhere. Therefore, security standards can be maintained for the organization from anywhere in the world. IoT technology can help eliminate security concerns and help the organization boost security. In construction organizations, sensors, advanced gears, and wearables can be used to get alerts to prevent dangers from happening.

Advancements in IoT technologies can help the organization raise their security standards to the next level. The IoT devices help organizations analyze data and take appropriate decisions for the enhanced security of the organization [22]. Advanced IoT technologies can be a shied between business organizations and the outside world.

2.4.4 Reduction in operational cost

Operational costs can be decreased significantly with the use of advanced IoT technologies, and that helps the organization earn maximum profit. Every organization across the world involve in reducing operating costs and maximize their profits, and IoT solutions will significantly help these organizations achieve these goals. The organization need to have a constant connection so that it can reduce operational costs. For manufacturing industries, IoT devices will help track and monitor equipment, and that help reduces the downtime of equipment because these smart devices help predict errors of equipment or future failovers easily. Another benefit of using IoT devices in manufacturing industries is a significant decrease in power consumption; therefore, the overall cost can be reduced [22].

2.4.5 Use of smart devices

IoT technology has applications in many industries, such as transportation, hospitality, education and healthcare. Organizations are significantly using IoT technologies to develop devices that help track and monitor things. As most organizations are using IoT devices for their businesses and taking maximum advantage, developments in IoT technology will further increase its application in various other industries to a maximum level. IoT devices not increase the productivity level but also brings confidence for the organization to maximize profits. IoT devices can help manage resources as well as real-time monitoring in the manufacturing sector. Integrating IoT with Automation will help in automating a daily routine task [23]. These devices help identify technical problems and eliminate them from the system.

2.5 Disadvantages of IoT

The main drawbacks of IoT technology include over-reliance on technology, breach of privacy, loss of jobs, security issues, the complexity of the system, lack of international standardizations, people becoming highly dependent and reduced mental and physical activity. IoT devices communicate with each other over networks because they are interconnected. However, these can lead to various kinds of network attacks due to little control in spite of any security measures. The fact that concerns IoT devices is that disclosure of users' critical information without the user's active participation is a privacy concern [24].

The other concern with IoT is the speculation about increased unemployment. Either skilled or unskilled workers, IoT technologies have the ability to replace them, and these people lose their jobs, which leads to high employment rates. Robots, smart washing machines, smart surveillance cameras and many other IoT devices are replacing humans who used to do these jobs earlier. The complexity of the system is also a major concern with respect to IoT. The design, development, maintenance, and enabling of IoT technology are quite complicated, and it will take time for people to integrate it into their lives [25].

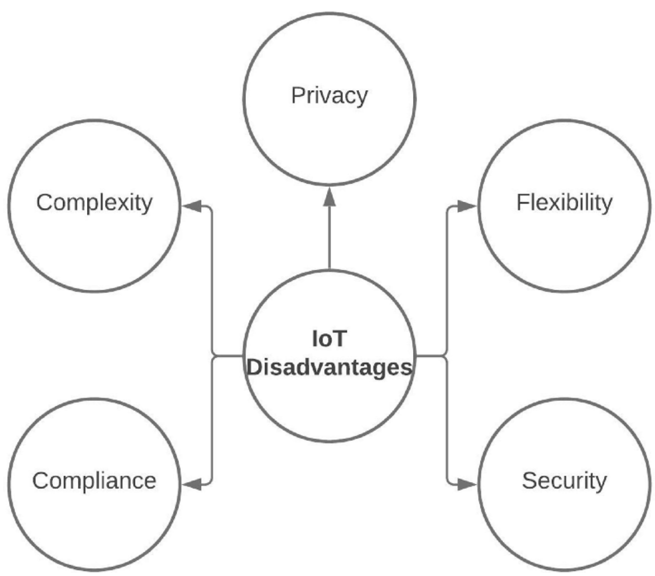


Figure 9 Disadvantages of IoT

Any bug in the IoT device makes it vulnerable to data breaches. Bugs in the system will increase the chances of other devices getting corrupted. Therefore, there are higher chances that the entire system will get corrupted [17]. Though governments across the globe understand the importance of IoT technology, establishing regulations and standards for the use of IoT technology is still under process. There are also no international standards that are compatible with IoT, and it will be problematic for manufacturers to make their devices communicate with other devices from other manufacturers. IoT requires heavy dependence on the internet, and IoT devices cannot function effectively without it. When people heavily depend on IoT devices, the lack of internet connectivity makes them useless [21]. Using the internet and technology heavily will make people less effective mentally and physically as they continuously depend on smart devices that let them become inactive and lethargic.

2.6 Future of IoT

Rapid advancements in technology are making things better for the world. If there is a world that is said to be having objects that can communicate, sense and share information and are interconnected over private and public internet protocol networks, things become easier for governments in preventing terror attacks, organizations to provide better services to the customers and people in conducting their duties [14]. These IoT objectives have the ability to regularly collect the data, and this data can be analyzed and used to take appropriate actions and decisions. Interconnected devices provide a wealth of intelligence for effective decision making, management and planning. The world has become the Internet of Things (IoT), which makes things much better for the world.

Figure 10 Future of IoT

Today, the internet is not only the network that consists of computers; it has been evolved into a network of devices irrespective of size and technology, such as toys, cameras, home appliances, smartphones, vehicles, animals, buildings, industrial systems and medical instruments which are connected and share information based on the protocols to achieve smart positioning, reorganizations, personal real-time online monitoring, tracing, safe & control, process control, online upgrade and process administration [18].

IoT technologies are enabling advanced services through virtual and physical interconnected things based on evolving and existing interoperable communication and information technologies. With IoT technology, communication has been extended through technology to all the things that we use daily and the things that surround us [12]. IoT becomes effective with the integration of its enabling technologies, such as wireless sensor networks, machine to machine communication, GPRS, GSM, microcontroller, microprocessor, GPS, RFID, 2G/3G/4G, etc.

These enabling technologies can be grouped into three categories they are technologies to improve security and privacy, technologies that enable objects to process contextual information and technologies that enable objectives to acquire information that is contextual. The technologies that enable objects to acquire and process contextual information are the functional building blocks that are required to build intelligence into things, which is essential to differentiate IoT from the internet [9]. The technologies to improve privacy and security is not functional, but it is an essential requirement without which the penetration of IoT would be severely decreased.

Internet of Things is not a single technology; it is a combination of different software and hardware technologies. The IoT offers solutions with the integration of information technology which refers to software and hardware used to retrieve, process and store data and communications technology that includes electronic systems, which are used for communication between groups or individuals [22].

The diverse mix of communication technologies can be adapted to address the requirements of IoT applications, such as reliability, security, speed and energy efficiency. In this setting, it is possible that the diversity levels can be scaled to a higher number of manageable connectivity technologies that can address the needs of the IoT applications that are proved to be serviceable and supported by the alliance of strong technologies. Standards in these categories include wireless and wired technologies, including Wi-Fi, Ethernet, GSM, ZigBee, Bluetooth, and GPRS.

Chapter 3 IoT Protocols

The common protocols that are used for tablets, smartphones or personal computers might not be suitable for specific requirements such as range, power consumption and bandwidth of IoT-based solutions. The Internet of Protocols (IoT) proceeds to another level of different internet, and the existing internet protocols were not enough or able to meet the expectations and requirements of IoT and provide seamless connectivity [26]. An IoT system consists of three-level architecture they are devices, gateways and data systems. The data in relation to IoT moves between the three-level architecture through four types of transmission Data Link Layer Protocols they are IEEE 802.15.4e, HomePlug, Wireless HART and IEEE 802.11ah [27].

3.1 Data Link Layer Protocols in the Internet of Things (IoT)

In this section, the four protocols with respect to data link layer protocols will be discussed.

3.1.1 IEEE 802.15.4e

The most generally used IoT standard for MAC is IEEE 802.15.4. The protocols define the frame format, how nodes can connect with each other and headers containing the destination and source addresses. The frame formats that are commonly used in conventional networks might not be appropriate for low-power multi-hop networking in the Internet of Things (IoT) due to the overhead. IEEE 802.15.4e protocol uses channel hopping and time synchronization to enable low cost and high credibility and meet the Internet of Things (IoT) communications necessity [26].

However, this standard does not define how scheduling needs to be done, but the standard needs to be constructed in a cautious way such that it can have the ability to manage mobility scenarios. This protocol can be centralized by a manager node that can be made accountable for building the schedule as well as informing others about the schedule, and that makes the other nodes follow the schedule. Network formation generally consists of components and advertisements [27]. A new device should be in a position that needs to pay attention to advertisement commands and upon receiving at least one such command from the user. The protocol with the combination of manager nodes can send a joint request to the advertising device.

3.1.2 Wireless HART

The Wireless HART stands for the Wireless Highway Addressable Remote Transducer, which is a data link layer protocol that involves operating at the top of IEEE 802.15.4 PHY and adopts TDMA (time division multiple access) in its MAC. HART is vendor-independent and an open standard, and it is the most supported protocol as vendors across the world are developing thousands of HART based products [28]. Wireless HART is a secure and authentic MAC protocol that involves using advanced encryption to calculate the integrity and encrypt the messages in order to offer trustworthiness. The Wireless HART consists of a security manager, network manager and a gateway to connect the wireless network to the access points, routers, wired networks, adapters, and wireless devices as field devices [28]. The standard proposed peer-to-peer, end-to-end or per-hop security mechanisms in end-to-end security mechanisms that involve enforcing security from sources to destinations and per-hop mechanisms involved in securing it to next-hop only.

3.1.3 IEEE 802.11 ah

IEEE 802.11ah is another data link layer protocol, and it is a lighter version of the original IEEE 802.11 wireless medium access norm; and it was designed with less overhead to meet the requirements of the Internet of Things. IEEE 802.11 standards are the commonly used standards for wireless, and they are being extensively used and adopted for electronic and digital devices, including digital televisions, tablets, mobiles and laptops [29]. It is obvious that general and actual Wi-Fi standards will be not appropriate for IoT applications due to power consumption and frame overhead.

Subsequently, IEEE 802.11 working group was involved in initiating the 802.11ah task group to develop the norm that supports the lowest level overhead as well as power congenial communication that is appropriate for motes and sensors [30]. IEEE 802.11ah was designed for low-power sensors, and it permits sleep periods for a longer time as well as waking up occasionally for the exchange of data.

3.1.4 Home Plug

The HomePlug Green PHY is another data link layer MAC protocol that is developed by the HomePlug Power line alliance that is most commonly used in home automation applications. HomePlug protocol is designed to be appropriate for both MAC and PHY layers, and it has three editions, including HomePlug AV2, HomePlug audiovisual, and HomePlug GP [30]. HomePlug is the first edition of HomePlug, and it is the basic power line communication protocol, which uses CA and TDMA and CSMA as MAC layer protocol endorsement adaptive bit loading that which allows it to transform its rate with respect to the noise level and utilizes four modulation techniques and Orthogonal Frequency Division Multiplexing.

HomePlug GP is the third edition of HomePlug, which is designed for the Internet of Things (IoT), particularly for smart grid and home automation applications. HomePlug GP is designed for decreasing the power consumption and expenditure of HomePlug AV while keeping its coverage, trustworthiness and interoperability [31]. HomePlug GP is designed in a way that it has a power-save mode which allows nodes to sleep much more than that of HomePlug by waking up only when essential through synchronization of their sleep time.

3.2 Network Layer Protocols

The Network Layer Protocols include both standard and non-standard protocols that are commonly used for routing in IoT applications. These routing protocols include RPL, CARP and 6LoWPAN. RPL is a network layer protocol, and it stands for Routing Protocol for Low-Power and Lossy Networks [29]. RPL is a distance-vector protocol that can endorse various data link protocols. RPL constructs a DODAG that has only one path for each of the lead nodes to the path to which the traffic from the node will be directed.

CARP is another network layer protocol, and it stands for Channel-Aware Routing Protocol which is a distributed routing protocol that is designed and developed for underwater communication. CARP has lightweight packets to make them useful for the IoT. CARP expects link quality, which is calculated based on historical well-formed data transmission that is collected from vicinal sensors in order to select the forwarding nodes [27]. CARP protocol involves performing two different functionalities they include data forwarding and network initialization.

6LoWPAN is another network layer protocol that stands for IPv6 over Low-Power Wireless Personal Area Network and is the most generally used standard. This protocol captures IPv6 long headers in IEEE 802.15.4 small packets that are either equal to or less than the size of 128 bytes [29]. The protocols support low bandwidth, length addressed, and various topologies, including low cost, power consumption, star or mesh, prolonged sleep time, unfaithfulness and mobility.

3.3 MQTT

Session layer protocols include MQTT XMPP. These are the protocols and standards for a message that is passing in the IoT session layer. These protocols are proposed by different standardized organizations [32].

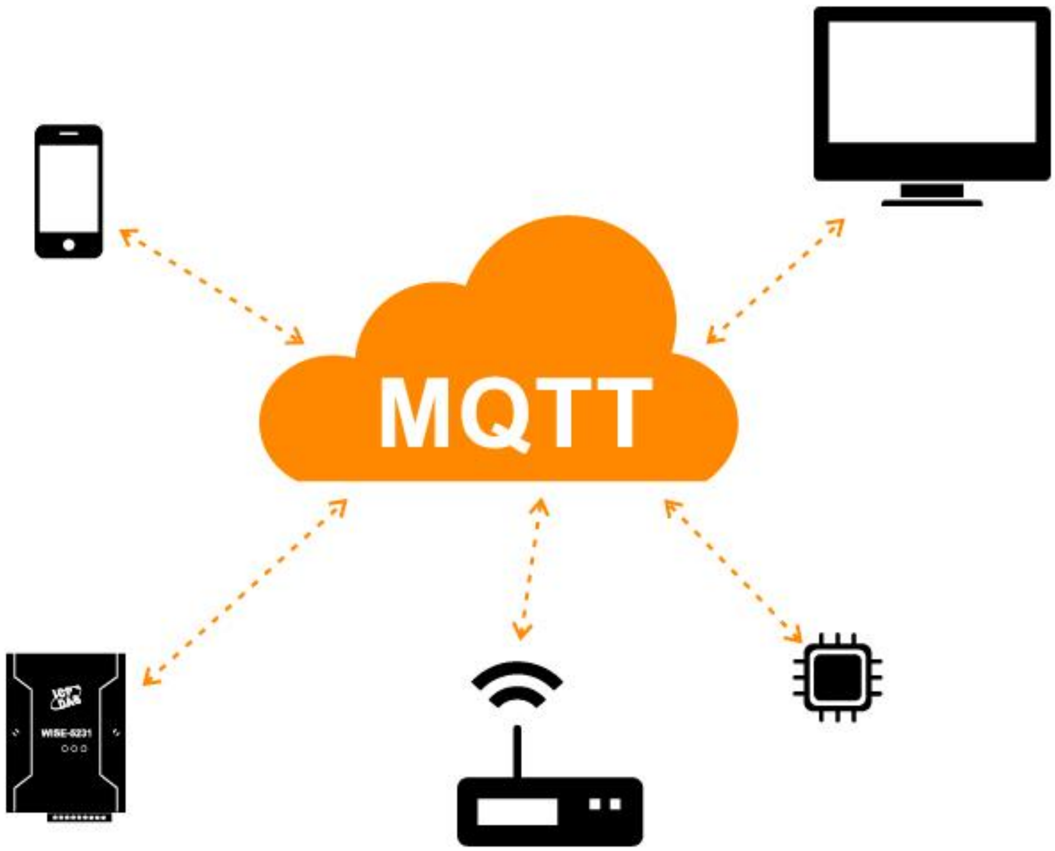


Figure 11 MQTT Protocol

MQTT is a session layer and messaging protocol, and it stands for Message Queuing Telemetry Transport. MQTT is proposed by IBM in the year 1999. Initially, MQTT was designed and built for monitoring sensor nodes and also for far away tracking in the Internet of Things (IoT) [32]. MQTT is designed to be compatible with low-power, low-memory, cheap and small devices.

This messaging protocol confers embedded connectivity between middleware and applications on one side, and on the other side, it connects communicators and networks.

The three main components of the MQTT system protocol are publishers, subscribers and a broker. In the viewpoint of IoT, publishers are lightweight sensors that involve in connecting to the broker in order to send the data and go back to sleep whenever it is feasible. In this scenario, subscribers are considered to the applications that are generally concerned with a certain aspect, or sensory data, so they involve in connecting to brokers to be informed whenever the data is received [33]. The brokers are involved in classifying the sensory data in topics or certain aspects and send it back to subscribers who are concerned with the topics.

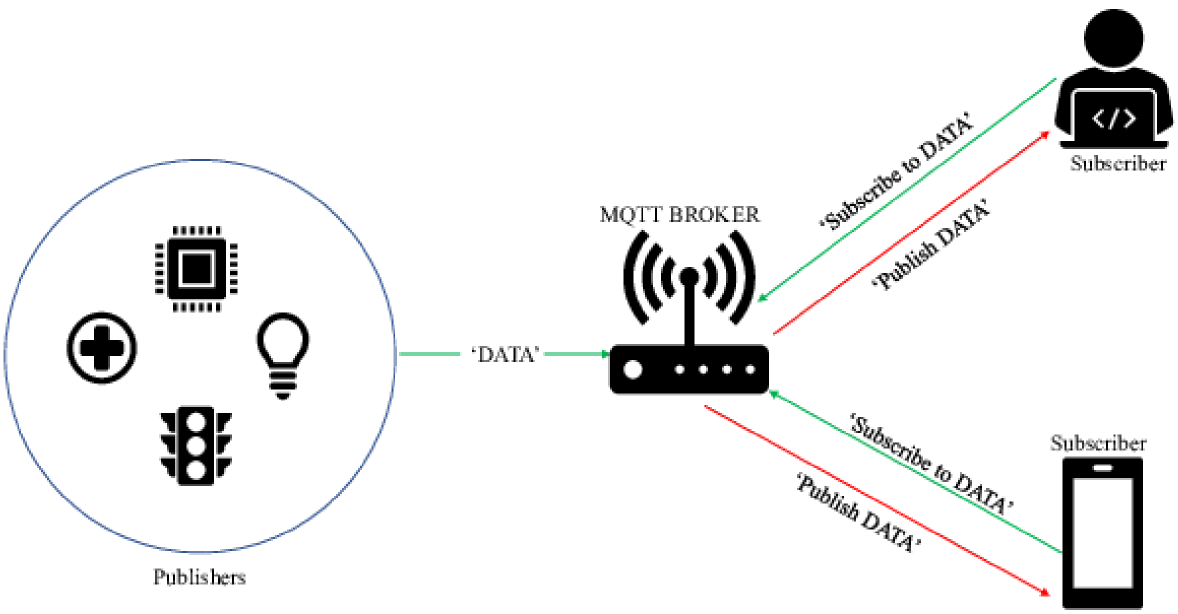


Figure 12 MQTT Components and Architecture

The queues in the protocol basically involve symbolizing the topics and the topics that are subscribed by subscribers, which will get the sensory data whenever the topics are accessible in the queue [32]. It is a known fact that the AMQP protocol may not be appropriate for sensor devices with limited network bandwidth, limited power and limited memory. AMQP is the only protocol that is feasible for end-to-end uses for selective Internet of Things (IoT) uses cases.

MQTT is the machine-to-machine IoT connectivity protocol which is a publish-subscribe and extremely lightweight messaging transport protocol. MQTT is the protocol that is mainly useful for connecting to the remote location when the bandwidth is said to be premium. These characteristics of MQTT make MQTT useful in various situations, such as for communication machine to machine and IoT contexts [33]. MQTT is a publish and subscribe system where messages can be published and received as a client. MQTT makes it easy to communicate between multiple devices. MQTT is also considered to be a simple messaging protocol that is mainly designed for controlled devices with low bandwidth, and it can be the perfect and right solution for IoT applications.

3.3.1 Characteristics of MQTT

MQTT is a messaging protocol, and it has some unique features that are not found in other protocols. Some of the unique features of MQTT are described below.

- MQTT allows the users to subscribe to what they want and lets users receive the information they are looking for. MQTT narrows the selection of topics; therefore, it will be easier for the user to receive whatever information they want.
- As it was a machine-to-machine protocol, it involved providing communication between the devices [34].
- MQTT is designed to be a lightweight and simple messing protocol that uses a publish/subscribe system in order to exchange the information between the server and the client.
- MQTT protocol does not require both the server and client to establish a connection at the same time.
- MQTT protocol provides faster data transmission than any other protocol like WhatsApp, which provides faster delivery. MQTT is a real-time messaging protocol [34].

3.3.2 History of MQTT

Dr Andy Standford-Clark and Arlen Nipper are the two persons who developed the MQTT. The previous versions of the MQTT protocol, including 3.1 and 3.1.1, are available under MQTT ORG. In the year 2014, the MQTT was published by OASIS, and it has become a hub for advancements in the development of MQTT. OASIS has come up with minor changes such as connect message and clarification to the 3.1 version [35]. The current version of MQTT is 5.0, and it is the successor of the MQTT protocol 3.1.1 version. Like version 3.1.1, version 5.0 is not backward or comfortable. When specifications are considered, version 5.0 has a significant number of features that will put the code in place.

Improvement in the error reporting enhancing the scalability of a large-scale system to make it compatible setting up with the millions of devices are the major functional objectives in version 5.0.

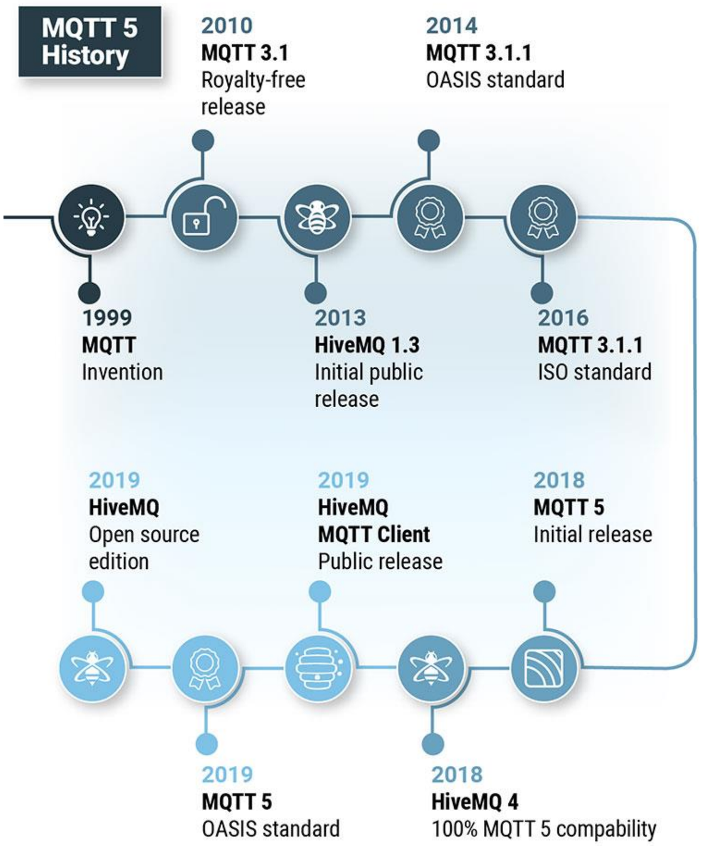


Figure 13 History of MQTT Protocol

3.3.3 MQTT protocol architecture

In order to understand the working principle of MQTT, it is important to understand the components of the MQTT protocol architecture. The components in the MQTT protocol are:

- Message
- Client
- Server or Broker
- TOPIC

Message

The message is a component of MQTT architecture where data is carried out by the protocol across the application network [36]. Whenever a message is transmitted over the network, the message is said to have the following parameters:

i. Payload data

ii. Quality of Service (QoS)
iii. Collection of properties
iv. Topic Name

Client

The client is another component in MQTT architecture, and the two roles played by the client are publisher and subscriber. If any device or program that uses the MQTT is referred to as a client. A device is said to be a client when it opens the network connection to the server, creates or publishes messages for the other clients, subscribes to the messages from which it is interested in receiving, unsubscribes to the messages from which it is not interested in receiving, and then closes the network connection to the server [36]. The two operations performed by the client in MQTT publish and subscribe. As a publisher, the client involves in sending data to the server, and this operation is called publish. As a subscriber, the client receives data from the server from which it wants, and this operation is called a subscription.

Server

The server is another component in MQTT architecture, and it is a program or device that allows the client to subscribe to the messages and publish the messages. A server involves accepting the network connection from the client as well as messages from the client, processing the unsubscribe and subscribe requests, forwarding application messages to the client and closing the network connection from the client [37].

Topic

The topic is a label provided to the message that is checked against the subscription is known by the server.

Figure 14 MQTT Component: Topic

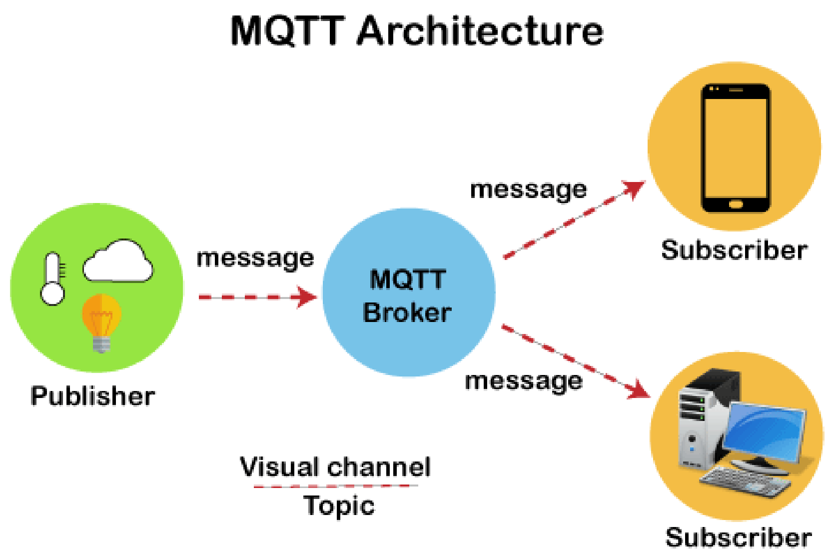


Figure 15 MQTT Architecture

The components of MQTT have been discussed earlier, and to understand MQTT more clearly, let's look at an example. Let's say a device that contains a temperature sensor and it wants to send the rating to the broker or to the server. If a desktop or phone application requires to receive this temperate rating on the other side, then here two things have happened. The publisher (the device) first defines the topic; here, temperate is the topic, and the message is temperature value. After publishing or sending the message, the desktop or phone application on the other side subscribes to the topic, i.e., receives the published message, i.e., the value of the temperature [38]. Here broker or the server's role is to deliver the published message to the desktop or the phone application.

3.3.4 Message format in MQTT protocol

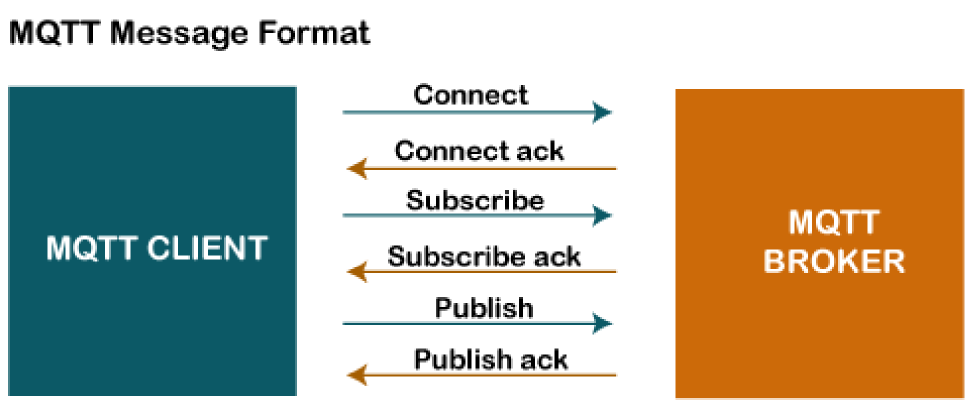


Figure 16 Message Format in MQTT

The MQTT protocol uses both command and the command acknowledgement format, where each command has a related command acknowledgement. In the figure above, the connect command has comment acknowledgement, publish command has published acknowledgement and subscribe command has subscribed acknowledgement [34]. This mechanism in the MQTT protocol is similar to that of the handshaking mechanism in the TCP protocol. Now let's look at the message format or packet structure of the MQTT protocol.

3.3.5 MQTT Packet Structure

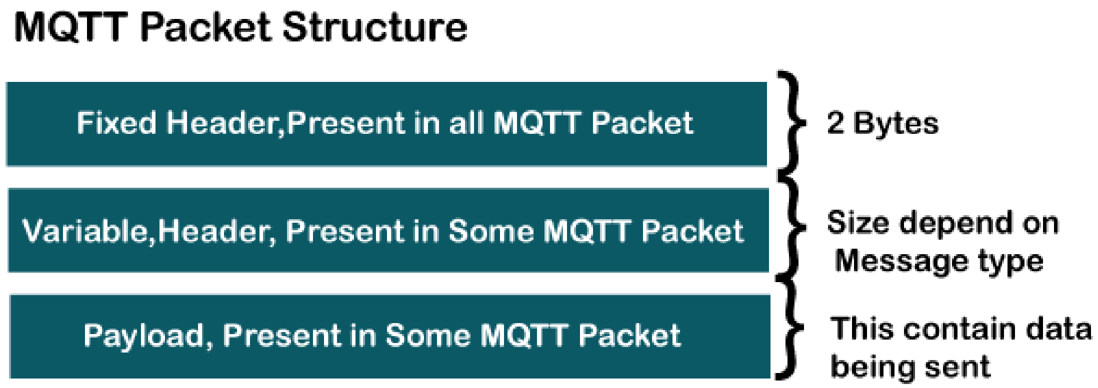


Figure 17 MQTT Packet Structure

The message format in the MQTT protocol consists of a fixed header that is 2bytes in size. This fixed header is present in all the MQTT packets. The second field in the MQTT packer structure is the variable header, and that is not present at all times, and its size depends on the message type. The third field of MQTT packet structure is the payload, i.e., present in some MQTT packets but also not always present [36]. The payload field in the MQTT packet structure contains the data that is being sent. Sometimes payload is considered a compulsory field, but it does not happen. Some commands in the MQTT packet structure do not use the payload field, for example, disconnect message.

Fixed Header

The format of the fixed header is shown below. In the figure below, the fixed header has two bytes. The first byte contains the following fields, including MQTT Control Packet Type and Flag specific to each MQTT packet type [39].

- The MQTT control packet type occupies 4 bits, i.e., 7 to 4-bit positions. The 4-bit size occupied by the MQTT control packet is an assigned value, and each bit represents the MQTT control packet type.
- The remaining 4-bits in the fixed header represent a flag specific to each MQTT packet type.

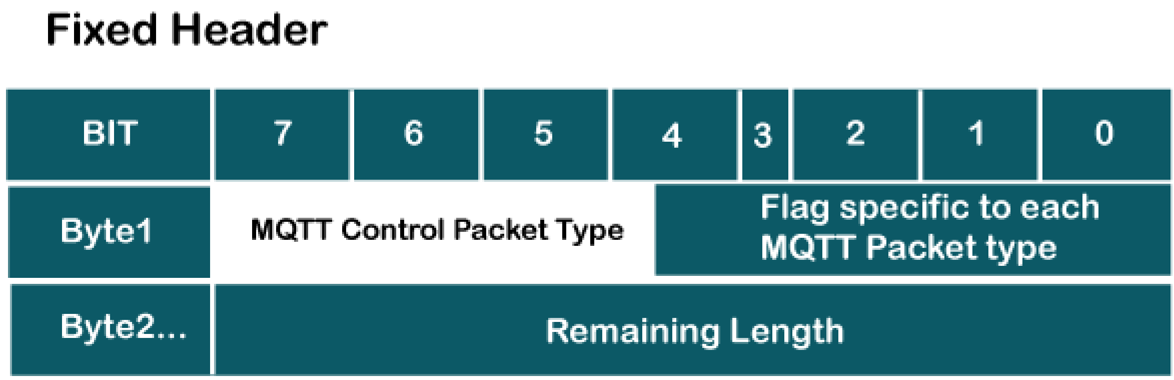


Figure 18 Fixed Header

The second byte, i.e., byte 2, contains the remaining length, which is a variable-length byte integer. The second byte represents the number of bytes that are remained in the current control packet, including data in the payload and variable header [32]. Therefore, the remaining length of the second byte is the sum of the data in the payload and variable header.

MQTT Control Packet Types

Table 1 below shows the different MQTT control packet types with the direct flow and 4-bit value. Every command has an acknowledgement command like SUBSCRIBE has SUBACK, PUBLISH has PUBACK, CONNECT has CONNACK, PUBREC, PUBREL, and UNSUBSCRIBE has UNSUBACK [38].

Table 1 MQTT Control Packet Types

MQTT Control Packet Types

Name	Value	Direction of flow	Description
Reserved	0	Forbidden	Reserved
CONNECT	1	Client to Server	Connection request
CONNACK	2	Server to Client	Connect acknowledgment
PUBLISH	3	Client to Server or Server to Client	Publish message
PUBACK	4	Client to Server or Server to Client	Publish acknowlegment(QoS1)
PUBREC	5	Client to Server or Server to Client	Publish received(QoS2 delivery part 1)
PUBREL	6	Client to Server or Server to Client	Publish release(QoS 2 delivery part 2)
PUBCOMP	7	Client to Server or Server to Client	Publish complete (QoS 2 delivery part 3)
SUBSCRIBE	8	Client to Server	Subscribe request
SUBACK	9	Server to Client	Subscribe acknowledgment
UNSUBSCRIBE	10	Client to Server	Unsubscribe request
UNSUBACK	11	Server to Client	Unsubscribe acknowledgment
PINGREQ	12	Client to Server	PING request
PINGRESP	13	Server to Client	PING response
DISCONNECT	14	Client to Server or Server to Client	Disconnect notification
AUTH	15	Client to Server or Server to Client	Authentication exchange

Flag Bit

The table.2 shows the flag value that is associated with each command. In the below table, reserved refers to future use, and it cannot be used right now. Let's consider the case of PUBLISH command; flag bits are classified into RETAIN, QoS and DUP, where DUP is a duplicate delivery of a PUBLISH packet, RETAIN is retained message flag, QoS is Quality of Service [40].

Table 2 MQTT Flag Values

Flags Bit

MQTT Control Packet	Fixed Header Flags	Bit 3	Bit 2	Bit 1	Bit 0
CONNECT	Reservd	0	0	0	0
CONNACK	Reservd	0	0	0	0
PUBLISH	Used in MQTTv5.0	DUP	QoS		RETAIN
PUBACK	Reservd	0	0	0	0
PUBREC	Reservd	0	0	0	0
PUBREL	Reservd	0	0	0	0
PUBCOMP	Reservd	0	0	0	0
SUBSCRIBE	Reservd	0	0	0	0
SUBACK	Reservd	0	0	0	0
UNSUBSCRIBE	Reservd	0	0	0	0
UNSUBACK	Reservd	0	0	0	0
PINGREQ	Reservd	0	0	0	0
PINGRESP	Reservd	0	0	0	0
DISCONNECT	Reservd	0	0	0	0
AUTH	Reservd	0	0	0	0

Remaining Length

As mentioned earlier, the remaining length is part of byte 2, and it is the variable-length integer that indicates the number of bytes that are remained within the current control packet, including the data in the payload and the variable header. Therefore, the remaining length is the sum of data in the payload and in the variable header [39].

Payload length + variable header length = Remaining length.

For example, if the length of the payload is 30 and the length of the variable header length is 20, then the remaining length is 50. The

In byte 2, the remaining length can be used up to 4 bytes starting from 2 bytes.

Variable Header

In some types of MQTT control packet types, there will be an optional field also, and it is called a variable header component. The field resides between the payload and the fixed header. However, the content of the variable header usually depends upon the packet type, and this variable header consists of a packet identifier field, and it is common in several packet types [40].

The list below contains the packet identifier field:

- PUBCOMP
- SUBSCRIBE

- SUBACK
- UNSUBSCRIBE
- UNSUBACK
- PUBLISH
- PUBACK
- PUBREC
- PUBREL

The key points that are related to the packet identifier field are described are:

- When a client sends a new PUBLISH, SUBSCRIBE and UNSUBSCRIBE MQTT control packet, then it must assign a non-zero packet identifier that is not has been used.
- A PUBLISH MQTT control packet should not contain the packet identifier field if the value of QoS is set at zero. If the value of QoS is greater than zero, then the PUBLIS packet must contain the packet identifier field.
- A PUBREC, PUBUREL, PUBREC, PUBACK are the command acknowledgement packets of the command PUBLISH, and they will have the same packet identifier as the command PUBLISH packet.
- When a server needs to send a new PUBLISH MQTT control packet, then it should assign a non-zero packet identifier that is not currently in use.
- The packet identifier is said to be reusable only after processing the corresponding acknowledge command packet [41].
- As discussed before, UNSUBACK and SUBACK are the acknowledged packets of UNSUBSCRIBE and SUBSCRIBE, respectively. Both these acknowledge packets use the same packet identifier as UNSUBSCRIBE and SUBSCRIBE packets.

If the value of QoS is considered as 1, then the acknowledgement packet of PUBLISH will be PUBACK. If the protocol processes the PUBACK, then the packet identifier of PUBACK is eligible for reuse. Let's say the value is 2, then the acknowledgement packet of PUBLISH will be either PUBREC or PUBCOMP [42].

Payload

In the MQTT packet structure, the last control packet is the payload. The payload field contains the essential information that needs to be sent. For example, in the case of the packet CONNECT, the payload is a client ID, the password and the username, and in the PUBLISH packet, the payload is considered as an application message [37].

Table 3 MQTT control packet that contains Payload

MQTT control Packet that contain Payload

MQTT Control Packet	Payload
CONNECT	Required
CONNACK	None
PUBLISH	Optional
PUBACK	None
PUBREC	None
PUBREL	None
PUBCOMP	None
SUBSCRIBE	Required
SUBACK	Required
UNSUBSCRIBE	Required
UNSUBACK	Required
PINGREQ	None
PINGRESP	None
DISCONNECT	None
AUTH	None

The next protocol that needs to be considered for this study is the CoAP protocol, i.e., the Constrained Application Protocol.

3.4 CoAP (Constrained Application Protocol)

Constrained Application Protocol (CoAP) is a web transfer protocol that is used with constrained networks and constrained nodes in the IoT. CoAP protocol is designed to enable constrained, simple devices to join the Internet of Things (IoT) even through constrained networks with low availability and low bandwidth. CoAP protocol is commonly used for machine-to-machine applications such as building automation and smart energy [43]. The CoAP protocol was designed by the IETF (Internet Engineering Task Force), and it is specified in IETF RFC 7252.

The protocol functions as a sort of HTTP for devices that are restricted and enables equipment such as actuators or sensors to communicate on the IoT. These actuators and sensors are controlled and contribute by transition along with the data as part of a system. The CoAP protocol is also designed for reliability in high congestion and low bandwidth through its low network and low power consumption overhead. In a network with limited connectivity or a lot of congestion, the protocol can continue to work where TCP-based protocols like MQTT fail to communicate and exchange information effectively [43].

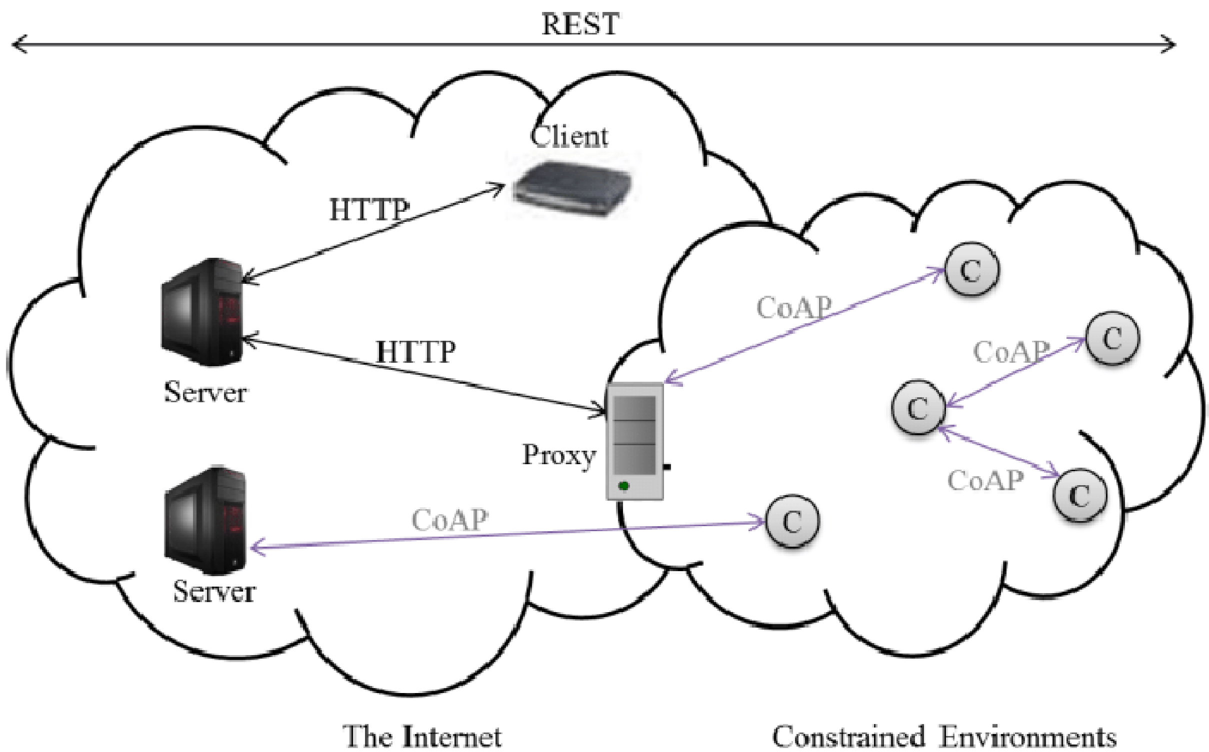


Figure 19 How CoAP Protocol Works?

In addition to the above, the conventional and effective CoAP features enable devices to operate in poor signal quality to send the data reliably or enable an orbiting satellite in order to maintain distant communication successfully. The CoAP protocol also supports networks that consist of billions of nodes. When security is considered, the Datagram Transport Layer Security (DTLS) parameters chosen for default are similar to or equal to that of 128-bit RSA keys. The CoAP protocol also uses user datagram protocol (UDP) as the underlying network protocol. The CoAP protocol is generally a client-server IoT protocol, where the clients are involved in making a request, the and server involves in sending the response back as it happens in HTTP [44]. The CoAP protocol uses the same methods used by HTTP, which is an application layer protocol.

3.4.1 COAP Security

When dealing with the IoT protocols, someone must involve in taking security into account. For example, the CoAP protocols involve using the UDP to transport information. CoAP generally relies on the security features of UDP to protect information. In the case of HTTP, the HTTP uses TLS over TCP. In the case of CoAP, the CoAP protocol uses Datagram TLS over UDP. The Datagram Transport Layer Security (DTLS) supports AES, RSA and so on.

The smallest CoAP message length is 4 bytes if Token, Payload and Options are omitted. The CoAP protocol mainly makes use of two message types they are responses and requests. The protocol uses these two message types by using a simple, binary and base header format. The base header may be followed by options in an optimized Type-Length-Value Format [45]. The protocol

CoAP is always bound to UDP and sometimes to DTLS in order to provide a high level of communications security.

Any bytes after the headers in the packet are considered to be the message body. The message body length is implied by the length of the datagram. When bound to UDP, the entire message must fit within a single datagram. When used with the protocol 6LoWPAN, as defined in RFC 4944, the messages should also fit appropriately into a single IEEE 802.15.4 frame in order to minimize fragmentation [45].

3.4.2 CoAP information exchange

The CoAP protocol is compatible with exchanging 4 types of information. They are:

- Acknowledgements confirming the failure or completion of an event.
- Resetting the messages that are empty, with confirmable as their nature.
- Confirmable are the messages that are sent again on timeout if confirmation doesn't arrive after the successful sending of a message.
- If the information that is sent is not confirmed, then it is just sent, and there is no guarantee of successful delivery as well as the acknowledgment of success either.

3.4.3 Key traits of CoAP

The key traits of CoAP include:

- Working for devices in the networks that are of the same type.
- Enabling data transmission, to and fro, for the general network-connected devices and internet-enabled nodes.
- CoAP protocol works effectively for SMSs that are shared over mobile network connectivity [46].
- CoAP protocol only helps the machines in the network to communicate
- CoAP protocol is capable of supporting multicast, translating HTTP, and exerting the bare minimum cost burden.
- CoAP protocol is compatible with the internet-operative applications that use sensors/devices and have resource limitations.

3.4.4 CoAP Architecture

The two foundational elements of the CoAP protocol architecture are the constraints ecosystem and the WWW. The server monitors help communications going on by using HTTP and CoAP, while proxy devices fill the existing gaps for these two ecosystems for smoother communications [45]. The CoAP protocol involves allowing the HTTP clients in order to exchange information/data with each other within resource constraints. In order to better understand the architecture of CoAP protocol, it is essential to gain acquaintance with some key terms, that include:

- The sender involves in creating and sending the original message;
- Client sending requests and replying to incoming requests;
- The recipient receives the information/data forwarded by the server or sent by the client.

- Endpoints are the nodes, and hosts are known about these;
- The server gets requests as well as forwards requests. The server also gets messages and forwards messages that are received in response to the requests the server has processed.

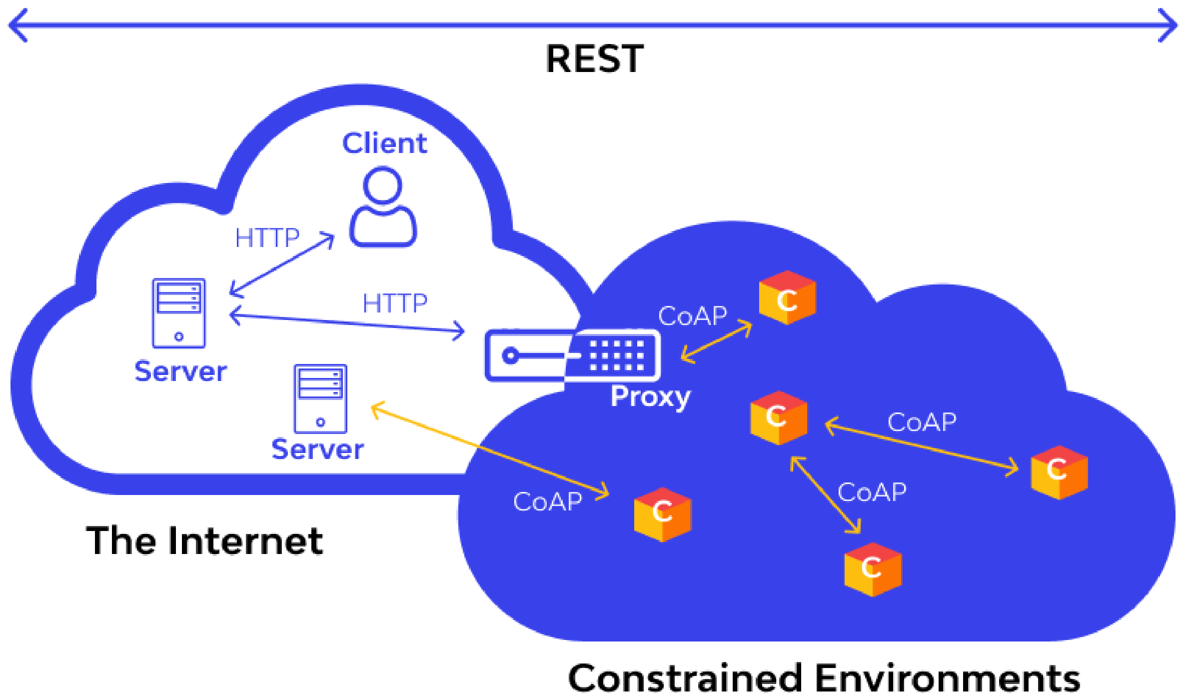


Figure 20 CoAP Protocol Architecture

3.4.5 CoAP Functions

The key function of the CoAP protocol is to act like HTTP protocol whenever there are restricted devices that are part of communication. The CoAP protocol not only fills the gap of HTTP but also enables the devices like sensors and actuators in order to interact over the internet. The devices, including sensors and actuators that are involved in the process, are controlled and administered by considering data/information as a component of the system [46]. In order to operate its functions effectively, the CoAP protocol needs an environment with extreme congestion and reduced bandwidth as it consumes reduced network bandwidth and power.

Networks that feature constrained connectivity and intense congestion are not a suitable condition for the protocols that are TCP-based to carry out their responsibilities. In these conditions, CoAP protocols come rescue and support web transfers. Web transfers that are made to happen using satellites and covering long distances can be achieved successfully to perfection using CoAP. CoAP protocol also helps the network featuring billions of nodes for information exchange. CoAP promises the highest-grade security regardless of the function role played or handled with respect to DSLP parameters as the counterpart of the 128-bit RSA key, the default security parameter. Deploying CoAP is simple and hassle-free. The CoAP protocol can be implemented from scratch for a straightforward application [47]. For an application ecosystem where the CoAP is not desirable, generic implements are meant to be offered for various platforms. CoAP implementations are mostly done privately, and only some of the implementations were published in open-source libraries like the MIT license.

3.4.6 Features of the CoAP protocol

CoAP protocol is similar to HTTP, and developers only face bare minimum difficulties whenever it is used. CoAP protocol can be paired with applications using cross-protocol proxies. CoAP can integrate with CBOR, XML, JSON and various other data formats seamlessly. During the integration process, the web client does not get any intimations about a sensor resource being accessed. Developers have the freedom to make choices in order to bring the ideal payload into action as they are endowed with various payloads [44].

An IoT application that works successfully requires billions of nodes at a time. The CoAP protocol has been designed to handle the huge mode amounts with full perfection at the same time keeping the overheads under control.

3.4.7 CoAP Layer

The CoAP protocol consists of two layers, and it works through these layers. The two layers are the CoAP Messages Model and the CoAP Request/Response Model.

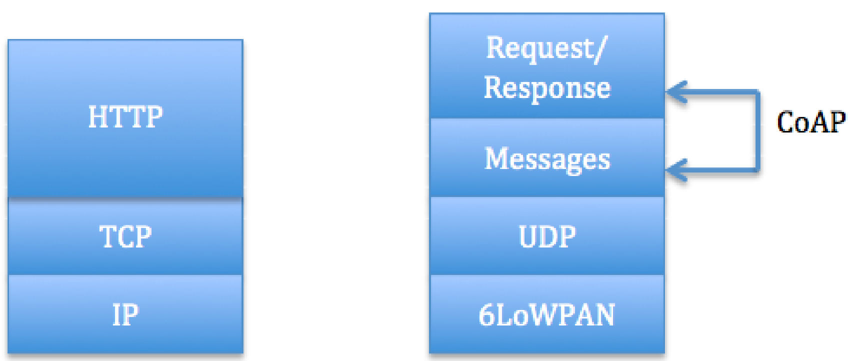


Figure 21 CoAP Layers

CoAP Messages Model

The CoAP Messages Model makes UDP transactions possible at endpoints in the non-conformable (NON) or confirmable (CON) format. Each CoAP message consists of a distinct ID in order to keep the possibility of preventing message duplications. The binary header, payload and computer option are the three key parts involved in building this layer [46]. In CoAP Messages Model, the confirmable texts are easy-to-construct messages and reliable that are resent and fast until the receipt of successful delivery confirmation with messaged ID.

CoAP Request/Response Model

The CoAP request/response model is a layer that involves taking care of NON and CON messages requests. Depending on the server's availability, these requests are accepted. Cases include:

- If idle, the server will involve in handling the requests right away and immediately. If there is a CON, then the client will get an ACK for it. If shared as a Token and it differs from the ID, then it is essential to map ACK appropriately by matching the pairs of request-response.
- If there is an involvement of wait or delay, the ACK must be sent as an empty text. Whenever the turn of ACK arrives, then the request must be processed, and the client must get a fresh CON [43].

The key traits of this model are:

- A CON response could be either forwarded as NON/CON or stored in an ACK message.
- The Request/Response model involves requesting methods for making calls that are declared in the process. The calls include DELETE, POST, PUT and GET.
- The response or request codes for CoAP are the same when compared to that of HTTP, except for one condition if the response or request codes are in binary format (0–8-byte tokens) in the case of CoAP [45].

3.5 AMQP protocol

AMQP stands for Advanced Message Queuing Protocol (AMQP) which is an open-source protocol for asynchronous messaging by wire. AMQP protocol is involved in enabling interoperable and encrypted messaging between applications and organizations. The AMQP protocol is mainly used in IoT device management as well as in client/server messaging. AMQP is secure, portable, efficient and multi-channel [48]. The binary protocol offers encryption and authentication by way of TLS or SASL by relying on a transport protocol like TCP.

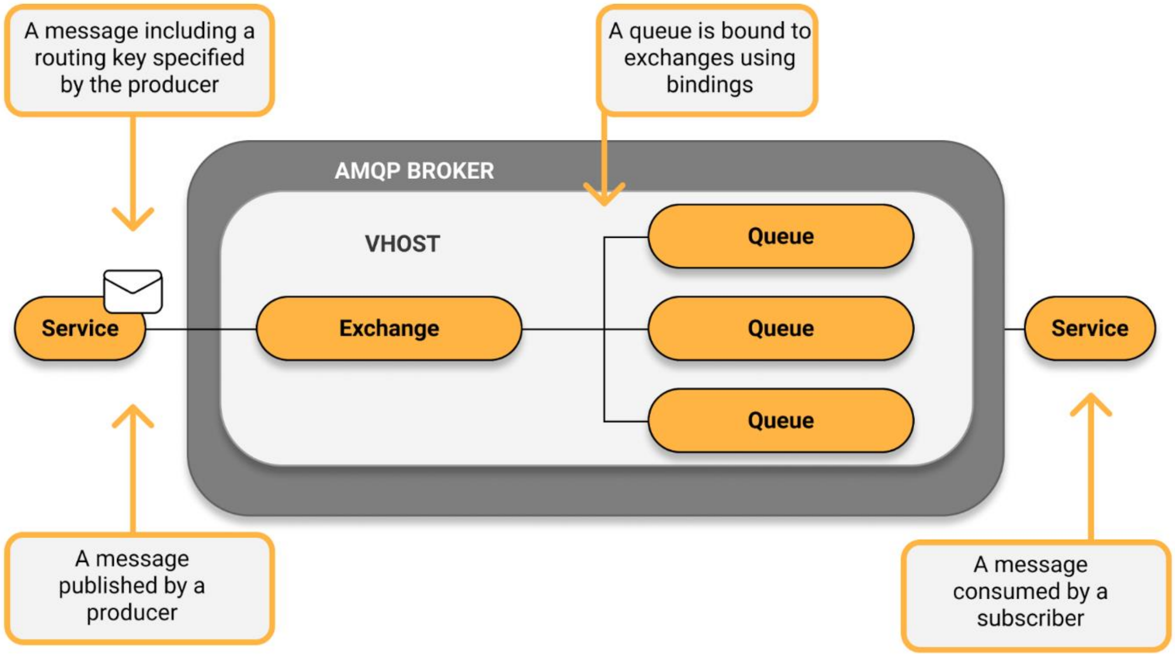


Figure 22 AMQP Protocol

The AMQP messaging protocol is fast, and it involves featuring guaranteed delivery with acknowledgement of received messages. AMQP provides a means for making servers manage immediate requests as well as delegating tasks faster. The AMQP protocol works effectively in multi-channel environments [49]. As it is a streamed binary messaging system that is strongly authorized messaging behaviour, the exchange and making use of information of clients from various vendors are assured.

AMQP protocol allows for different definite messaging modes indicating a message be sent:

Exactly once (assuring a one-time-only delivery)

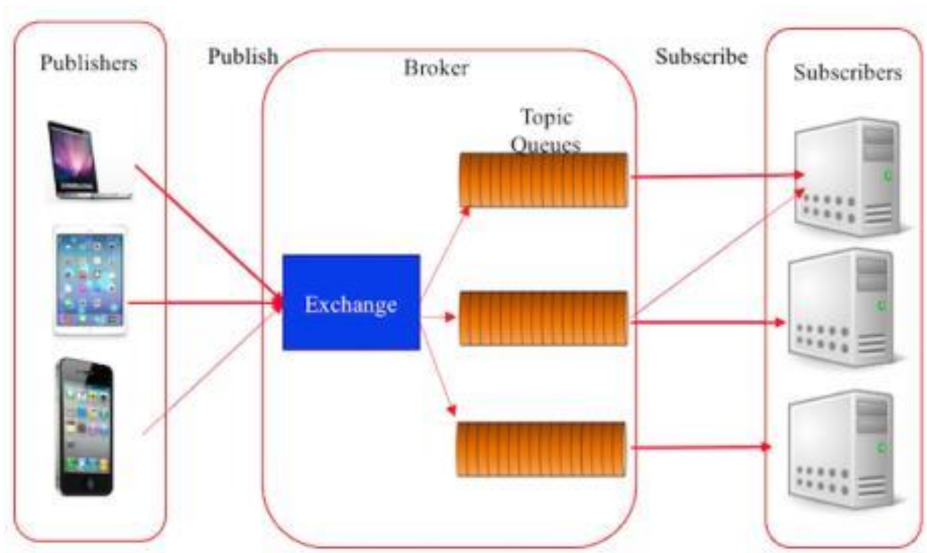
At-most-once (message sent one time with the possibility of being missed)

At least once (guaranteeing delivery with the possibility of duplicated messages)

AMPQ was apprehended by a member of the J.P. Morgan Chase company in the year 2003 and started as a cooperative effort beginning with the iMatrix Corporation. Version 1.0 of the AMPQ protocol was released on October 30, 2011. However, before this release, the working group for AMQP protocol had grown up to 23 organizations, including Credit Suisse, Barclays, Progress Software, HCL Technologies Ltd, Goldman Sachs, Microsoft Corporation, Informatica, INETCO Systems Limited, IIT Software, Deutsche Borse, Cisco Systems, Bank of America, my-Channels, JP Morgan Chase, Solace Systems, Red Hat, Novell, TWIST Process Innovations Ltd, Software AG, VMware, Tervela Inc. and WSO2 [50].

3.5.1 AMQP Architecture

The AMQP is an IoT protocol, and it consists of a fast ad hard of components that save and route messages within a broker carrier, with a set of guidelines and procedures for binding or connecting components together.



AMQP Architecture

Figure 23 AMQP Architecture

This IoT protocol involves enabling patron programs in order to talk to the dealer as well as to engage with the AMQP model. Version 1.0 has three additions when compared to the previous version. These additives might link into processing chains in the server in order to create the favoured capability [51]. The three additives are exchange, message queue and binding.

Binding

Binding states the connection between the exchange and the message queue.

Message queue

Message queue involves storing messages until they may be systematically processed through the eating client software.

Exchange

The 'exchange' addition to AQMP protocol involves receiving messages from publishers primarily based on routes and programs them to message queues.

3.5.2 Key features of AMQP Network Protocol

- The AMQP Network Protocol is a peer-to-peer protocol.
- In AMQP protocol, one peer plays the role of the client application, and the other peer plays the role of trusted message delivery and routing service or broker.
- These peers in the AMQP Network Protocol define how to connect to services that include a method for failing over connections to alternative services.
- The AMQP protocol defines a mechanism for enabling the peers, including client application and broker, to discover one another's capabilities.
- For seamless end-to-end confidentiality, the AMQP protocol uses SSL and Kerberos, which are comprehensive security mechanisms [48].
- The AMQP Network Protocol defines how to multiplex a TCP/IP connection to make multiple connections happen over one TCP/IP connection. Which greatly simplifies firewall management.
- The protocol defines how to address a source of messages with the peer-related network and specifies which messages are of interest.
- The protocol defines the lifecycle of messaging through acknowledgement, processing and fetching. The AMQP protocol keeps it very clear when transferring the message from one peer to another peer to enhance reliability.
- The protocol defines how to enhance performance by pre-fetching messages across the network that are ready for the client to process without delay.
- The protocol defines a way of processing batches of messages within a transaction.
- The protocol defines a mechanism for allowing the complete transfer of a message from login to log out in one network packet for lightweight applications [49].
- The protocol has very capable flow control that involves enabling consumers of messages to slow producers to a manageable speed and that enables different workloads order to proceed in parallel at different rates over one connection.
- The protocol defines the mechanism to resume message transfers when connections are re-established and lost, for example, in the event of intermittent connectivity or service failover.

The AMQP network protocol is a low-level network protocol that is capable and comprehensive, but it is normally invisible to the users of messaging software applications. Users of email who send emails to different users don't know the details of intermediaries that are processing the user's request [50]. This shows that the networking specialists can use the AQMP protocol for other purposes, but the protocol is majorly used for binding messaging clients to the messaging brokers. The broker hosts queues and topics and takes care of routing, delivery and safe storage.

The AMQP protocol is commonly referred to as an open-standard application protocol middle that is majorly involved in enabling server-to-server communication. The protocol is independent of both the language and the platform that every end-server may be using. As the protocol allows flow-controlled communication, it enables delivery options such as exactly-once, at-least-once or at-most-once [51].

Delivery authentication in AQMP protocol is provided by Simple Authentication and Security Layer (SASL). Encryption is provided by Transport Layer Security (TLS), which is the successor to Secure Sockets Layer (SSL).

3.5.3 Applications of AMQP Protocol

AMQP Protocol can be used in various enterprises to address various issues. The enterprises include banking and financial institutions, web services and the stock market.

Banking

Banking companies like JP Morgan Chase are involved in the development of AMQP for addressing various issues faced by banks when there is an increase in customer relationships. Communication with customers is very important in banks and financial institutions to improve relationships, and it requires a messaging system [49].

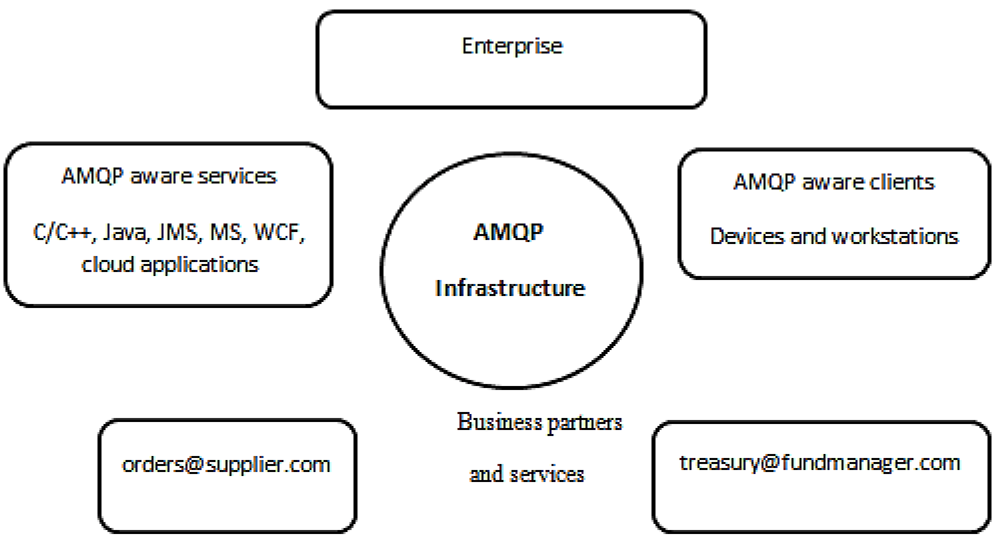


Figure 24 AMQP Application in Banking

It is simple and easy for banks to manage the transmission of messages with a small number of customers, but with the increase of customers, it will become difficult for banks to manage the transmission of messages. Banks and financial institutions use various solutions in addressing this issue, but there is a need for a standard solution to solve this issue, and the result is the AMQP protocol. AMQP protocol provides a standard and secure way of transmission of business-related messages [49].

Web services

Web services have the capacity of receiving a large number of requests. Similarly, accounting software is one of the applications that perform many things, and one of them is receiving and processing the request of that web service. If AMQP protocol is implemented between the accounting software and the web service, there will be the following advantages, including:

- Reduction of coupling due to the requirement of configuration parameters that are known by both applications.
- The very rapid increase in the frequency of requests on the receiving end makes the accounting software handle conditions very easily.

Stock market

The pub-sub is a routing technique in which one source will transmit the message, and multiple listeners accept it. The phenomenon of transmission and acceptance of messages is implemented by stock trading software. With the help of the stock trading software, the users can be updated about the latest stock price [50].

Integration of Languages

AMQP protocol can be used for the integration of languages. As there is much message-oriented middleware that which have SDKs supporting multiple platforms and various languages, AMQP can be used to integrate applications working on different platforms [51].

Telecommunication

AMQP protocol helps not only in the development of a network where telecommunication systems are connected with each other but also ensures secure communication between these telecommunication systems.

Government Schemes

In India, the AMQP protocol is used in the generation of Aadhar cards as well as in the other schemes of the Indian government. The protocol is mainly used for the purpose of scaling.

3.5.4 Issues with AMQP protocol

The main issue with the AMPQ protocol is that the latest version of the protocol is not compatible with the older version. If there are any components that are developed in older versions could become difficult to incorporate into the newer projects [50].

3.6 Device Management TR-069

TR-069 is a technical specification which is designed by the Broadband Forum (BBF) for standardizing the management of devices. TR-069 is the Technical Report-069 of BBF, and all the technical reports of BBL are strictly numbered documents that are dependent on each other [52]. The TR-069 protocol involves specifying server and client requirements for the management of devices across the internet by using a client-server architecture in order to provide communication between the Auto Configuration Server (ACS) and the Customer Premises Equipment (CPE).

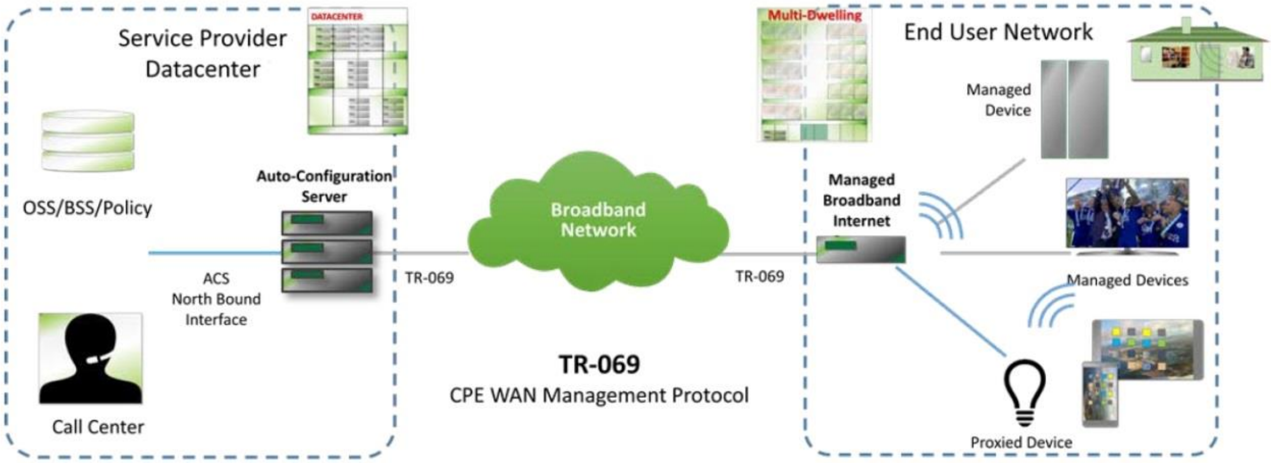


Figure 25 TR-069 DM Protocol

This protocol is mainly helpful in managing complex networks where many devices such as VoIP phones, gateways, routers, modems and mobile tablets compete for resources. The TR-069 protocol defines the CPE WAN Management Protocol (CWMP), which is necessary to manage end-user devices remotely [53]. CPE (Customer Premises Equipment) Wireless IoT Wide Area Network (WAN) in combination with ACS involves providing automatic configuration for the devices.

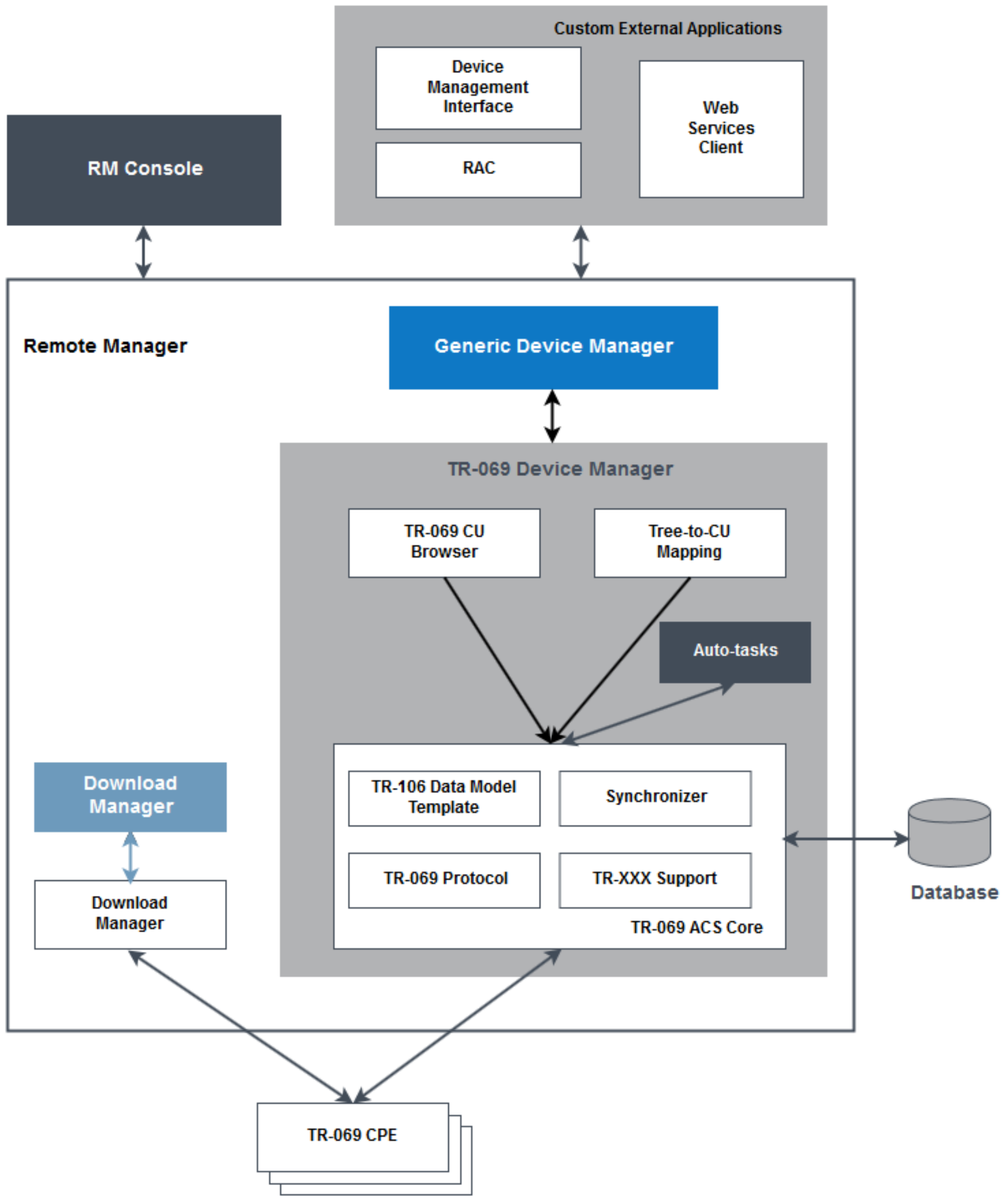


Figure 26 TR-069 DM working model

The TR-069 protocol involves incorporating secure auto-configuration and other customer premises equipment management functions within a common framework. The TR-069 protocol represents the Application Layer Protocol, and it usually involves communicating with an ACS. The main purpose of the TR-069 protocol is intended to communicate between the ACS and a CPE. The protocol defines a mechanism that incorporates secure auto-configuration of a CPE and also encompasses other management functions of CPE into a common framework. The TR-069 document mainly specifies the generic requirements of the management protocol methods that can be applied to any TR-069 CPE [52].

3.6.1 Functional Components

The protocol is intended to support a variety of functionalities to manage a collection of CPE. The primary capabilities include:

- Diagnostics
- Status and Performance Monitoring
- Software/Firmware Image Management
- Auto-configuration and dynamic service provisioning
- Software module management

Diagnostics

The protocol provides support for a CPE in order to make available information that the ACS might utilize for diagnosing and resolving service or connectivity issues, as well as the ability for executing defined diagnostic tests [53].

Status and Performance Monitoring

The protocol provides support for a CPE in order to make information available to make the ACS use it for monitoring the status and performance statistics of CPE. The protocol also defines mechanisms for allowing the CPE to notify the ACS actively about the changes to its state.

Software Module Management

The protocol enables an ACS for managing modular software and execution environments on a CPE. The protocol has the ability to update, install and uninstall software modules as well as notify the ACS about the success and failure of each action. The protocol also involves providing support to start and stop applications on the CPE for enabling and disabling execution environments and inventory the software modules that are available on the device.

Software/Firmware Image Management

The protocol also provides a tool for managing the downloading of CPE firmware/software image files. The protocol offers the mechanisms to identify the version, initiate file download, and the notification by the ACS about the success and failure of a file download.

Auto-Configuration and Dynamic Service Provisioning

The protocol allows an ACS to collect CPE based on a variety of criteria. The provisioning mechanism involves allowing CPE provisioning at the time of initial connection to the broadband access network and the ability to re-configure or re-provision at any subsequent time. This includes the provision for asynchronous ACS-initiated re-provisioning of a CPE [44].

3.6.2 Security Goals

The CPE WAN management (device management TR-069) protocol is designed for providing a high degree of security. The security model is also designed to meant to be scalable.

The protocol is intended to allow basic security for accommodating less robust CPE implementations and also allows greater security for the things that can support more advanced security mechanisms [52]. The security goals of the protocol are:

- Prevention of tampering with the management function of an ACS or CPE or the transactions that take place between an ACS and CPE.
- Prevention of theft of service.
- Providing appropriate authentication for each type of transaction.
- Providing confidentiality for the transactions that occur between an ACS and CPE.

3.7 OMA (Open Mobile Alliance)

The OMA protocol is a device management protocol that is specified by the OMA and Device Management (DM) working group and the Data Synchronization (DS) working group. The currently approved specification of the OMA-DM protocol version is 1.3. The OMA device management protocol is a secure management protocol that runs between a DM Client and a DM Server [54]. This protocol runs within the context of a DM session and uses a request/response transaction model. When OMA-DM protocol architecture is considered, after establishing a device management session, the device management server sends commands to the Client alternatively and receives responses from the client.

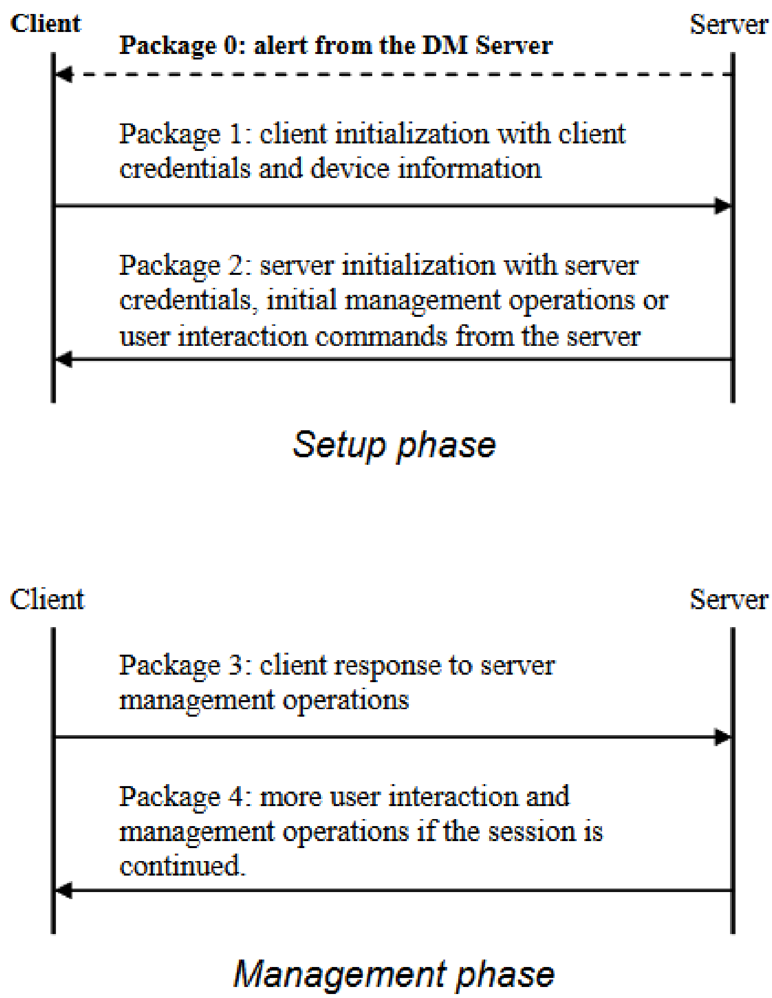


Figure 27 Device Management Session in OMA

The Client is also involved in informing the Server about the events that could have occurred on the device through Generic Alerts. A device management session consists of two phases they are set-up phase and the management phase. The management phase comes after the setup phase. The setup phase involves authentication and device information exchange. In the management phase, the device management service involves issuing commands which are processed by the device management Client [42]. The device management Client is thus involved in providing the statuses of the commands that are issues as well as any responses that might be required.

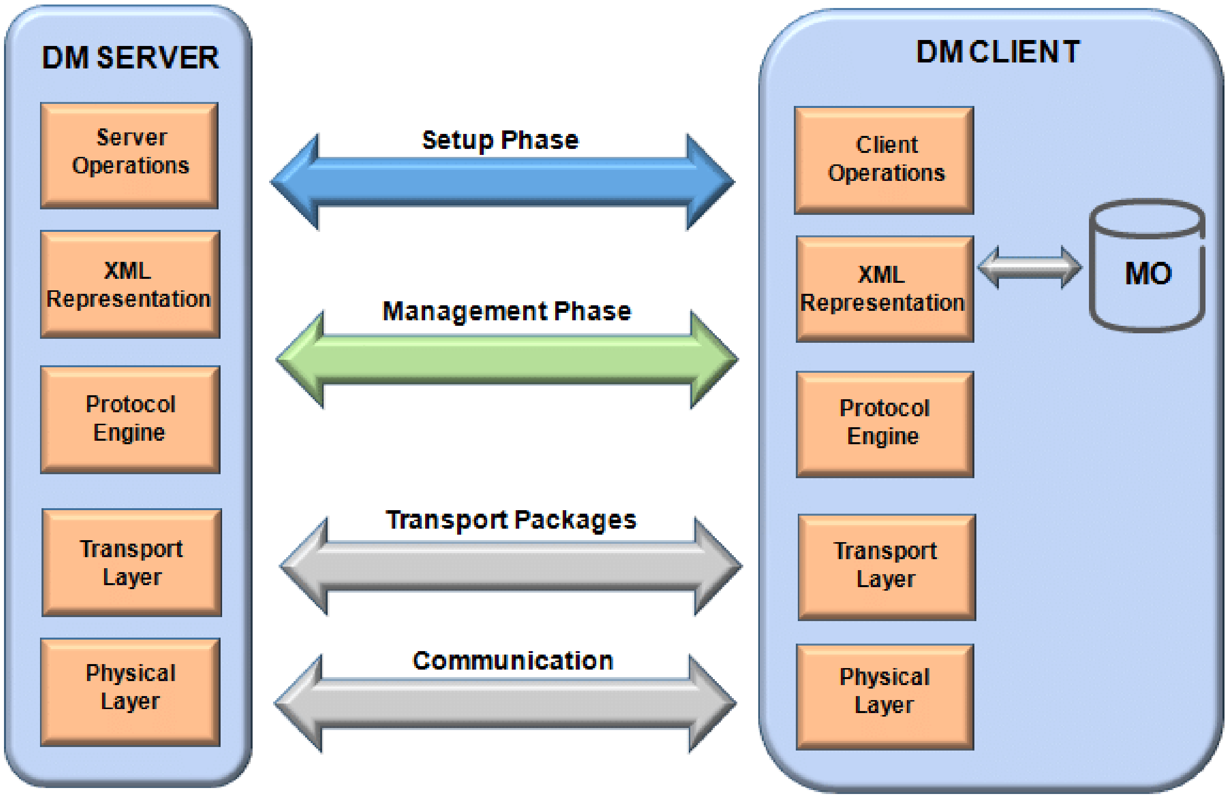


Figure 28 OMA Architecture

The OMA device management protocol supports the notion of packages. A package is a collection of messages that are related to each other and are transferred between a recipient and an originator [54]. Commonly, a Package mostly consists of a single message. Though, in cases where the data that need to be transferred between the sender (originator) and the recipient exceeds the size limitation of a device management message, the information can be sent over multiple messages within the Package that is the same [47]. However, each message in a Package must be responded to individually.

The device management sessions are always originated from the DM Client. However, a Client can be triggered by a Server to initiate a session by sending an unsolicited message, and that is called the device management (DM) notification, to the Client. The device management (DM) notification wakes up the user's device and makes the device initiate a session with the requesting DM Server. This notification which is referred to as a message can be delivered over a variety of transports, including SIP, HTTP and SMS [48]. Generally, a device management session ends when the device management (DM) Server sends a message that is empty to the DM Client. However, both the Server and the Client have the capability to abort the session at any time.

3.7.1 Standard Objects

The OMA device management protocol involves in maintenance and management of complete separation of schema from protocol. Most of the management objects (MOs) that are standardized by OMA protocol lie outside the core device management specification. The protocol has the knowledge of only a handful of MOs, and those are referred to as Standard Objects (SOs)

[54]. These SOs has the capability of controlling the core protocol itself, rather than some domain-specific device management (DM) functionality like device diagnostics or firmware update.

The SOs for OMA-DM is:

- Device Details: This SO contains device-specific parameters. Unlike the device information parameters, the device-specific parameters are sent to the device management (DM) server only when there is a demand. The support for SOs is mandatory for all the Clients of the OMA-DM protocol.
- Device Account: This SO is specially used for managing the bootstrap settings for a device management Server. Among the other things, this SO contains the Server and Client security credentials for the DM Server that is in question.
- Device information: This SO contains the information that is related to the device. This information is sent to the device management Server at the start of each device management session.

3.7.2 Security Considerations

The OMA device management protocol is a secure protocol. Only after the establishment of the trustful relationship the communication between the DM Client and DM Server is allowed through the DM Bootstrap Process. The OMA Device Management Protocol supports multiple authentication schemes [54]. In the case where a DM Client supports multiple authentication schemes, the DM Server can indicate the preferred authentication scheme. Both the DM Client and the DM Server could challenge each other if no credentials were given in the authenticated request or the credentials are considered to be very much weak. The OMA device management is also involved in supporting an access control mechanism for ensuring that only authorized DM Servers are authorized to invoke commands on the Management Tree.

SECTION II

Chapter 4 Machine Learning

Machine learning, artificial intelligence (AI) and cognitive computing are the hottest topics that are being in the dominating conversations about how these emerging advanced data analytics can offer organizations a competitive advantage the business [55]. However, there is no space for debate about how the current business leaders are facing new and unexpected competitors. These businesses are now looking for strategies that can make them stronger and prepare them to face what is coming in the future.

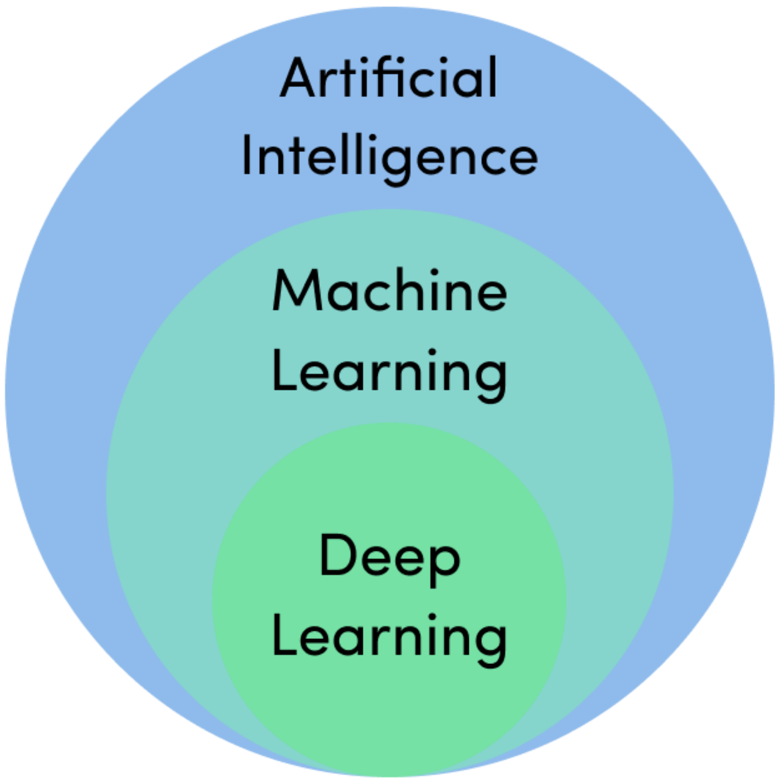


Figure 29 Artificial Intelligence, Machine Learning and Deep Learning

While a business has the freedom to formulate and implement various strategies, for making decisions regarding these strategies, the business needs essential and authentic data that they can depend on. This chapter delves into machine learning, its importance and how to value it could be for the organization's business strategy [56].

4.1 What is Machine Learning

Machine learning is one of the hot topics in the development organizations which are continuously looking for innovative approaches for leveraging data assets in order to help the organizations in gaining a new level of understanding about the customer, the business environment and others to make better and informed decisions about the organization' future. With the use of appropriate machine learning models, businesses across the globe will have the power to continually forecast changes in the business environment so that they become the best ones in predicting what's going to happen next [57].

With the continuous addition of data, the machine learning models will involve in ensuring that the solution is constantly updated. The value machine learning offers to businesses is straightforward. If the business uses the most appropriate and constantly changing data sources in the context of machine learning, then the organization gets the ability to predict the future [58].

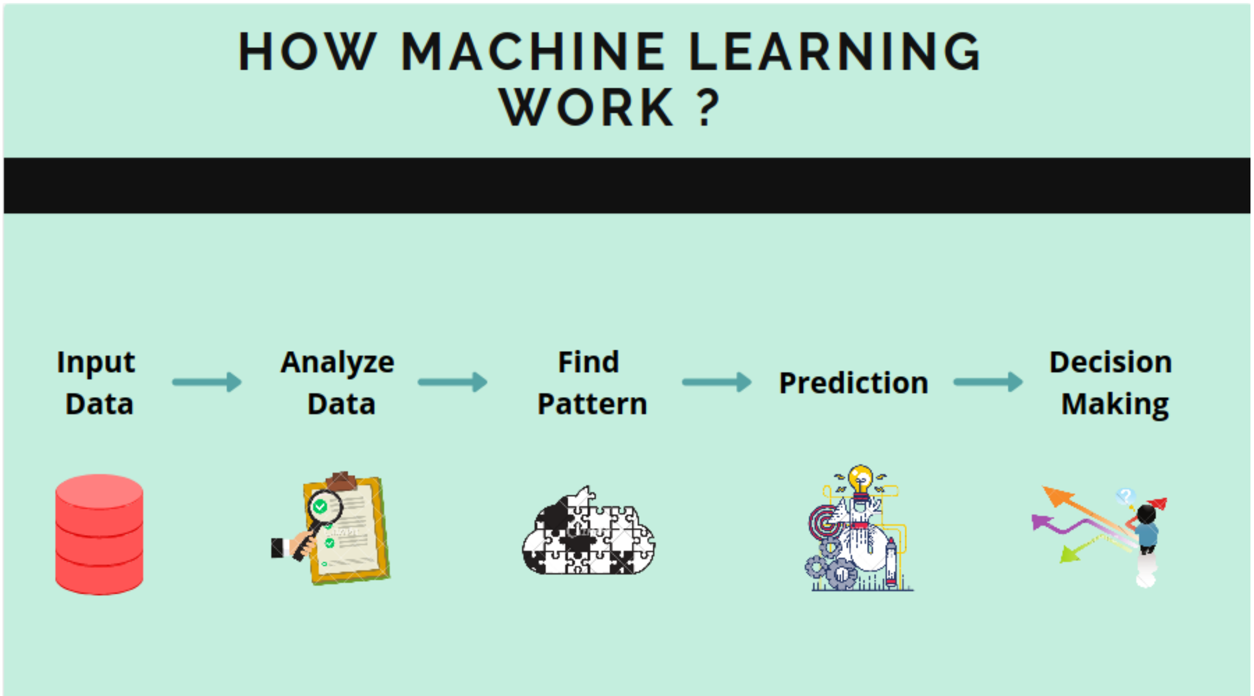


Figure 30 How Machine Learning Works?

Machine learning is a form of Artificial Intelligence (AI) that powers a system to gain senses and learn from data rather than via explicit programming. However, machine learning should not be considered a simple process. It uses various algorithms that involve iteratively learning from data for improvement, describing data and predicting outcomes. As the algorithms swallow training data, then it makes it more possible for producing more precise models based on that data [59].

When the machine learning algorithm is trained with the data, then it generates a machine learning model as an output. After training, whenever input is given to the model, then it gives an output. For example, a predictive algorithm helps in the creation of a predictive model. Whenever data is provided to the predictive model, then the user receives a prediction based on the data that trained the predictive model. Today, machine learning has become one of the essential things for creating analytics models.

It is a subfield of computer science and evolved from the study of computational learning theory and pattern recognition in artificial intelligence. Machine learning involves exploring the building and study of algorithms that can learn from as well as make predictions on data. These algorithms operate by building a model with the given input in order to make data-driven predictions or decisions rather than following the static program instructions.

Machine learning has a close relationship with computational statistics, a discipline that is essentially used for prediction-making. Machine learning also has a strong association with mathematical optimization, that which delivers theory, methods and application domains to the field. Machine learning is commonly used in a range of computing tasks for designing and programming explicit algorithms is feasible. Example applications that are used and developed using machine learning are spam filtering, search engines, optical character recognition and computer vision [57].

Machine learning is sometimes blended with data mining, even though it focuses more on exploratory data analysis. Both pattern recognition and machine learning can be considered as two facets of the same field, and when these are employed in industrial contexts, the methods with respect to machine learning can be referred to as predictive modelling or predictive analytics.

It is most likely common for everyone to interact with machine learning applications without realizing they are machine learning applications. For example, whenever a user visits an e-commerce website and starts viewing products and going through the reviews, then the user gets recommendations about other and similar products that the user might get interested in. The recommendations provided to the user are not hardcoded by any developer. The recommendations are served to the user through the machine learning model [57]. The machine learning model consumes the user's browsing history along with the other shopper's browsing and purchasing data to present the user with similar products that the user might want to purchase.

4.2 Iterative learning from data

Machine learning involves enabling models for training on data sets before being deployed. Whenever new data is ingested, some online machine learning models continuously adapt to the new data accordingly. On the other side, the offline machine learning models that are derived from machine learning algorithms, once deployed, do not change. The iterative process of online machine learning models leads to an improvement in the types of relations that are made between the data elements [59]. Due to the size and complexity, these associations and patterns could have easily been ignored by human observation. After training a model, the model can be put into a position in real-time to learn from data.

In addition, algorithms that are complex can be managed automatically to rapid changes in variables, such as customer sentiment metrics, sensor data, weather data and time. For example, inferences can be made from a machine learning model. If there is a quick change in the weather, then the weather predicting model has the capability to predict a tornado, and then a quick siren as a warning can be triggered. The improvements such as accuracy in predicting things can be achieved through the training process and automation that is part of machine learning [60]. Online machine learning algorithms continuously refine the models by continuously dealing with the new data in training the system and in near real-time to adapt to changing associations and patterns in the data.

4.3 Machine Learning Approaches

Machine learning techniques are essential for improving the accuracy of predictive models. Depending on the state in which the business problem is being addressed, there are Depending on the nature of the business problem being addressed, there are different approaches based on the volume and the type of the data [59]. The different approaches to machine learning are supervised learning, unsupervised learning, reinforcement learning, neural networks and deep learning.

4.3.1 Supervised Learning

Supervised learning is an effective machine learning approach that typically begins with an established set of data and an understanding of how the data has been classified. The main purpose of supervised learning is to find patterns in data that can be used to apply to an analytics process. The labelled features in the data define the meaning of data. For example, there are countless images of animals with explanations of what each animal is, and then a machine learning application can be created to distinguish from one animal to another [61].

When the types of animals are labelled, then there will be an opportunity to have hundreds of categories of different species. This is because of the attributes and the meaning of the data that has been identified, then the users can well understand the trained modelled data so that it fits the details of the labels [58]. When the label is continuous, then it is a regression. If the data comes from a definite set of values, then it is called classification.

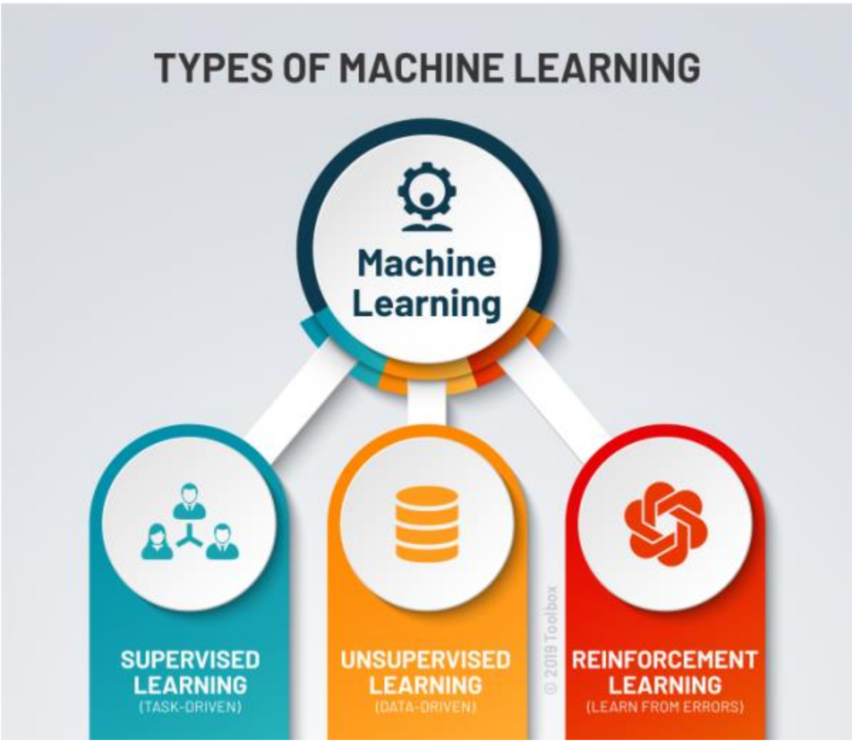


Figure 31 Types of Machine Learning

At the core, regression is mostly used for supervised learning that which helps the user understand the relation between variables. Weather forecasting is a fantastic example of supervised learning. Weather forecasting uses regression analysis to provide a prediction of the weather by taking current conditions and historical weather conditions into account [62]. The machine learning algorithms in the case of weather forecasting are trained using preprocessed examples, and at this point, the algorithm's performance is assessed with test data. Rarely patterns that are determined in a subset of the data cannot be noticed in the large volume of data.

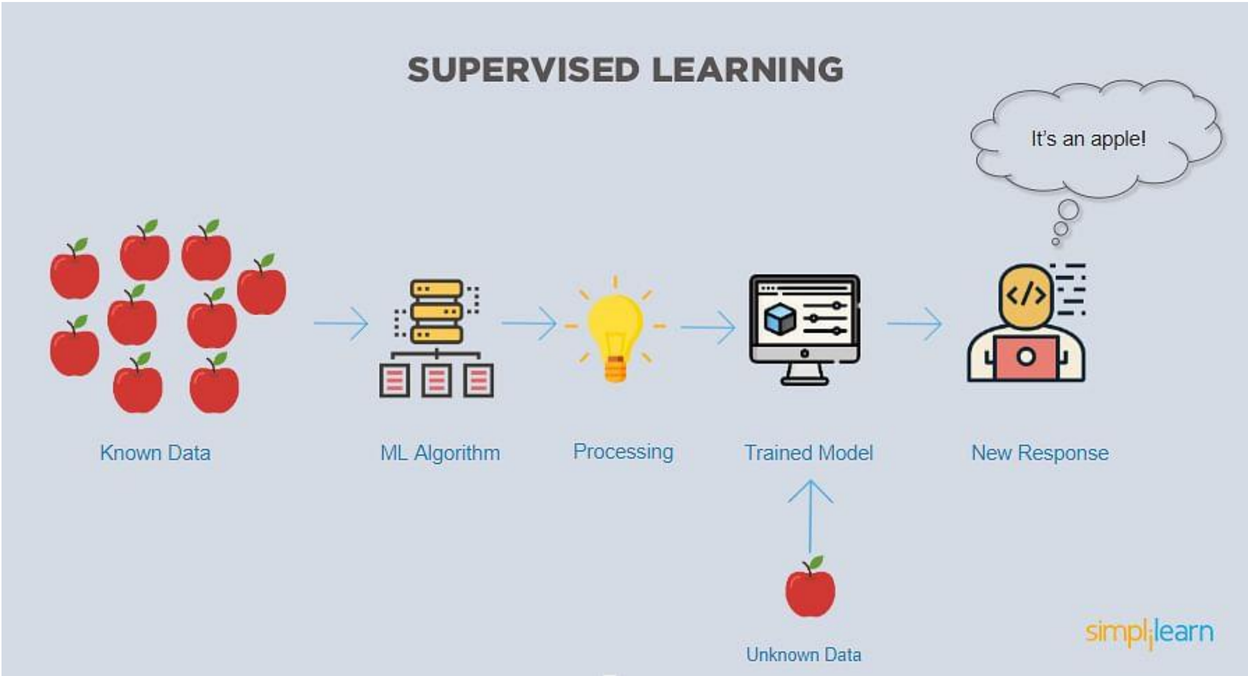


Figure 32 Supervised Learning

If the machine learning model is fit to only embody the patterns that exist in the training subset, then the user creates a problem called overfitting. Overfitting is nothing, but the machine learning model has been precisely tuned for the training data, but it might not be applicable for large volumes of unknown data. In order to get protected against overfitting, the testing needs to be done against unknown or unforeseen labelled data [60]. Using unforeseen or unknown data for testing helps assess the accuracy of the machine learning model in predicting results and outcomes. Supervised training models are set to have broad applicability to a variety of problems associated with the business, including speech recognition, fraud detection, risk analysis or recommendation solutions.

4.3.2 Unsupervised Learning

An unsupervised machine learning model is the right learning model when a problem requires large amounts of unlabeled data. For instance, social media applications, such as Snapchat, Instagram and Twitter, and so on which, have massive amounts of unlabeled data. In order to understand the meaning behind this data, it requires an algorithm or algorithms that can instigate to understand the meaning based on being able to organize the data based on the clusters or patterns it finds [62]. Consequently, supervised machine learning conducts an iterative process that involves analyzing data without the intervention of any human being.

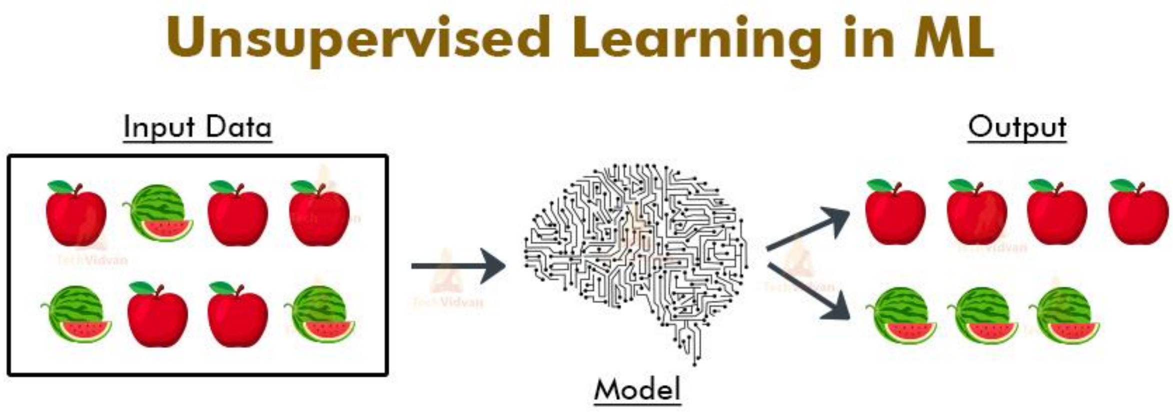


Figure 33 Unsupervised Learning

Unsupervised machine learning is commonly used with email spam-detecting technology. Spam and legitimate emails mostly consist of far too many variables that are difficult for an analyst to flag unwanted bulk emails. Instead, machine learning classifiers that are based on association and clustering are applied for identifying unwanted emails. Unsupervised learning algorithms involve segmenting data into groups of features of groups of clusters [61]. The unlabeled data involves classifying the data and creating the parameter values. Importantly, this process involves adding labels to the data so that it becomes supervised.

Unsupervised machine learning can identify the outcome or result when there is a large amount of data. In this case, the application developer is unaware of the context of the data that is being analyzed, so labelling is impossible at this stage. Hence, this type of learning can be used as the first step before transmitting the data to a supervised learning process. Unsupervised learning algorithms serve the purpose of understanding massive amounts of new and unlabeled data. Therefore, businesses can clearly benefit from this kind of algorithm.

Similarly to supervised learning, unsupervised algorithms involve looking for patterns in data; but the major difference between these algorithms is that the data is not yet understood.

Let's consider the example of the healthcare industry. The healthcare institutions involved in collecting massive amounts of data with respect to a specific disease can help practitioners in gaining insights into the patterns of symptoms that are related to the outcomes of patients. However, it takes too much time to label all the data in relation to the disease [63]. Therefore, in this case, the unsupervised learning approach is suitable for determining the outcomes from the data very quickly rather than through a supervised learning approach.

4.3.3 Reinforcement Learning

The reinforcement machine learning model is a behavioural learning model. The reinforcement learning algorithm involves receiving feedback or response from the data analysis so that the user is directed to the best outcome.

Reinforcement learning is different from other types of supervised learning because the system here is not trained with the sample data set. In the case of reinforcement learning, the system learns through trial and error. Consequently, successful decisions that come in a sequence result in the process being "reinforced" because it involves solving the problem at its best at hand.

Reinforcement learning is most commonly applied in game-playing and robotics. Let's consider an example where a robot needs to be trained to navigate a set of stairs. The robot thus changes its approach to navigating the terrain based on the outcomes of its actions [58]. When the robot falls, the data is calibrated again so that the steps are navigated differently until the robot is trained by trial and error to make it understand how to climb stairs. In other words, the robot here learns how to climb the stairs based on a successful sequence of actions. The reinforcement learning algorithm should be in a position to learn the association between the sequence of events that lead to the outcome and the goal of climbing stairs successfully without falling.

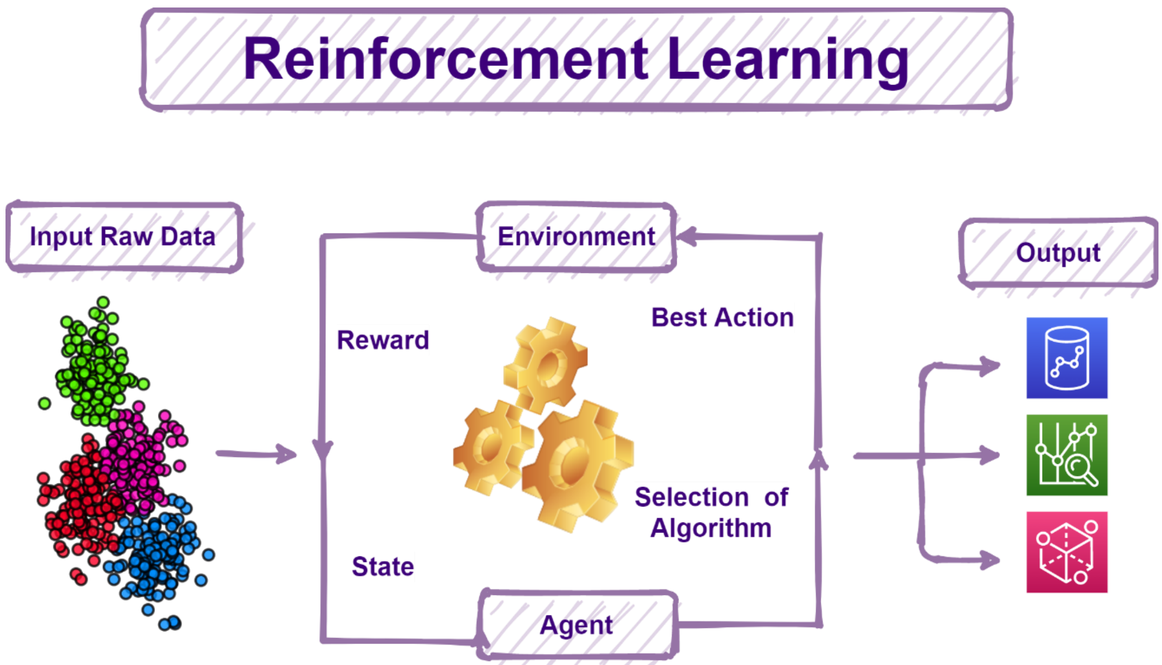


Figure 34 Reinforcement Learning

A reinforcement learning algorithm is also used for self-driving cars. Training a self-driving car is an incredibly complex job in many ways due to so many potential obstacles. If all the cars are self-driving cars, then the trial and error will be easier to overcome [62]. Human drivers are highly unpredictable in the real world, and this makes it more complex to train self-driving cars. In this complex scenario, the algorithm can be enhanced over time in order to identify the ways to adapt to the state where actions are considered to be rewarded.

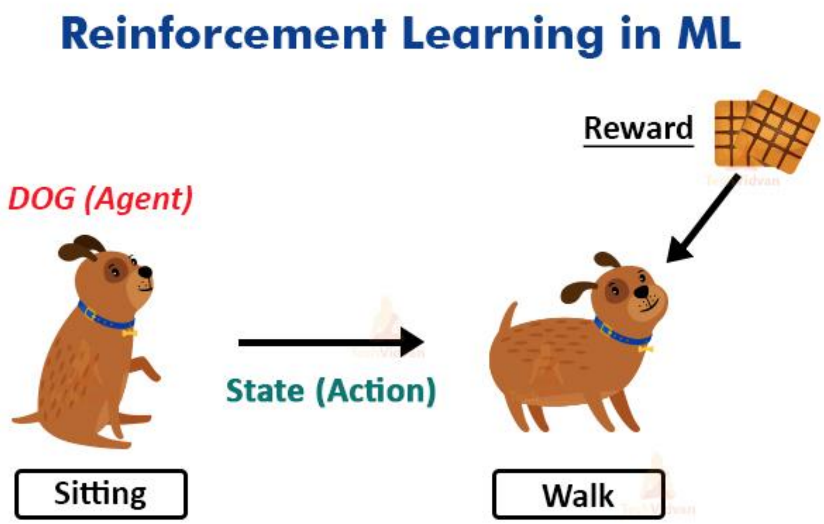


Figure 35 Reinforcement Learning (Example: Dog)

One of the simple and easy ways to think about this learning is the way a living being, like an animal to trained to take specific action based on reward. It is common for dogs involved in taking commands whenever the owner offers a treat for the dog [63].

4.4 Neural Networks and Deep Learning

Deep learning is a specific machine learning method that involves incorporating neural networks in successive layers to learn from data in an iterative manner. Deep learning is considered to be more useful when the user is trying to learn patterns from unstructured data [64]. Deep learning and neural networks are designed to match how the human brain works so that the computers can be trained to deal with problems ad abstractions that are poorly defined.

A school-going child can recognize the difference between the face of a crossing guard and her teacher's face. In contrast, the computer has to go through a lot in order to find out who is who. Deep learning and Neural networks are often used in computer vision, speech recognition and voice recognition applications.

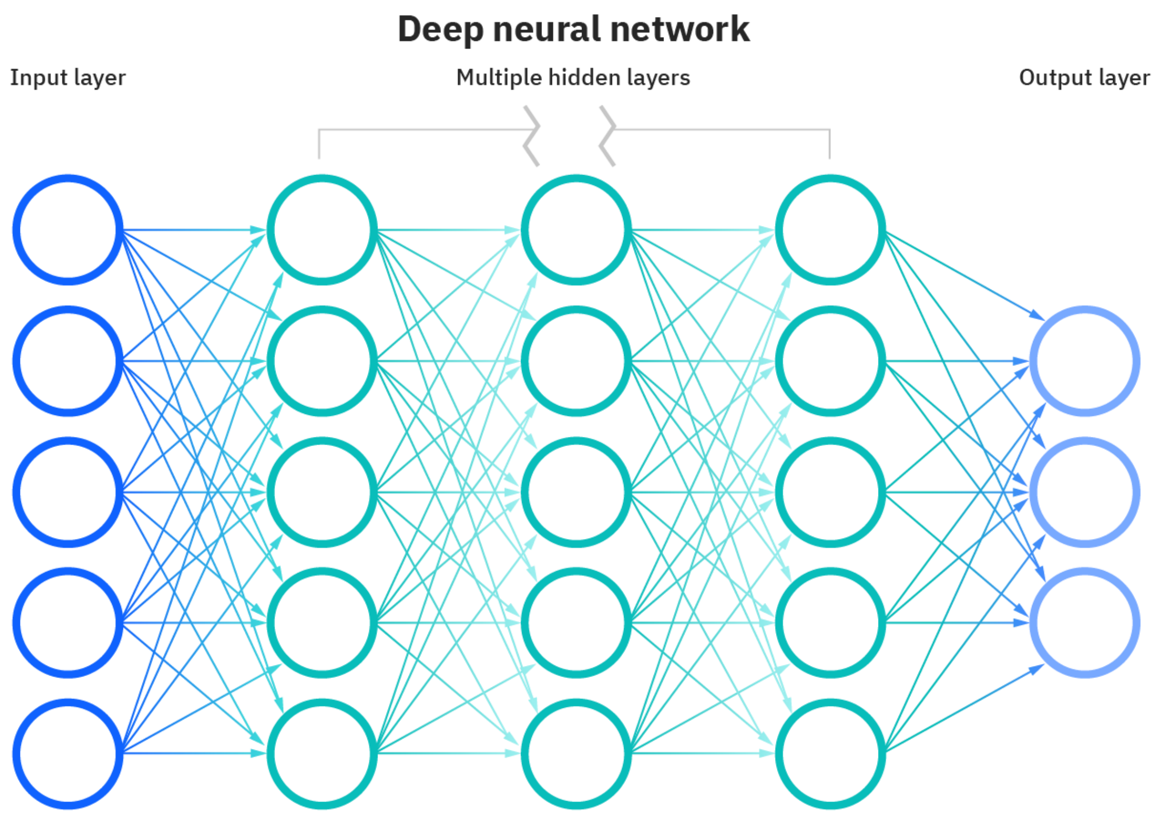


Figure 36 Deep Neural Network

A neural network might have three or more layers, including an input layer, an output layer and one or more hidden layers. In a neural network, the data is ingested through the input layer. Later, the data goes through the modifications in the hidden layer and the output layers based on the weights that are applied to these nodes. A typical neural network may contain densely interconnected simple processing nodes in thousands or millions. Deep learning is the term that is used only when there are multiple hidden layers within a neural network [65]. Using an iterative approach, a neutral network continuously involves adjusting and making inferences until an endpoint is reached. Neural networks are more often used for computer vision and image recognition applications.

Deep learning uses hierarchical neural networks to learn from a combination of supervised and unsupervised algorithms. Deep learning is also referred to as a sub-discipline of machine learning. Deep learning comes into action when there are more hidden layers in the neural networks. Deep learning learns from unstructured and unlabeled data. Though deep learning is mostly similar to that of the traditional neural network, it will have more hidden layers than the neutral network. If the problem is more complex, then there will be more hidden layers in the model.

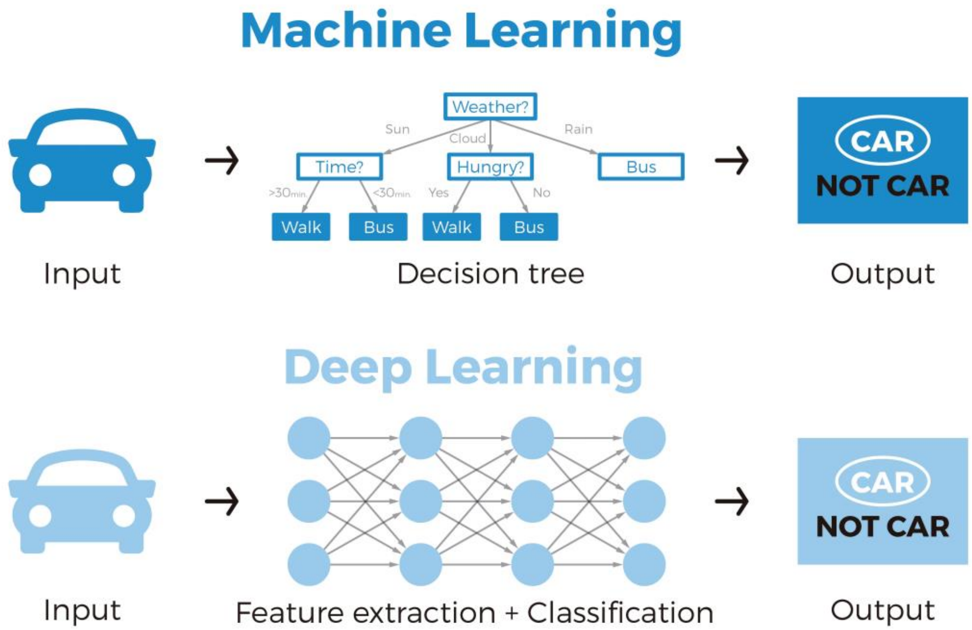


Figure 37 Machine Learning Vs Deep Learning

Deep learning will have an impact on businesses in many areas. For example, voice recognition is applied in everything from customer management to automobiles. Deep learning can be used to predict the malfunction of a machine in IoT manufacturing applications [66]. Law enforcement can also make use of deep learning algorithms to keep track of the movements of a known suspect.

Chapter 5 Artificial Intelligence (AI)

Artificial Intelligence is already playing an essential role in our lives. The emergence of smartphones and the availability of the internet brought AI into the daily lives of human beings. For example, we use smartphones, and today the common feature in all smartphones is an assistant that guides us through the locations, responds to our questions and provides support reasonably [67]. These assistants include SIRI from iPhone, Bixby from Samsung, Alexa from Amazon, Google Assistant from Google and Cortona from Microsoft. These assistants are the AI applications that are designed by top technological companies to assist and support people in their daily lives. For example, an AI assistant takes commands from a human being to carry out various tasks, including reading news showing results on the internet for queries and others.

Figure 38 Artificial Intelligence

Businesses and governments are increasingly applying AI tools and techniques in order to solve various problems related to the business, improve business processes and for improved decision-making. Bringing AI into the lives of human beings brings new realities to social life. These new realities not only change things in our lives but also lead human beings to spend time on social media platforms and various media environments for social and professional reasons. Most of the technologies that humans are currently interacting with are designed and driven by new technologies and specifically by Artificial Intelligence (AI) [55].

AI is the intelligence that is exhibited by software or machines. AI is also the name of the academic field of study, which involves studying how to create computer software and computer machines capable of intelligent behaviour. AI is generally defined as the study and design of intelligent agents, in which the intelligent agent is a system that involves perceiving the environment and taking actions to maximize its chances of success. Artificial Intelligence (AI) is first coined by John McCarthy, and he defines AI as the science and engineering of making intelligent machines [68].

5.1 Artificial Intelligence Research

AI research is highly specialized and technical, and it is divided into subfields that often fail to communicate with each other. Various factors, including economic, social and cultural are the reasons for these divisions. The subfields of AI have grown up around particular institutions and the work of individual researchers. Several technical issues are also the reasons for division in AI research. As some of the AI subfields involve focusing on the solution for specific problems, the other subfields focus on several possible approaches or towards the successful accomplishment of a particular application or use of a particular tool [69].

However, the central problem of AI research in all fields includes learning, planning, knowledge, reasoning, perception and the ability to move, natural language processing, i.e., communication and the ability to manipulate and move objects. Currently, the popular approaches for intelligence include traditional symbolic AI, computational intelligence and statistical methods. AI uses a large number of tools, including the versions of search and mathematical optimization, methods based on economics and probability, logic and many others.

The AI field is considered to an interdisciplinary, in which a number of professions and sciences are covered, including linguistics, psychology, mathematics, computer science, neuroscience and philosophy, as well as other specialized fields such as artificial psychology. The AI field was founded on the claim that a central property of human intelligence, i.e., the sapience of Homo Sapiens. Homo Sapiens is a machine that can be made to simulate intelligence [70]. This has brought philosophical issues about the nature of ethics, and the mind of creating artificial brings ability with human-like intelligence, issues that have been addressed by philosophy, fiction and myth since antiquity. Artificial intelligence is also considered the subject of tremendous optimism, but it is suffering from stunning setbacks.

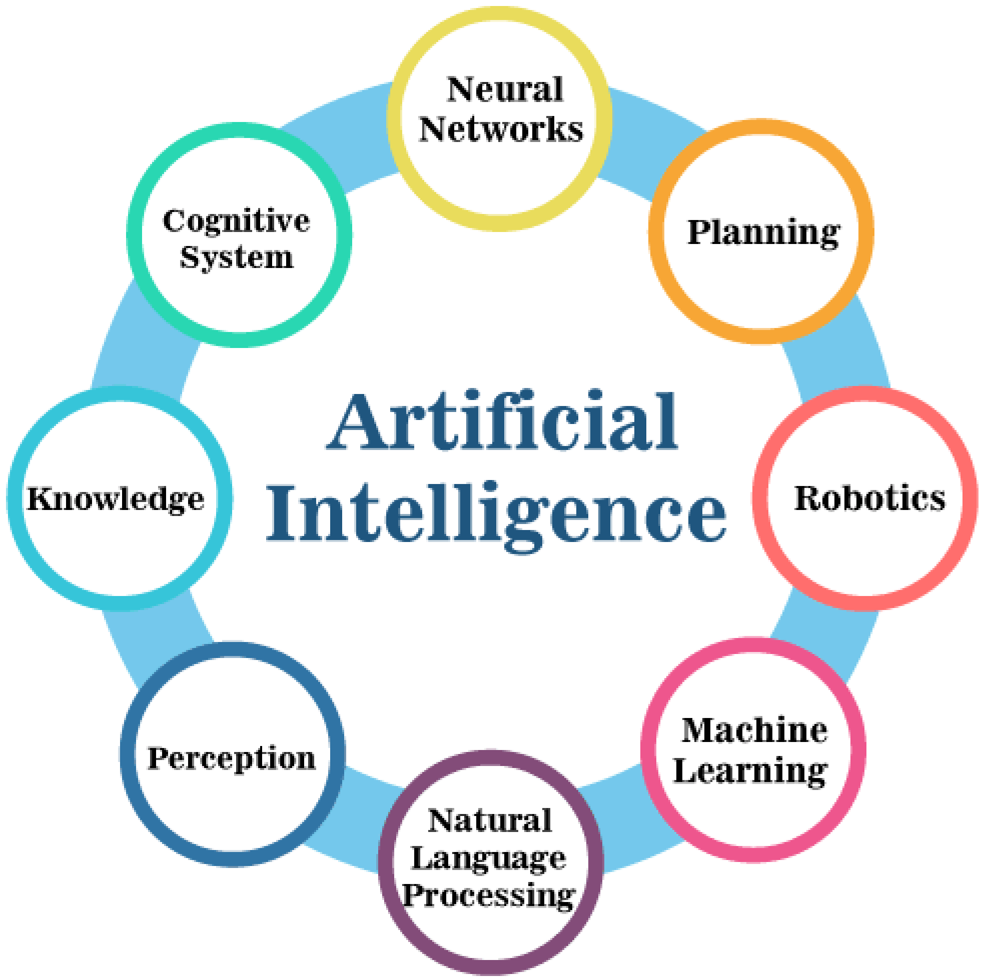


Figure 39 Goals of AI

Today, AI has become a significant part of the technology industry ad continuously provides heavy lifting for many of the most difficult and challenging problems associated with computer science [71].

5.2 Key Research Areas

The key research areas in AI are problem-solving, planning and search, knowledge representation, automated reasoning, machine learning, natural language processing, computer vision and robotics. Initially, the researchers of AI developed algorithms that imitated reasoning step-by-step similar to that of humans who use that method in solving puzzles and making logical deductions. But in the late 1980s and 1990s, AI researchers have developed highly successful methods to deal with incomplete or uncertain information, employing concepts from economics and probability [72].

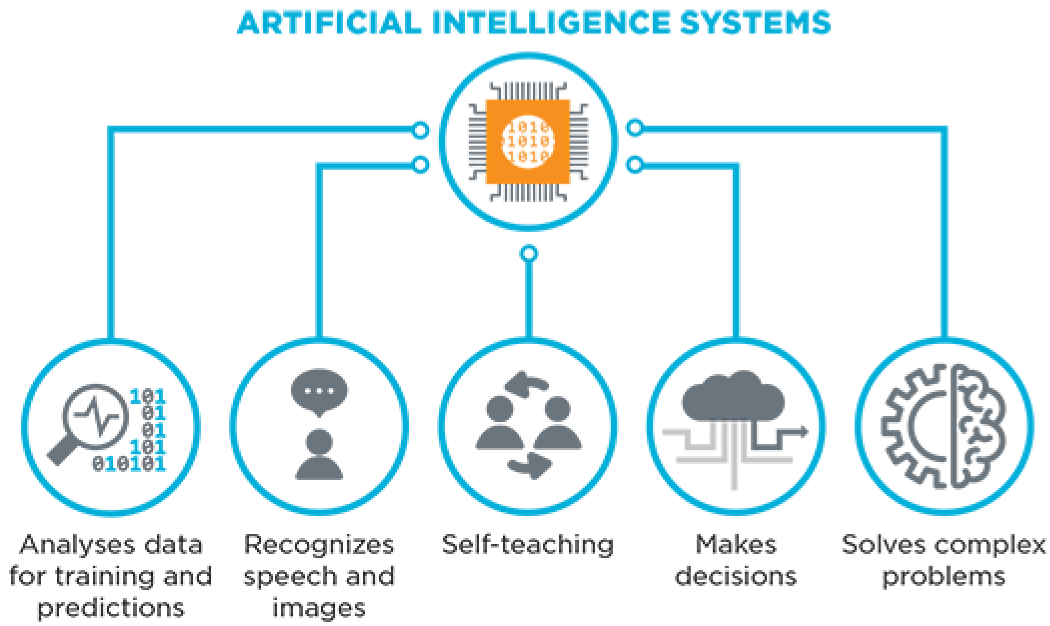


Figure 40 AI Systems

For most challenging and difficult problems, these algorithms require huge computational resources as well as power. The amount of computer time or memory required has become planetary when the size of the problem goes beyond a certain size. The high priority for AI research is to search for more efficient problem-solving algorithms. Human beings are typically involved in solving their own problems using intuitive and fast judgements rather than the step-by-step, conscious deduction that early AI researchers tried to model [73]. The AI has made some progress in imitating the problem-solving approach as humans use; personified agent approaches highlighted the significance of sensorimotor skills for higher reasoning; neural net research attempts involved in simulating the structures inside the brain to give rise to the skill; statistical approaches to artificial intelligence imitate the probabilistic nature of the human ability to guess.

Artificial Intelligence is more concerned with simulating any intelligent behaviour or action that can be observed in the worlds of living beings, including plants, animals or humans. By imitating, AI has started to display promising solutions for any business or industry as well as in our daily lives. Later, AI is mostly concerned with the intelligent activity that machines can display. These activities could range from a machine or robot's behaviour in grabbing an object to the positions where chatbots are involved in communications with the customers in their language in order to make their decisions with respect to purchasing [74]. However currently, AI focuses on various tasks in narrow domains, but the idea of simulating the intelligence of a human still needs to happen.

5.3 Artificial Intelligence Systems

Artificial Intelligence Systems are broadly divided into three categories they are Artificial Narrow Intelligence, Artificial General Intelligence and Artificial Super Intelligence.

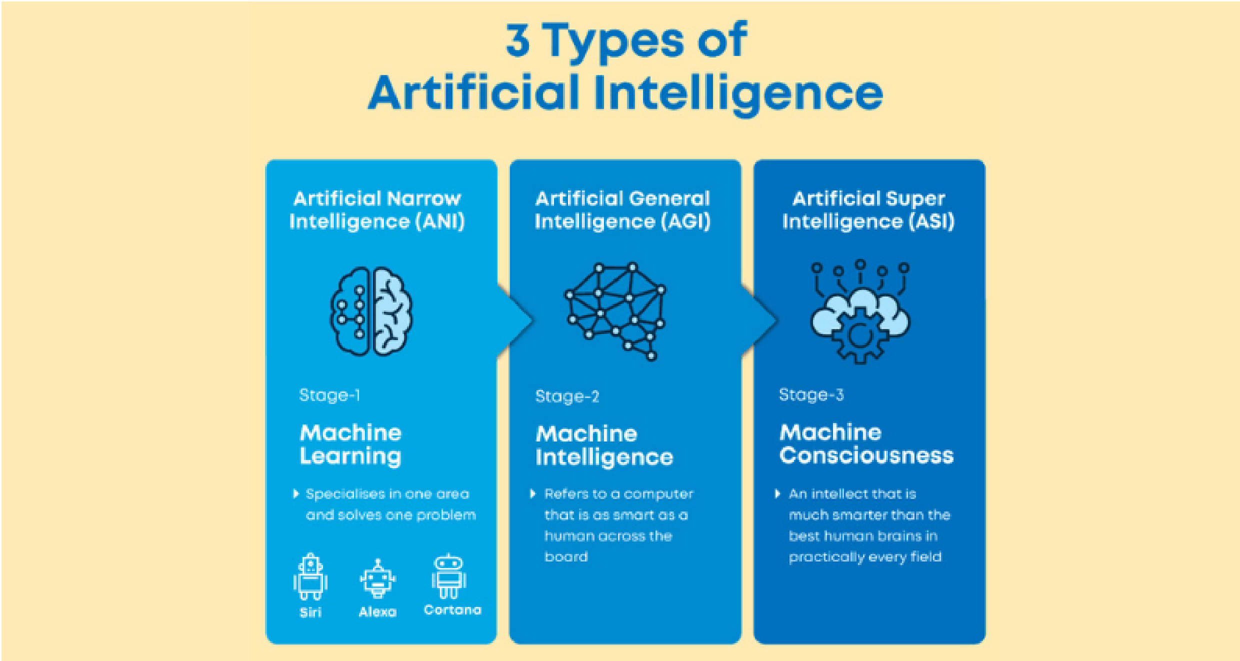


Figure 41 Types of AI

5.3.1 Artificial Narrow Intelligence

Artificial Narrow Intelligence refers to Domain-Specific AI or Weak AI. The Artificial Narrow Intelligence systems are the systems that we almost use at this moment. These AI systems are mostly characterized by specific domains and are built on boundaries or rules that govern the domain. For example, it is not difficult for businesses now to develop an AI that is excellent in chess or any other game, as every game has certain rules on how to play the game. These AI systems have the ability to master quickly such specific domains and offer intelligent solutions for that domain [75]. Therefore, it is called Narrow Intelligence or Weak Artificial Intelligence, which is too far from general human-level intelligence and only works with a specific domain.

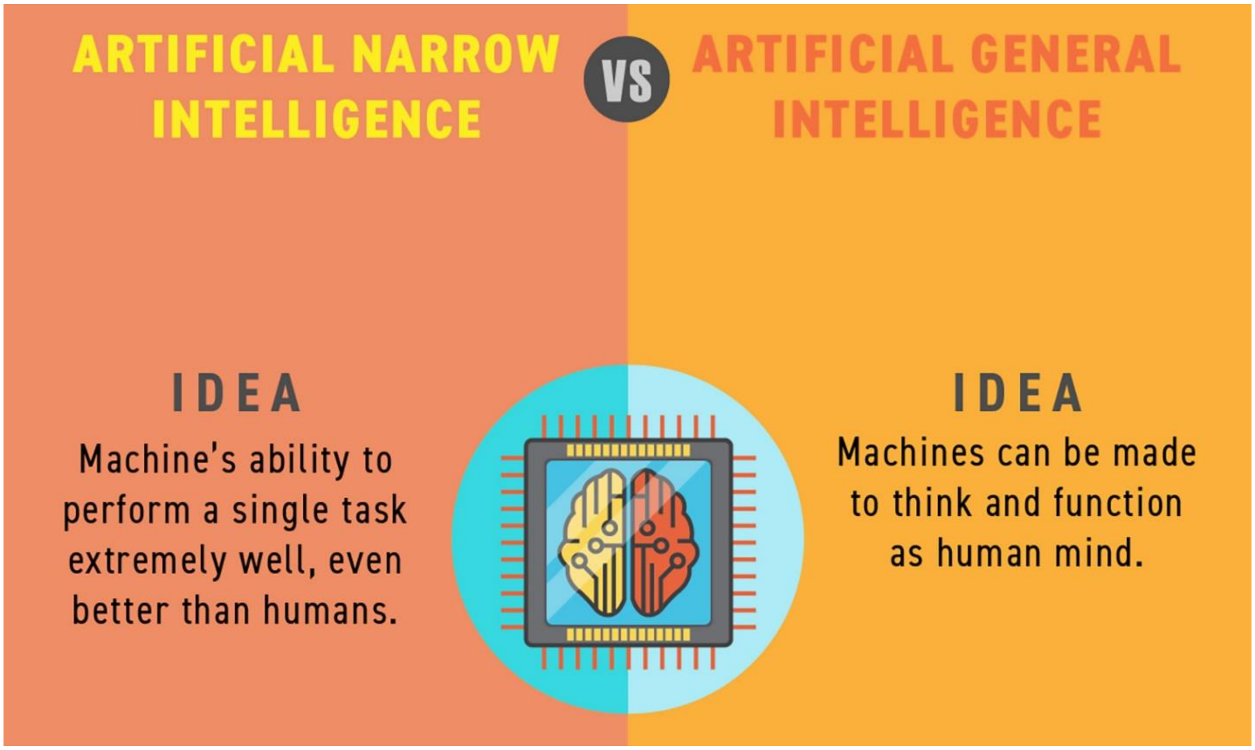


Figure 42 Artificial Narrow Intelligence VS Artificial General Intelligence

5.3.2 Artificial General Intelligence

An Artificial General Intelligence system is a type of Artificial Intelligence System where the intelligence is learned in one domain and is generalized to other similar domains or an unrelated domain as human beings do. For example, humans have the ability to walk on different surfaces, such as smooth surfaces, to move forward or backwards with stability and control. Humans can even walk on uneven terrains and on some degree of slopes [76]. Generalization in AI is essential for domain-specific tasks as well as to reach human-level intelligence. However, the issue of generalization is proven to be hard when the human level is considered. Hence, the issues at the human level are named as strong AI issues to differentiate them from weak AI and general intelligence.

5.3.3 Artificial Super Intelligence

Artificial Super Intelligence systems are AI systems that are considered to be more intelligent than humans in most aspects. Though this is an imaginary scenario that could be possible in future. This imaginary scenario touches on issues such as robots being the superior beings that can control humans in the world and replicating super intelligence to dominate future civilizations [77]. However, in the current situation, there is no supporting evidence for this hypothetical and imaginary scenario. It is essential to differentiate these AI approaches and AI terms in order to clearly learn and understand the real capabilities of artificial intelligence and the boundaries of hype that is associated with AI. The concepts that are discussed above may be misleading when they are out of the context of Narrow AI. The successes of current AI systems mostly exist within the Narrow AI [71].

5.4 Artificial Intelligence (AI) Techniques

In this real-world, knowledge and intelligence have some unwelcomed properties:

- The knowledge is not well-formatted or well-organized
- The volume of the knowledge is huge, next to unimaginable
- It keeps on changing constantly.
- Requires a larger memory size to fit the knowledge within the systems.

Artificial Intelligence Technique is all about organizing and using the knowledge efficiently in such a way that:

- It should be modified to correct errors
- It should be understandable by the people who provide it.
- It should be useful in many areas, even though it is inaccurate and incomplete.

The AI technique must have the ability to elevate the accuracy in executing a complex program that it was equipped with [73].

The AI techniques can be classified into various categories depending on the system's capacity to use past knowledge and experience to predict the future, self-awareness, decisions and memory. Initially, IBM came up with an AI program called Deep Blue which is a chess program that has the ability to identify the pieces on the chessboard. But the AI program lacked the ability or memory to predict future actions. Though the system is useful, it cannot be applied to another situation.

The other types of AI systems use past experiences and knowledge with limited memory to predict future decisions. An example of this kind of AI can be found in the case of self-driving cars. In self-driving cars, the AI system has functions of decision-making. Using the help of the information provided by the sensors, the AI predicts the direction in which the car must go. For example, if the sensor attached to the car detects an object within a certain distance, then the sensor sends this information to the AI, and the AI takes the decision of moving the car in the direction where there is no object or slows down to prevent hitting the object [75].

In the case of self-driving cars, the observations help in taking action immediately, but the data is not stored permanently because the observations with respect to self-driving cars change frequently. In the future, with the advance in technology, it might be possible for creating AI integrated systems for sensing and being conscious of understanding the current state of things to predict the future and inform what needs to be done. However, currently, such systems do not exist.

The techniques of Artificial intelligence are machine learning, natural language processing, machine vision and automation and robots.

5.4.1 Machine Learning

Machine learning is thoroughly discussed in the previous chapter. Machine learning is one of the applications or techniques of AI where machines are not explicitly programmed to perform actions, but they have the ability to learn and improve from experiences automatically. The deep learning that was discussed in the previous chapter is based on artificial neural networks for predictive analysis [65]. As discussed earlier, there are various machine learning algorithms are Supervised Learning, Reinforcement Learning and Unsupervised Learning. In unsupervised learning, the algorithm does not use any kind of classified information to perform an action without any guidance. In Supervised Learning, the algorithm assumes a function from the training data that consists of a set of input objects and desired output objects. The other type of machine learning algorithm is reinforcement learning, which is commonly used by machines in order to take appropriate actions to increase the reward; it identifies the best possible solution that can be taken into account [69].

5.4.2 Natural Language Processing (NLP)

Natural Language Processing (NLP) is one of the techniques of AI where computer systems are programmed to process natural languages for improved interaction between humans and computers. The most reliable technology for NLP is Machine Learning, as it helps the NLP to obtain meaning from human language. In NLP, the machine involves in capturing the audio of a human speech. Then the audio will be converted into text, and then the text that is processed for response is converted into audio for the human to receive. Here, the audio is converted into text format to make the machine understand the meaning, and in the response, a text will be converted to audio to make the human heart [70]. Interactive Voice Response (IVR) is one of the applications of NLP, which is most commonly used in customer care centres, call centres, and word processors such as Microsoft Word to check the accuracy of grammar in text and in language translation applications like Google Translate.

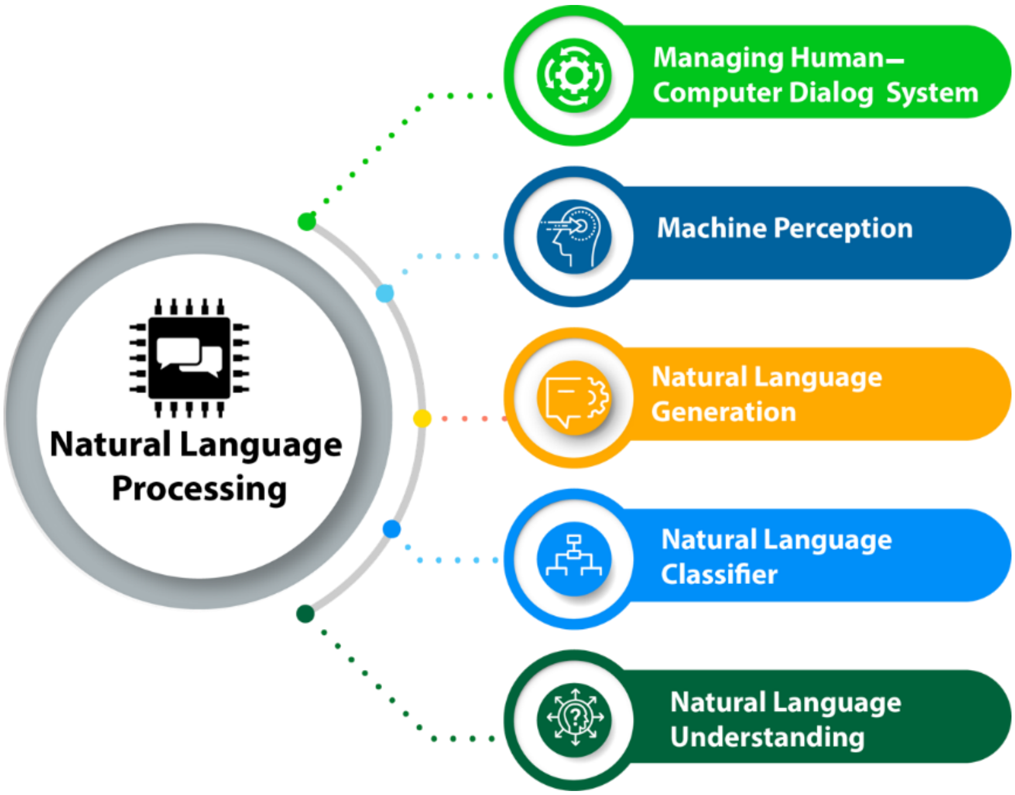


Figure 43 Natural Language Processing

However, the nature of human languages makes it difficult for NLP because of the rules that are associated with the passing of information using natural language, and it is not that easy for computers to understand. Therefore, NLP uses algorithms to identify and abstract the rules of the natural languages where the unformatted data from the human languages are converted into a format that can make it easy for the computer to understand [68].

5.4.3 Automation and Robotics

The main purpose of automation is to make machines do monotonous and repetitive tasks to improve productivity. Improved productivity leads to more efficient results. The automation mechanism is cost-effective when compared to humans who involve in doing the same tasks repetitively.

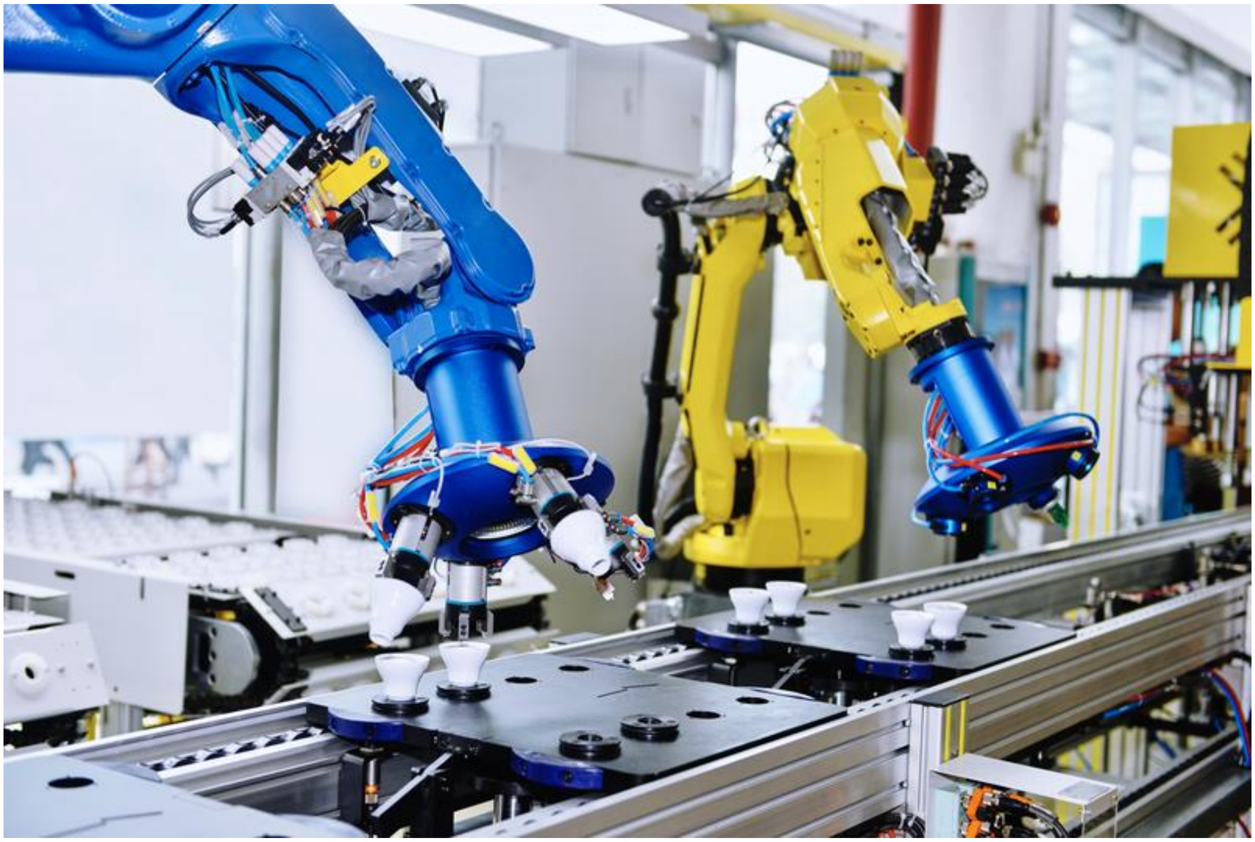


Figure 44 Automation and Robots

Many organizations across the world use graphs, neural networks and machine learning in automation. Such automation is much helpful in preventing fraud issues during online financial transactions using CAPTCHA technology [76]. In robotics, AI automation is programmed in a way to perform high volume repetitive tasks which can adapt to the change in different circumstances.

5.4.4 Machine Vision

Machine vision is one of the AI techniques involved in capturing and analyzing visual information. Here high-resolution cameras are used for capturing visual information, the image that was captured is converted into digital through the analogue to digital converters, and digital signal processing will be employed to process the data.

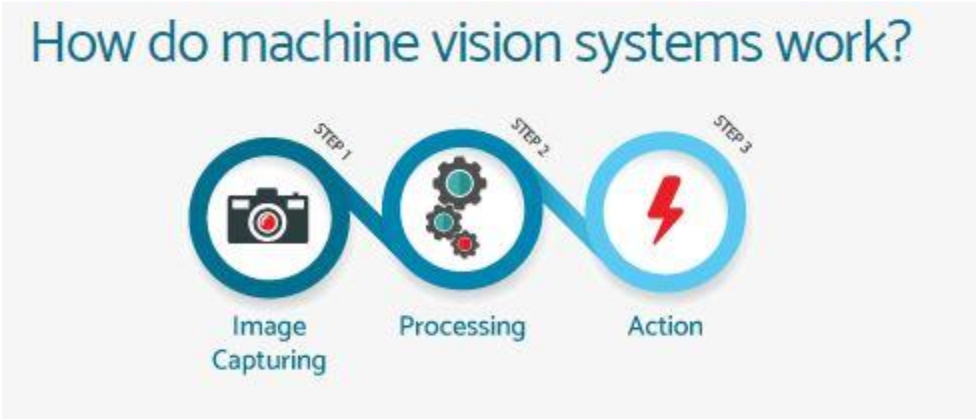


Figure 45 How does Machine Vision Work?

Then the data that which obtained after these processes are fed to a computer. The two vital aspects of machine vision are sensitivity and range. Sensitivity is the ability of the machine to observe instincts that are weak and resolution. The range is for making the machine distinguish the objects [72]. Machine vision applications are found in pattern recognition, signature identification and medical image analysis, etc.

Chapter 6 Applications of Artificial Intelligence

Artificial Intelligence has its applications in various sectors. In the financial sector, AI is used to collect personal data for the purpose of providing better financial advice. In the education sector, AI is used to automate the grading systems through which the student's performance can be assessed, and better strategies will be implemented in the learning process to improve students' performance [68]. In the healthcare sector, AI is effectively used to perform better diagnoses where the machines are used to understand natural language for a better response to the questions asked. Computer programs like AI chatbots are used for assisting customers in various ways, such as purchasing a product, enquiry about a product, scheduling an appointment and others.

Businesses are effective in capitalizing on the opportunities offered by AI. Manufacturing businesses use AI for the automation of repetitive tasks that are usually carried out by humans with the help of Robotic Process Automation. In order to increase user satisfaction, companies use machine learning algorithms integrated with data analytics in understanding the needs and requirements of the customer and recommend the best solution to the customer [69]. AI is also in IoT devices like Smart Home Devices, navigation and travel, security and surveillance, music and media streaming and video games, etc.

AI also plays a dominant role in the fields of gaming, expert systems, natural language processing, vision systems, speech recognition, intelligent robots and handwriting recognition. Online games like chess, poker, tic-tac-toe and others consist of a computer player, and that role is played by AI. Here the machine can think of a large number of possible actions for the move based on previous experiences and knowledge [71]. AI is used to interact with the computer through NLP. Expert systems or applications that integrate software, machine and special information offers explanation and advice to the users.

AI vision systems can understand, interpret and understand visual input on the computer. For example:

- A physician uses a clinical expert system to diagnose a patient
- A drone aircraft can take images that are used to identify the map of the areas on the earth or to identify spatial information.
- A law enforcement officer uses computer software to recognize the face of the criminal with the portrait image stored in the data.

In addition to the above, there are some intelligent systems that have the capability of hearing and understanding the natural language in terms of sentences and their meanings whenever a human talks to it. The best examples of these AI systems are SIRI, Bixby, Google Assistant, Cortona and others, which are designed to handle different accents, noise in the background, slang words, and changes in the human voice [69]. AI is used to develop handwriting recognition software to read the text that was written on paper by pen or on-screen by a stylus pen. It can recognize the letters, gaps between words and other characteristics and converts them into editable text.

Intelligent robots are AI robots that are designed for performing actions with the given command by a human. These robots are connected with sensors for detecting physical data from the real-world such as sound, bumps, pressure, movement, temperature, heat and light. In order to exhibit intelligence, these intelligent robots consist of efficient processors, huge memory and multiple sensors [67]. These intelligent robots are capable of learning from their mistakes as well as adapting to a new environment.

6.1 Applications of AI in real-world

The term artificial intelligence is not only something that big technology companies are related to; through the devices we are using daily, we are allowing AI to change our daily lives. Most people who use electronic gadgets encounter AI. The examples of how AI is already in human use are described below.

6.1.1 Face ID to Unlock Apple iPhone

Apple Inc. is an innovative company that brings innovative features to its devices. One of those features is face unlock. Users of the Apple iPhone can unlock their iPhone by just showing their face to the front camera [72]. Apple has created a facial biometric system that involves capturing the face of a human being to create a Face ID.

Figure 46 Apple iPhone Face ID feature

This biometric system uses machine learning algorithms for comparing the face scan with the facial information stored in the system to unlock the device. If the face scan fails to match with the facial information stored in the system, then the device will be still locked.

6.1.2 Social media

In this fast-moving world, people prevent themselves from spending time knowing what is going around them. Therefore, they depend on newsfeeds that are customized for them based on their interests. For example, on Facebook, YouTube, Instagram and other social media, the AI works to give the user personalized content by figuring out the user's interests, people suggestions based on habits and interests, news feeds based on recent browsing history, recommended videos based on previous search history and others. At the same time, machine learning works to prevent cyberbullying [67].

6.1.2 Grammarly

Grammarly is an AI tool that involves checking a text for any grammatical mistakes and incorrect spellings. Grammarly uses AI and NLP to process the text, identify mistakes, and suggestions for corrections.

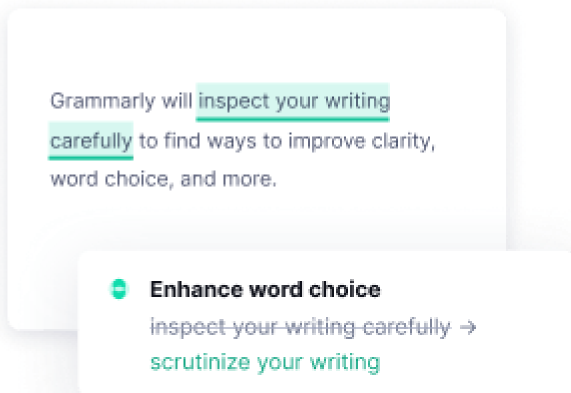


Figure 47 AI application in Grammarly

Similarly, anti-virus software uses machine learning to detect any threats in the device to protect the device and data in the device from hacking.

6.1.3 Digital Voice Assistants

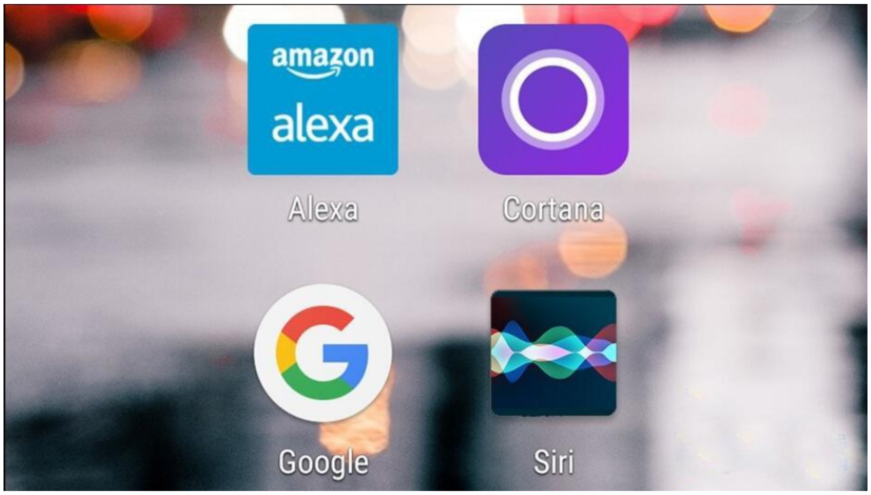


Figure 48 Digital Voice Assistants

Hey Siri! is used commonly by iPhone users to wake Siri and get responses to various queries. Like Siri, there are various digital voice assistants like Google Assistant, Bixby, Cortona, Alexa and others that offer assistance to users. These digital voice assistants use NLP and generators driven by AI to give responses to the user's questions.

6.1.4 Smart home devices

People are across the world, in some way or the other, bringing AI into their daily lives, and one of those things is AI [71]. Smart water heaters, smart refrigerators, smart lighting, smart fans and others are devices that use machine learning and other AI techniques to learn users' daily habits and adjust them accordingly as per user's preferences.

Figure 49 Thermostat

SECTION – III

Chapter 7 Current Transformations of IoT in Enterprise

Businesses across the world have understood the benefits and opportunities that digital technologies could offer from a digital marketing perspective and Covid-19 Pandemic. Due to the Covid-19 pandemic, companies across the world have started to adopt digital technology to market their products as well as provide an enhanced and personalized experience to customers. The changes in the business with the pandemic made digital transformation the heart of business strategies [78].

The digital transformation of a business starts with the commitment of leadership. The commitment from executive leadership is essential for organizations to innovate on the experience that they want to offer to the customers. Digitally enabled companies are a threat to the existing businesses because the customer prefers the services and products from the companies that offer them personalized experiences. The starting point to prevent the threat of being disrupted is by adopting technologies and approaches that help companies to innovate as well as provide an innovative experience to the customers. However, disruption doesn't come externally; it should happen internally [79]. Companies need to transform their business models to create more value for the customers as well as to capture the value from the customer.

Today, companies are more focused on transitioning their business models from mass-marketing to consumer-centric models. Business model transformations are essential for businesses to deliver on the promises represented by the new, personalized and engaging experiences. The technology supporting the IoT -acquiring, analyzing and activating data – is a significant element of transforming operating models and generating innovative experiences.

According to a survey conducted by IDC in 2015, it was reported that about 58% of companies across the world would see the IoT as a strategy for their business, and 30% of businesses see IoT as a transformation in their businesses [80].

7.1 Business Perspectives on the Internet of Things (IoT)

IoT plays a major part in most of the initiatives that are related to digital transformation, but these initiatives are not related to IoT projects. Businesses might use or integrate IoT into their business operations to deliver specific value [81]. The current and future use cases of IoT can be categorized into three groups they are strategic asset management, customer experience and product and service experience.

Figure 50 IoT in Business

7.1.1 Strategic Asset Management

The biggest business transformation that the Internet of Things has brought in the 21st century is in the logistic or supply chain management business processes. Using IoT-enabled technologies, retailers are achieving higher degrees of control over warehousing, logistics, inventory, and point of sale processes. For example, attaching GPS enabled IoT devices to specific storage containers [82]. The IoT device connected to the internet will transmit its location, and it makes it easy for the user to track the location of storage containers.

Strategic asset management is nothing but managing strategic business assets. Track location, monitor the status and track the movement of physical assets owned by the organization to increase efficiency, performance, security, safety and the number of individual assets and groups of assets. Assets may be maintained and managed, but the main focus will be on the asset, including the security and risk management of that asset.

7.1.2 Customer experience

Providing personalized and interactive experiences to the customer is proven to be a more successful marketing strategy rather than other marketing tactics and strategies. However, in order to provide a customized experience to the customer, the company need to collect information about the customer and must be done same to the employee for improved productivity. The focus on the customer experience includes physical security and safety [82].

7.1.3 Product and service experience

Enhance a product experience or deliver a service based on an IoT-enabled product. This involves collaboration in shared systems and extends from the product inbound supply chain to the current delivery of the good or service. Data flow can be machine to human or machine to machine. The product or service experience may be B2C or B2B. Although the focus is on the product or delivery of service, which should improve the customer experience [83]. As most of the initiatives with respect to IoT match one of the above-mentioned categories, they are clearly different with respect to the context of each industry.

In the Omdia'a 2021 IoT Enterprise Survey, it has been reported that most of the organizations surveyed are currently using or in the process of deploying IoT solutions as part of their digital transformation strategy. 92% of respondents described their IoT deployments as either core or broad and might not touch every part of their businesses, but they are used across multiple product lines and departments [84]. The remaining 8% of respondents described that they were using IoT in a targeted way, i.e., for a single department, geographic location or process.

The report also describes that the enterprises were much further in IoT deployments as they are increasing the number of IoT-based projects. About 75% of respondents said that their IoT projects were either in the trial stage or in the full deployment stage, i.e., 4% up when compared to the previous year. When compared to the survey conducted in 2020, there is a 25% increase in the development of IoT projects. Today, 40% of the enterprises participated in the survey working on more than five IoT projects [82].

Enterprises are in full confidence that their IoT investments can bring them good returns in the form of energy efficiency, productivity gains and work and facility safety. Most of the organization's IoT investments increased by almost 50% in 2021 when compared to the previous year. In the year 2020, the IoT investments by an organization are $0.5 million, and in 2021 it was nearly doubled, i.e., $1 million in the year 2021 [81].

7.2 Enterprise concerns about IoT

IoT security and compliance are the top enterprise concerns IoT. The survey shows that data security, network security, compliance with data protection and cybersecurity regulations are top concerns for companies that are deploying IoT solutions. More than 50% of the respondents said that data security is their top concern with respect to IoT, and about 50% say that data governance is their top IoT concern [85]. Therefore, data security and data governance are the major challenges for companies to adopt IoT organizations. Comprehensively, the top concerns for enterprises to IoT in their organizations are device authentication breaches, identity breaches, lateral breaches, DDoS attacks and ransomware.

Enterprises are looking for IoT vendors who have key capabilities, including integrated IoT security, predictive/proactive IoT data analysis, and open APIs. Cloud services companies, including Google Cloud, Azure and AWS, accounted for 42% of the IoT products and services that are used by enterprises.

7.3 IoT adoption trends in Enterprises

The total number of IoT devices that come into usage will reach 18 billion by 2022, as enterprises are continuously increasing their IoT spending to improve their business performance. A critical source for any company to provide excellent and personalized service is data. IoT integration into business operations makes it possible to harvest and exchange huge amounts of data [86]. IoT has the ability to hear and see what is going around the company, and it is up to the organization to harness its transformative power or not.

Using various predictive analytics, companies are using the data obtained from IoT devices to make predictions about future events and to identify business risks and opportunities based on current business environment facts and trends. Predictive analytics of large amounts of IoT data is possible with the deep learning techniques of machine learning and artificial intelligence. The combination of IoT, artificial intelligence and machine learning will give more power to the companies to expand their business opportunities beyond anything previously possible.

The most important way in which the IoT is driving enterprise transformation is by improving customer experiences. Customers today are looking for companies that provide them better and personalized experiences. For example, iPhone users pay a premium for the experience the phone provides to them, which is different from other phones in the market. The experience could be in any form, such as security, functionality, safety, premium, quality and others [82]. Companies can collect valuable data from the customer by making IoT devices the customer touchpoints throughout the customer journey. The collection can be analyzed using machine learning and artificial intelligence tools to offer the customer personalized experiences by considering their unique needs and desires.

In order to articulate and better understand the industry initiatives toward IoT, the international data centre has conducted four industry focus groups they are healthcare, retail, discrete manufacturing and consumer products [79].

7.3.1 IoT in Healthcare

IoT helps different organizations in different ways. IoT in healthcare organizations means different things to different people, including the IT staff. For most people, IoT means, is a form of connectivity, typically wireless, which connects objects and people across the healthcare ecosystem in order to collect, combine and analyze data to garner valuable and actionable insights. The most common use cases of IoT in healthcare involve connecting caregivers, clinicians and patients [87]. Most healthcare organizations prefer not to use IoT when they refer to initiatives such as fitness and activity tracking, medication adherence, remote health monitoring, or personal emergency response for monitoring patients who are ill or under treatment. Most people from healthcare organizations commonly prefer using telehealth rather than connected health when describing the initiatives to trace and track physical things such as supply levels and medical equipment.

Once embraced, IoT has the ability to become a disruptive force in healthcare. Even though the industry is not yet completely ready for digital or IoT transformation, international data centre report shows evidence of progress.

Figure 51 IoT in Healthcare

Healthcare enterprises across the world have piloted various connected health projects that are aimed at improving patient engagement with medical services. Though the information related to ROI is vague, IoT transformation offers various qualitative benefits such as improved patient outcomes, improved ability of the physician to connect with the patient and study the health behaviour of patients to make better decisions regarding the patient health that which could lead to better health outcomes as well as lowers healthcare costs [79].

7.3.2 IoT in Consumer Products

Consumer products include various kinds of products, including food and beverages products, health and beauty products, and other products. These products are fast-moving consumer goods. The consumer products industry is a mature and relatively slow-growing industry that stands in the middle ground in terms of thought leadership and technology within the overall industry [83]. Given their core business functionalities, manufacturing industries mostly focus on product innovation, and the consumer takes superiority, though areas such as supply chain and trade promotion management are also significant for improved productivity and logistics. The impact of IoT on this industry is significant, especially in terms of how these enterprises interact with their customers and significantly the target consumers. Looking into the future of IoT within the industry, IoT can be embraced by the industry to offer personalized experiences for the customers.

7.3.3 IoT in Discrete Manufacturing

Discrete manufacturing includes a broad range of industry sectors, including defence, industrial machinery, farm, aerospace, automotive, high tech, industrial machinery and construction [81]. However, enterprises in this sector may have different priorities that impact how they adopt the Internet of Things and where they have to apply it first, to supply chains? Products? or assets?

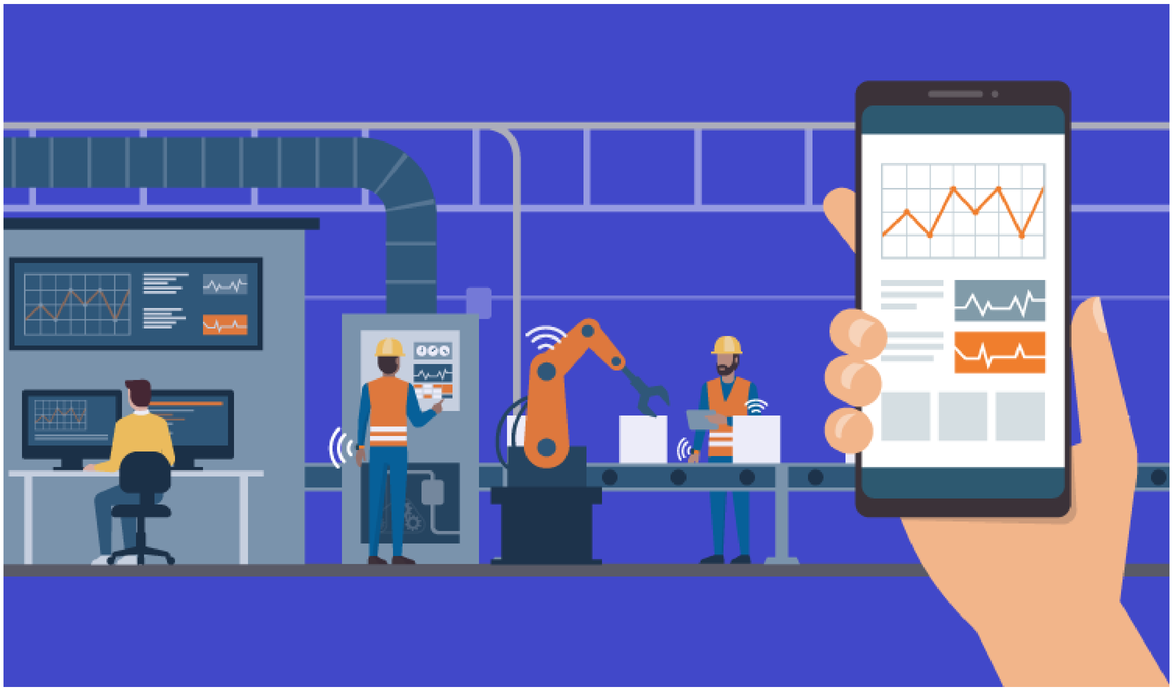


Figure 52 IoT in Manufacturing

According to the results from the survey conducted by International Data Center, companies that own manufacturing facilities are likely to be early adopters of the Internet of Things (IoT) in the plant, and the companies that have long product life cycles may adopt IoT to change their products and services. Along these, the players in the manufacturing industry were mostly interested in how the Internet of Things impacts their services and products with strong representation from innovation, research and development and engineering.

It is important to consider that most of the manufacturers are not looking in investing in IoT, but they are proactively looking for IoT-enabled solutions and, ultimately, digital business transformation [86]. Companies that start with investing can evolve over time. For example, most manufacturing companies start to invest in IoT with simpler expectations with regard to tracking or visibility and eventually progress to more classified processes that require predictive or automated responses and workflows and provide a level of outcome or resource optimization.

7.3.4 IoT in Retail

For most people in retail, IoT means it is a form of connectivity, typically wireless, which connects objects and people across the retail ecosystem in order to collect, combine and analyze data to garner valuable and actionable insights and execute more efficiently. The most common use cases of IoT in retail involve connecting consumers, service providers and associates to products and information about the product and collecting information about consumer journeys for better planning, decision making, marketing and placement [79]. Retail companies invested in

IoT in terms of inventory management and connected consumer-related projects to improve consumer engagement.

Figure 53 IoT in Retail

Chapter 8 Role of AI in Enterprise Transformation

Data has become crucial for organizations today. Organizations across the world are using various tools to collect data, analyze data and understand data to make decisions that are important for the business to achieve competitive advantage as well as to sustain in the high competition. As the world is growing tech-savvy, businesses are growing data-driven [88]. As customers are increasingly adopting electronic gadgets like smartphones, Alexa, tablets, and others, companies consider these gadgets as platforms to provide personalized experiences to the customer. Companies also collect information about the customer through these mediums only.

Today, customers are looking for something easy that provides them easy access. At the same time, organizations need to promise speed, convenience, and comfort, along with cost optimization. All these requirements demand digital transformation. Therefore, digital transformation is the only way businesses can be able to meet the changing requirements and needs of the customer.

With digital transformation, companies can power themselves to bring experiences to the fingertips of people. Even though companies require a more intelligent solution to solve customer problems ad help them find their desired things and services faster. Artificial Intelligence (AI), Internet of Things (IoT) and Machine Learning (ML) and others are the smart trending technologies that can offer businesses intelligent solutions.

Artificial intelligence application development is currently is in high demand, and digital transformation could be one of the top reasons for the trend. AI helps businesses to effectively transform their business models in order to stay competitive. AI helps businesses to develop strong and robust strategies, such as data transformation, after getting real-time input from market intelligence [89]. AI enables businesses to get rid of traditional business tactics such as consumer conversion and retention strategies and adopt strategies that support businesses to enhance customer experiences.

8.1 AI and business

AI should be seen as a supporting tool rather than serving as a replacement for human intelligence and ingenuity. Completing commonsense tasks using AI (Artificial Super Intelligence) is difficult in the real world; it is effective at processing and analyzing the data much faster than the human brain or human intelligence [90]. AI applications can then return with synthesized courses of action and present them to the human user. In this way, businesses can use AI to help the game out of possible sequences of each action and streamline the decision-making process.

Figure 54 AI in Business

AI should be seen as software that helps itself in making a decision on its own to make things able to act in a situation not foreseen by the programmers. AI has a wider latitude of decision-making ability as opposed to traditional software [91].

8.2 Benefits of AI

Artificial Intelligence has its applications in various sectors. In the financial sector, AI is used to collect personal data for the purpose of providing better financial advice. In the education sector, AI is used to automate the grading systems through which the student's performance can be assessed, and better strategies will be implemented in the learning process to improve students' performance. In the healthcare sector, AI is effectively used to perform better diagnoses where the machines are used to understand natural language for a better response to the questions asked. Computer programs like AI chatbots are used for assisting customers in various ways, such as purchasing a product, enquiry about a product, scheduling an appointment and others [92].

Businesses are effective in capitalizing on the opportunities offered by AI. Manufacturing businesses use AI for the automation of repetitive tasks that are usually carried out by humans with the help of Robotic Process Automation. In order to increase user satisfaction, companies use machine learning algorithms integrated with data analytics in understanding the needs and requirements of the customer and recommend the best solution to the customer [93]. AI is also in IoT devices like Smart Home Devices, navigation and travel, security and surveillance, music and media streaming and video games, etc.

AI also plays a dominant role in the fields of gaming, expert systems, natural language processing, vision systems, speech recognition, intelligent robots and handwriting recognition. Online games like chess, poker, tic-tac-toe and others consist of a computer player, and that role is played by AI. Here the machine can think of a large number of possible actions for the move based on previous experiences and knowledge [94]. AI is used to interact with the computer through NLP. Expert systems or applications that integrate software, machine and special information offers explanation and advice to the users.

AI vision systems can understand, interpret and understand visual input on the computer. For example:

- A physician uses a clinical expert system to diagnose a patient
- A drone aircraft can take images that are used to identify the map of the areas on the earth or to identify spatial information.
- A law enforcement officer uses computer software to recognize the face of the criminal with the portrait image stored in the data.

In addition to the above, there are some intelligent systems that have the capability of hearing and understanding the natural language in terms of sentences and their meanings whenever a human talks to it. The best examples of these AI systems are SIRI, Bixby, Google Assistant, Cortona and others, which are designed to handle different accents, noise in the background, slang words, and changes in the human voice [95]. AI is used to develop handwriting recognition software to read the text that was written on paper by pen or on-screen by a stylus pen. It can recognize the letters, gaps between words and other characteristics and converts them into editable text.

Figure 55 Benefits of adopting AI

Intelligent robots are AI robots that are designed for performing actions with the given command by a human. These robots are connected with sensors for detecting physical data from the real-world such as sound, bumps, pressure, movement, temperature, heat and light. In order to exhibit intelligence, these intelligent robots consist of efficient processors, huge memory and multiple sensors [92]. These intelligent robots are capable of learning from their mistakes as well as adapting to a new environment.

Chapter 9 Combination of AI And IoT and their Impact on Business Processes

IoT and AI have bought fundamental changes to the current business landscape. The merger of AI and IoT technologies assists businesses in making informed decisions effectively and accurately. Here, IoT devices help businesses to accumulate huge amounts of data, and AI techniques help businesses to assimilate and evaluate this data. Machine Learning, on the other hand, involves identifying the patterns and detecting the faults in the data collected by IoT devices.

When AI and IoT are combined, the result is a smart machine that can make a well-informed decision with little or no human intervention. We are now surrounded by thousands of connected devices which involved in collecting and sharing valuable data. Companies that develop IoT applications can enable modern companies to get real-time data and transform them into meaningful information with the help of AI advancements [96].

Be it an image, video, audio or any unstructured data, IoT devices involve in gathering everything quickly. As IoT devices collect huge amounts of data, it will be difficult for humans to process it as well as to get actionable insights. In order to process and get actionable insights from data, AI should be put in place.

This role of Artificial Intelligence is one of the big reasons for increased sales and massive revenue boost of connected devices. By 2025, the use of connected devices will reach over 73 billion as per an estimate by IDC. The AI and IoT combination has a bright future. Both these technologies have a broader scope in almost all industry domains. Businesses can make most of both these technologies by merger [97].

Improved services, better decision making and accuracy with enhanced security are some of the significant business benefits of the AI and IoT combination.

9.1 AI-Powered IoT in the Real World

Many companies have been using AI-powered IoT devices to improve customer experience as well as to create new revenue models.

9.1.1 Manufacturing Robots

Manufacturing companies are the early adopters of emerging technologies such as robotics, deep learning, facial recognition, AI, IoT and others. Factory robots are now becoming smarter with implanted sensors that facilitate data exchange. Furthermore, the robots also learn from the fresh data because they are equipped with AI systems [98]. This approach not only saves time and money but also improves the manufacturing process in the long run.

9.1.2 Autonomous Vehicles

The best example of AI and IoT working together is Tesla’s self-driving car. Self-driving cars use AI to predict pedestrian and card behaviour in various situations [99] [100]. Self-driving cars help in identifying road conditions, ideal speed, and weather, and now they are continuously wiser with continuous data coming in continuously.

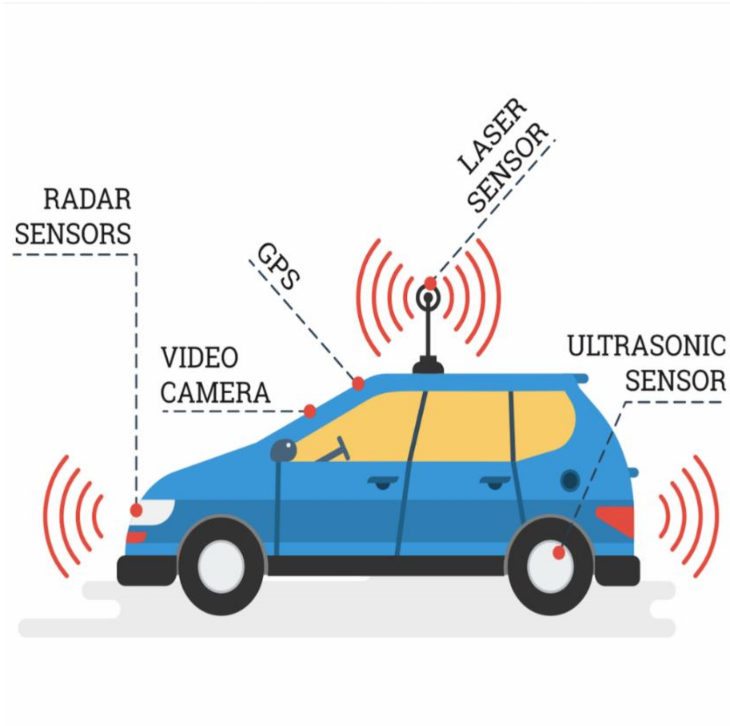


Figure 56 Self-driving Car

9.1.3 Retail Analytics

Many data points from sensors and cameras are used in retail analytics for tracking the movements of customers and forecasting when they are going to arrive at the checkout line. As a result, the system can recommend dynamic staffing levels in order to boost productivity and shorten checkout times [101].

9.1.4 Smart Thermostat

One of the examples of AI-enabled IoT is Nest's Smart Thermostat. Based on the user's temperature preferences and work schedules, the smartphone integration may verify and regulate the temperate from anywhere [102].

Figure 57 Thermostat

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