International Journal of Advanced Research in Engineering Technology & Science
ISSN: 2349-2819
Email: editor@ijarets.org Volume-8, Issue-6 June- 2021 www.ijarets.org

MANUFACTURING SECTOR PREDICTIVE MAINTENANCE BASED ON THE INTERNET OF THINGS

Ajay Singh
,Research Scholar,
Dept of Computer Science, Kalinga University, Raipur, Chhattisgarh

Dr Rajesh K Deshmukh,
Professor,
Dept of Computer Science, Kalinga University, Raipur, Chhattisgarh

Abstract: Industry 4.0, which enables several technology advancements, including big data analytics and machine learning techniques, to merge into and mix with traditional manufacturing processes, is what enables the growth of smart manufacturing. Industrial Internet of Things (IIoT) technology is used in smart manufacturing strategies to enhance production processes. These methods make use of sensors from the Internet of Things that are mounted on physical assets. Industrial facilities may become smart and communicate information on their own thanks to IoT sensors. Making decisions concerning a company's operations may then be done using this information. Smart manufacturing techniques provide businesses a competitive advantage over their competitors since they may lead to higher profit margins, lower maintenance costs, lower energy usage, and better product quality. An architecture for predictive maintenance utilizing IIoT is suggested within the context of this study. An example case study from the auxiliary vehicle industry is given to show how a predictive model may be used to anticipate sudden failures of industrial equipment. Because of this, the manufacturing and maintenance cycle may be "smart."

1. IntroductionBased on Internet of Things

In this work, we present an infrastructure that can do predictive maintenance by using the Industrial Internet of Things. (Fig. 1). Sensors connected to the internet of things are put to use in the monitoring and data collecting that takes place in real time [1]. After the data has been collected, a PdM model is constructed using it via the use of various statistical tools and computer programs. An inventory of the components that comprise PdM systems is shown in the following.:

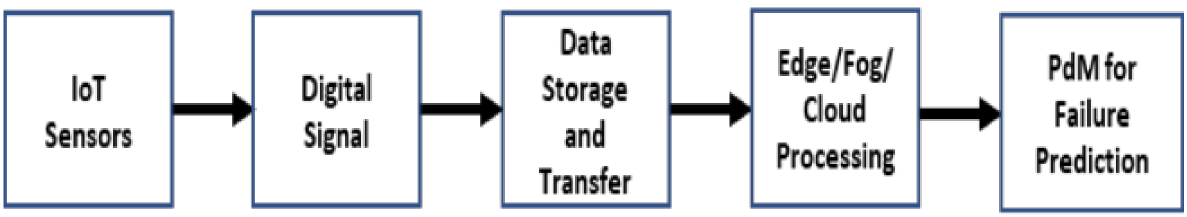

Fig. 1: An Overview of Architecture

1.1. Internet of Things Sensors

It is feasible for many kinds of sensors and cyber-physical systems to interact with one another and communicate with one another. Sensors are used to collect raw data. The temperature, humidity, pressure, current, vibration, air quality, footfall, gas, and weight are just some of the things that may be measured by some of the most popular types of industrial sensors that are enabled by the Internet of Things [2]. Another kind of sensor that finds broad use is the photoionization sensor. This sensor measures the amount of photons in the environment. This specific sensor is put to use for the purpose of determining the relative concentrations of various gases and volatile inorganic compounds [3]. When it is necessary to interpret the high-frequency sounds that are brought on by leaks, the ultrasonic sound sensor is put to use.

1.2.Manufacturing impacts of industrial revolutions

It is possible to identify the distinctive characteristics of each distinct industrial revolutionary age, the range of technological advancements, and specific milestones. [4] The adoption of steam engines and new production processes by the textile industry in the 18th century marked the beginning of the first industrial revolution. Manual labor is no longer used in production. Efficiency and production at work have consistently increased. The steamboat was yet another important advancement in the transportation industry. Additional characteristics include the use of modern materials like steel and the specialization of the personnel. [5] The second industrial revolution took place in the 19th and 20th centuries.

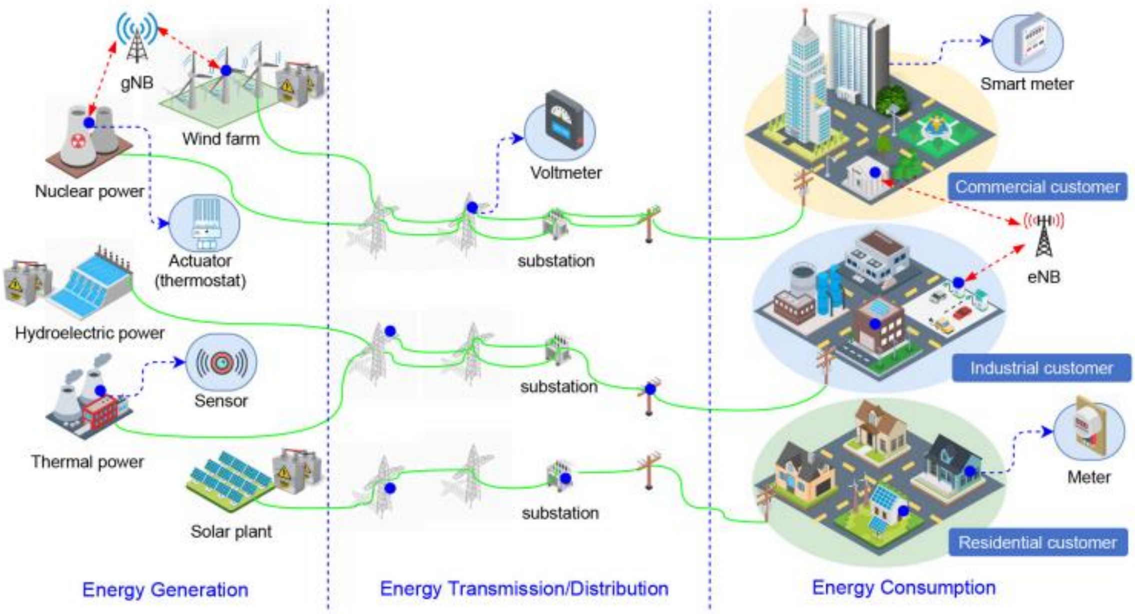

Figure 2 depicts the lifecycle of intelligent energy.

The basic pillars of this period were the invention of electricity and the concept of the assembly line. Henry Ford introduced belt manufacturing to the automotive industry, which once again opened up chances for increasing output while simultaneously reducing costs. The first automated procedures also came into existence along with the development of computers. [6] The third industrial revolution began in the middle of the 20th century. The most noticeable elements are those related to digital technology, including robots or programmable logic controllers (PLCs).

1.3.Benefits of using the Industry 4.0 idea in manufacturing firms

In general, Industry 4.0 may be very advantageous to industrial organizations. [7] . Agile supply chain technology offers excellent support for logistical ideas like JIT. (just-in-time). It is very easy and quick to modify orders, respond in a timely manner, and customize the process to your needs on both the supplier's and the customer's end.

• Tools for prediction and monitoring - Because production organizations often operate continuously around-the-clock, it's necessary to be on the lookout for possible IT system and production technology problems and production halts. Strong monitoring technologies that help with the early identification of issues or system failures fit us well within the framework of the Industry 4.0 concept.

• System flexibility - Previously, there was minimal room for adjustment in the production process. The use of Industry 4.0 technology makes it possible to produce many variants of the produced item at once on a single line (different colors, different components on the line, etc.) while keeping the intended order [8].

• Network technology flexibility extends beyond only designing network parts for communication speed, although this is essential for the manufacturing phase. The possibility of interacting with and communicating with the outside world does exist, however. As a consequence, the whole production process becomes more flexible and dynamic. Obviously, adhere to the essential security precautions while communicating outside of the company.

• Digitization of documents and processes - this might also be considered as a prerequisite for the implementation of automated processes [9]. The horizontal chains (supplier-company-customer) should also be digitalized in addition to the vertical level. (Across the organization's departments).

• Industry 4.0 technologies enable an increase in production capacity and efficiency. They can be used to optimize energy consumption, the manufacturing process itself, better resource redistribution, manufacture more items on the production line, and at the same time identify possible improvement areas. Saving money is always a valid defense for a benefit. Routine maintenance and fast monitoring improve the dependability of technologies by preventing unexpected outages and the effects they cause, such as equipment damage and downtime that has a negative influence on the entire production plan.

The result of properly functioning technology is a natural reduction in errors and accidents at work. [10] According to Deloitte's current resources and insights, automation, high-speed connectivity, machine learning, and low are the key criteria for the success of today's organizations. It is thus suggested to digitize all activities and invest in the most cutting-edge technology. Emerging technology currently carries competitive advantage. [11] The company also provides a list of crucial queries that a company should do if it wishes to thrive in Industry 4.0:

1.4.Industry 4.0's perspective on automation

In the context of Industry 4.0, the term "automation" may be understood as a group of technologies that allow the execution of machine operations and system operations with little to no human intervention. [12] This is the key contrast from manual labor. Such a system or device should include the following features: enough information on the device's running / operating state; cautions regarding possible hazards; and the capability of manual restriction or human intervention. Such systems may include, but are not limited to: HMI panels (Human Machine Interface), SCADA visualisations (Supervisory Control and Data Acquisition), PLC programmable devices, industrial robots, autonomous logistical devices, and other systems. Another possibility is the possibility of automated processes converging even at the system level. These gadgets either execute, backup, or keep an eye on something. (Automated surveillance). [13] Each of the several production terminals has distinct qualities that enable interaction, programming, monitoring, and optimization amongst them. Some devices can also be operated remotely or on their own. The most common representation is of a robot since they can be programmed, are autonomous, and have security features. In situations like welding operations or on assembly lines, these robots replace humans. When considering automation within Industry 4.0, it is essential to describe enabling technologies like Internet of Things (IoT), cloud computing, big data analysis, 3D printing, artificial intelligence.

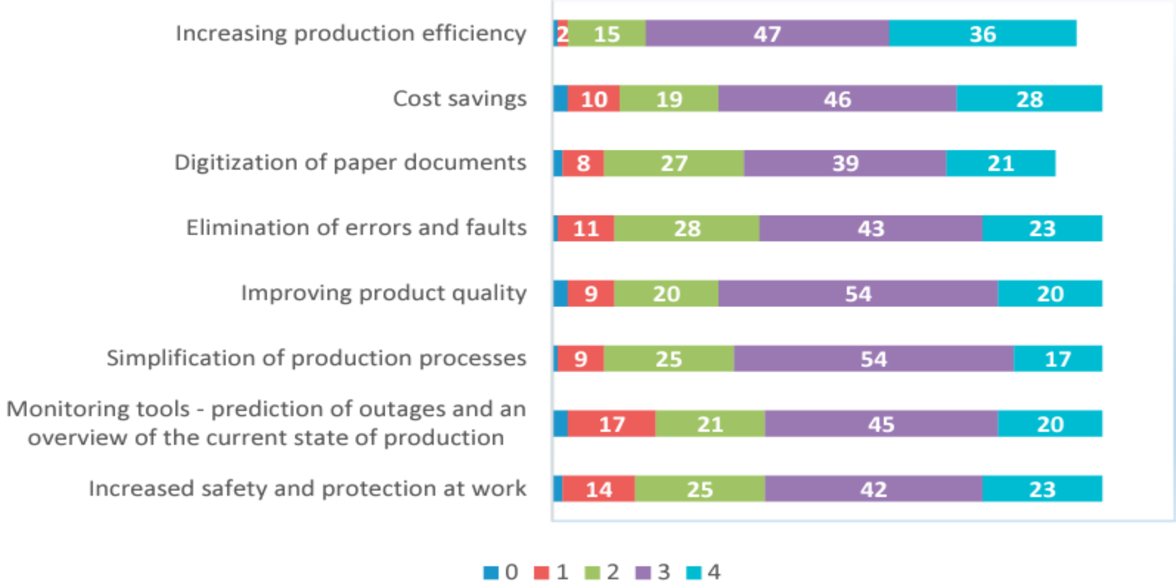

Fig. 3 illustrates the benefits of using automated manufacturing.

1.5.IoT data gathering and connection

Technology advancements throughout the most recent decades have changed how people acquire information. Information is currently being assembled from a number of sources. Mobile phone use, the use of wearable technology, and other technical advancements have become necessities. Despite the fact that data is being collected at a quicker pace, its structure has become more complex.

The biggest challenge is the timely analysis of such massive data sets that have been collected from various sources and settings in order to use them for better decision-making in crucial areas like real-time operations management, the processing and evaluation of data that is generated by devices, and instantaneous defect and risk detection. Zhang, Li, Wan, Wang, and the others (2016).

The Internet of Things (IoT), which connects objects, systems, and people, has changed industrial processes as a result of the rapid development of data protocols, smart devices, and technology [14]. This is taking place as a consequence of the fusion of these components. (2018) (Ansari, Erol, & Sihn). Production systems can interact with one another and exchange data thanks to the Internet of Things (IoT), which is at the heart of the revolution brought on by Industry 4.0. This increases overall industrial efficiency.

(Lu, 2017). High-tech, self-sufficient robotic equipment that is surrounded by Internet of Things (IoT) sensors and connected with sophisticated software systems is often used in today's contemporary industrial operations [15]. The integration of robotic and autonomous equipment has been more popular in recent years, which has significantly increased the efficiency of industrial systems.

1.6.Applications of artificial intelligence in manufacturing

Predictive maintenance, however, may benefit from data-driven AI systems that employ data acquired from IoT devices (Kanawaday& Sane, 2017; Yu et al., 2019; Wang et al., 2017). The goal of this project is to develop a predictive maintenance system that, by using machine learning methods, is able to provide precise forecasts of likely production line faults before they occur [16]. The most efficient model for addressing this problem was developed after a thorough analysis and comparison of many algorithms using a dataset based on the real world.

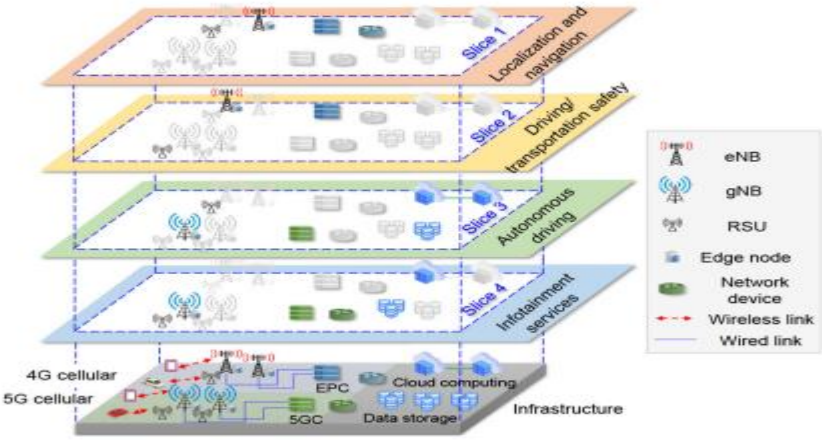

Figure 4 shows the architecture for network slicing used in intelligent transportation.

implementing the recommended strategy in a plant that produces consumer goods In order to test the effectiveness of the proposed system, we have installed it in a real-world manufacturing plant in Turkey as a use case in an additive layered manufacturing process. This will enable us to evaluate the system's effectiveness. This factory makes personal care goods including baby care, feminine hygiene, and home care products for a company that is the market leader in the production of consumer goods [17]. The next subsections will demonstrate how to use the suggested system and the underlying machine learning modeling. This will make it possible to convey our overall strategy via the prism of a particular case.

1.7.Data preprocessing

The dataset was acquired from production lines at a plant that was really running in the real world, making baby diapers. The data values that are produced by the device and that change over time are included in the variables. Data readings from a variety of in-built Internet of Things sensors made up the dataset. These sensors were primarily used to detect characteristics on various pieces of machinery in the manufacturing lines, such as motion, speed, weight, temperature, electrical current, vacuum, and air pressure [18]. The information was gathered using Internet of Things sensors that were checking on the production system every three to six seconds. The dataset was composed of 8,389,515 rows and 101 total attributes.

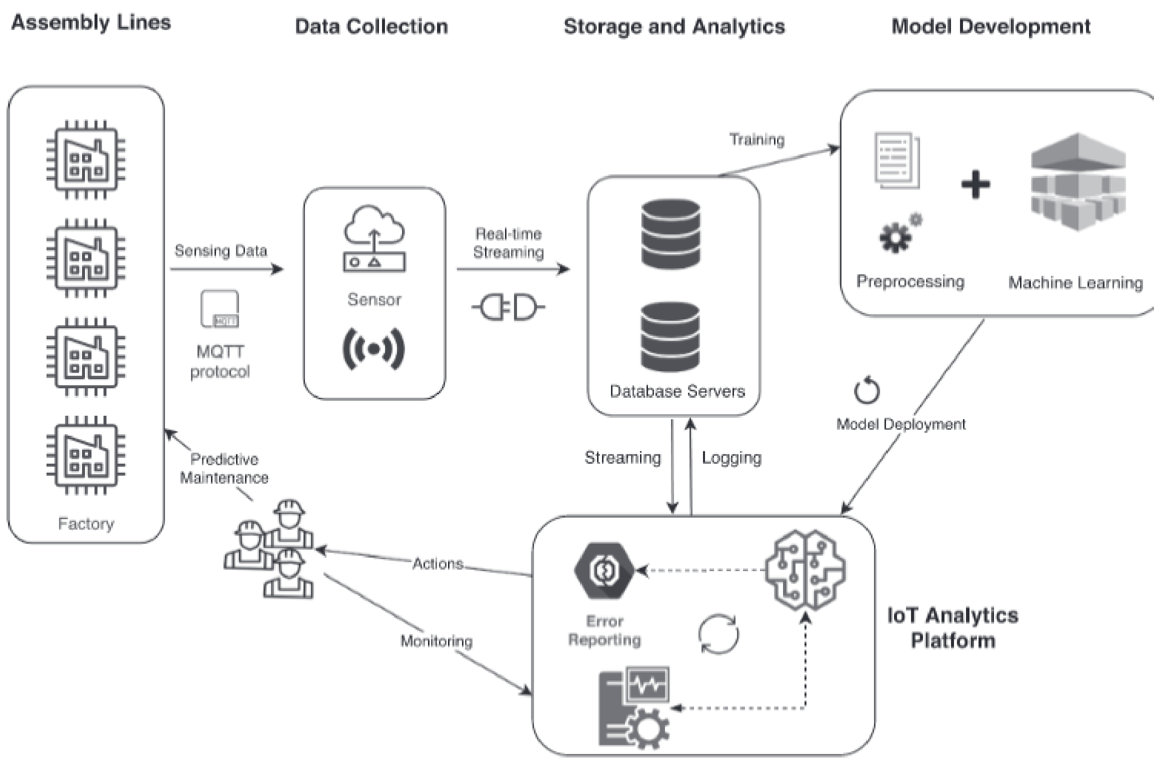

Fig. 5 shows the predictive maintenance system's architecture.

The columns in the dataset were generally full with information. There were just a few columns with a small proportion of missing values, or around 1% of the data. It's possible that errors were made during recording the sensor reading in the database [19], which led to the missing figures. Since the percentage of missing data was so low, the median values of the pertinent columns were automatically filled in for the missing values. The only columns that weren't integers were timestamps. The analytical approaches become quite practical as a result.

1.8.advanced manufacturing

Utilizing state-of-the-art information and manufacturing technology to the fullest extent is the aim of intelligent manufacturing, also known as smart manufacturing, which aims to maximize production and product transactions [20]. It is regarded as a breakthrough manufacturing model based on cutting-edge science and technology that vastly enhances the design, production, management, and integration of the whole life cycle of a typical product. The whole product life cycle may be made more efficient by using advanced materials, clever devices, a range of smart sensors, adaptive decision-making models, and data analytics. There will be advancements in production effectiveness, service level, and product quality [21]. The capacity of a manufacturing organization to handle the turbulence and changes of the global market may boost its competitiveness.

Figure6..scenarios in the field of intelligent transportation.

This idea is realized, in part, via the intelligent manufacturing system (IMS), which is thought of as the next-generation manufacturing system and is obtained by adopting new models, new forms, and new techniques to transform the traditional manufacturing system into a smart system. In the Industry 4.0 era, an IMS leveraging service-oriented architecture (SOA) over the Internet to deliver collaborative, adaptive, flexible, and reconfigurable services to end users makes it feasible to create a highly integrated human-machine production system [22]. In order for managerial, technical, and organizational levels to coexist, this high level of machine-human collaboration aims to build an ecosystem of the many production components in IMS. Through the provision of common aspects like learning, reasoning, and acting, AI plays a significant part in an IMS. As part of the German government's Platform Industrie 4.0 strategic goal, one example of an IMS is the Festo Didactic cyber-physical factory, which provides technical training and certification to major suppliers, academic institutions, and schools [23]. The use of AI technology may cut down on the amount of human involvement in an IMS. For example, materials and production compositions may be created automatically, and production processes and manufacturing activities can be monitored and controlled in real-time [24]. As Industry 4.0 continues to gain popularity, autonomous sensing, intelligent connectivity, intelligent learning analysis, and intelligent decision-making will finally become a reality. An intelligent scheduling system, for instance, may schedule tasks using AI techniques and problem solvers, and it can be made accessible to other users as a service on a platform with Internet connectivity [25].

1.9.IoT-enabled manufacturing

Smart manufacturing objects (SMOs), which can sense, connect, and interact with one another to carry out manufacturing logics automatically and adaptively, are a cutting-edge idea in IoT-enabled manufacturing, which transforms traditional production resources [26]. In IoT-enabled production settings, links between humans, machines, and machines themselves are realized, allowing intelligent perception [27]. Therefore, the use of IoT technology in manufacturing may facilitate on-demand resource pooling and utilisation. Industry 4.0 describes the Internet of Things (IoT) as a contemporary manufacturing concept that incorporates cutting-edge IT infrastructure for data gathering and sharing, which has a substantial influence on the operation of a production system.

1.10.The production of clouds

The phrase "cloud manufacturing" refers to a paradigm for advanced manufacturing that leverages cloud computing, the Internet of Things, virtualization, and service-oriented technologies to turn production resources into services that can be widely used and distributed [29,30]. The "manufacturing cloud" is often thought of as a parallel, networked, and intelligent manufacturing system where production resources and capabilities may be controlled intelligently. It includes all phases of a product's extended life cycle, including design, simulation, manufacture, testing, and maintenance. Thus, with the manufacturing cloud, all various types of end consumers may get manufacturing services on demand [28].

During cloud manufacturing, a variety of production resources and capabilities may be intelligently identified and connected to the cloud. IoT technologies like RFID and barcodes can automatically manage and regulate these resources so they can be transferred to digital form for distribution. This concept is supported by technologies based on the cloud and service-oriented architecture. Thus, manufacturing resources and capabilities may be virtualized, packaged, and distributed into a range of usable services [29]. Such services may be categorized and aggregated with the aid of well-defined criteria. Manufacturing clouds control a variety of manufacturing services and exist in different shapes and sizes. Numerous users may look for, access, and employ the qualified services via a virtual manufacturing environment or platform.

• Ingenious design. The emergence of new technologies like augmented reality (AR) and virtual reality (VR), which are developing quickly, will update conventional design and usher in the "smart era." • Intelligent gadgets. Design software like computer-aided design (CAD) and computer-aided manufacturing (CAM) may communicate with actual smart prototype systems in real time thanks to three-dimensional (3D) printing technology coupled with CPSs and AR. Industry 4.0 may employ smart robots and numerous other intelligent things to build intelligent machines that are capable of real-time sensing and interacting with one another. For instance, CPS-enabled smart machine tools may gather real-time data and communicate it to a central system that is hosted in the cloud, enabling the synchronization of the machine tools and the services that are provided in order to provide smart manufacturing solutions.

Fig. 7. A framework of the Industry 4.0 IMS.

• Excellent observation. Monitoring is necessary for the proper functioning, upkeep, and scheduling of Industry 4.0 production systems. The widespread usage of a variety of different kinds of sensors makes smart monitoring possible.

For instance, it is possible to gather real-time data and information on a range of industrial characteristics, such as temperature, power usage, vibrations, and speed.

• Adaptive management. Industry 4.0 may accomplish high-resolution, adaptive production control (also known as smart control) by developing cyber-physical production-control systems. Using a cloud-enabled platform to physically operate a variety of smart equipment or devices is the fundamental goal of smart control. Customers may switch off equipment or robots using their cellphones [30].

• Astute preparation. The smart scheduling layer largely uses the sophisticated models and algorithms to extract information from the sensor data. Complex decision architecture and data-driven approaches may be used for intelligent scheduling. For instance, to achieve reliable scheduling and execution in real-time.

1.10. Associated smart manufacturing technologies

The efficient fusion of many technologies is a must for smart manufacturing processes. The most notable ones are shown in Fig. 8 and described in more detail below.

1.11. Integrated technologies

New techniques for developing, presenting, and engaging with applications, material, and experiences are referred to as immersive technology. By combining the senses of sight, sound, and touch, this technology has completely changed the digital experience. Virtual reality, augmented reality, and mixed reality are the three subcategories of immersive technologies that are now available. In this paragraph, we describe each of their contributions to smart manufacturing.

the online world

The use of virtual reality (VR) in the industrial industry is growing. Virtual reality technology merges computer-generated and simulated movies with real-world activities. Prototyping takes less time and money when the design can be seen from the start without the real product. In a simulated target environment, the product's uses may also be digitally seen, which increases the potential for product customisation and other significant modifications to the product design [41].

1.12. Virtual reality

Augmented reality (AR) merges the real and virtual worlds via wearables and mobile devices. An artificial environment that digitally observes and analyzes every item and its usage is constructed using a computer simulation. In AR devices, the dynamic fusion of different pertinent videos, images, animations, sounds, texts, etc. functions as a universal interface to improve human-machine interactions [47]. Using the AR device, the operators may evaluate ambient intelligence and react appropriately to manufacturing-related activities in real-time. Thus, the information gained may improve decision-making's efficacy and quality, producing superior overall results [47]. Additionally, it may be used to create seminars, carry out online training, and assess products by looking at their digital prototypes. Standard equipment may be used to deploy AR; expensive, highly specialized equipment is not required [49]. Similar to VR, augmented reality technology may be used to improve training for new recruits.

Fig. 8 illustrates the technologies used in smart manufacturing.

Through the use of an AR, a technician may quickly see how to dismantle equipment, see how the components interact inside, and perform service or repairs without any previous training [48]. When AR is used, industrial processes become more productive. A commercial AR tool, for instance, is used by GE Healthcare warehouse staff to kit and collect list orders up to 46% quicker. The AR tool's link to a smart warehouse network allows the employees to get easy-to-read guidance on where to locate the objects around the warehouse [50]. By utilizing the Microsoft AR tool to examine holographic models of certain complex aircraft components and the instructions required to manufacture them, Lockheed Martin was able to cut the time needed for component assembly by 30% [50].

Engineers can benefit from virtual reality and augmented reality (VR and AR) technologies in a variety of ways, such as (i) accelerating support for production lines, (ii) helping shop floor operators operate equipment more effectively, (iii) providing instruction for assembling components via virtual training, (iv) effectively monitoring warehouse activities, and (v) supporting advanced diagnostics integrated into modules .

Mixed reality (MR), a novel environment where digital and physical objects co-exist and interact in real time, combines the real and virtual worlds. The use of MR in the smart manufacturing system is growing, much like its equivalents in VR and AR. MR De- vices will provide the maintenance personnel with thorough training on the tools they will use. In the virtual world, they work flawlessly.

2. Additive manufacturing

Additive manufacturing (AM), which is basically computer-controlled 3D printing of objects, is a key component of smart manufacturing. The creation of samples for R&D in production units is subject to limitations. (R&D). The production of these 3D prototypes may be completed much more quickly with the right component material composition and design requirements . For research purposes, AM is particularly useful for generating complex components rapidly and correctly. This expedites the bulk customization and design processes, as well as any necessary revisions in the following stages . In order to better meet customer demand, a product's target design, materials, related attributes, and safety measures are improved as a result. In a facility with several 3D printing machines, the AM procedure may be remotely handled online and goods that users have expressly described can be printed within each machine [41]. Additive manufacturing drastically cuts down on both time and cost during R&D. By using 3D printing, it is possible to generate a product's designated application area and get insight into how effectively it functions overall. Smaller companies and customers could gain from AM's aid in developing innovative concepts and product prototypes on their own as self-designers and manufacturers [37]. Online shoppers may purchase designs and then change the materials, colors, and other aesthetic features to suit their own preferences. They might simultaneously check for equipment and supply availability. As a consequence, customers may purchase specific products and submit their ideas promptly [38].

2.1.Industrial Internet of Things (IIoT)

The Industrial Internet of Things (IIOT) is essential in the emerging Industry 4.0. In this method, sensors are attached to each stage of a manufacturing line to monitor the operation of the machinery and the results of the process. The sensors are connected through the Internet cloud to enable the fusion of all process steps [35]. Better production planning is made possible by this integration's smart process management of tool and material optimization, preventative maintenance, identifying machine problems, and enhanced human-machine interaction . With the help of IIoT-enabled interconnected digital supply networks (DSNs), conventional factories may become smarter by being more efficient, less expensive, and less risky to operate [30]. Manufacturers are able to discover a range of difficulties, which lowers manufacturing costs and delays, by utilizing machine learning and big data analytics to gather and analyze the data from all the sensors. The IIoT is a crucial part of smart manufacturing and offers various benefits for supply chain effectiveness, predicting equipment failure, and quality control [40]. The sensor data is saved in the cloud through an IoT connection, where it is further analyzed, integrated with the necessary 242information, and shared with authorized stakeholders. IIoT significantly improves industrial outcomes by increasing productivity and reducing material waste, enabling speedier manufacturing while maintaining high-quality goods.

2.2. AI's impact on smart manufacturing

Checks for quality

Quality checks are the most important step in a manufacturing process because they may remove undesired goods from the production process before they reach the market. Finding effective ways to do thorough quality checks is challenging, however. Manual inspections take time, and since mistakes are certain to happen, they may result in inconsistent and subpar product quality. In order to ensure consumer satisfaction and loyalty, extremely sophisticated quality checks must be performed across the whole supply chain in addition to inspections on the production line. Robots, autonomous machines, and gadgets can view, recognize, and analyze pictures autonomously thanks to machine vision, an imaging-based inspection technology. Additionally, these gadgets have the ability to autonomously assess product quality and transmit information from the assembly line to the warehouse for fulfillment to the distribution center.

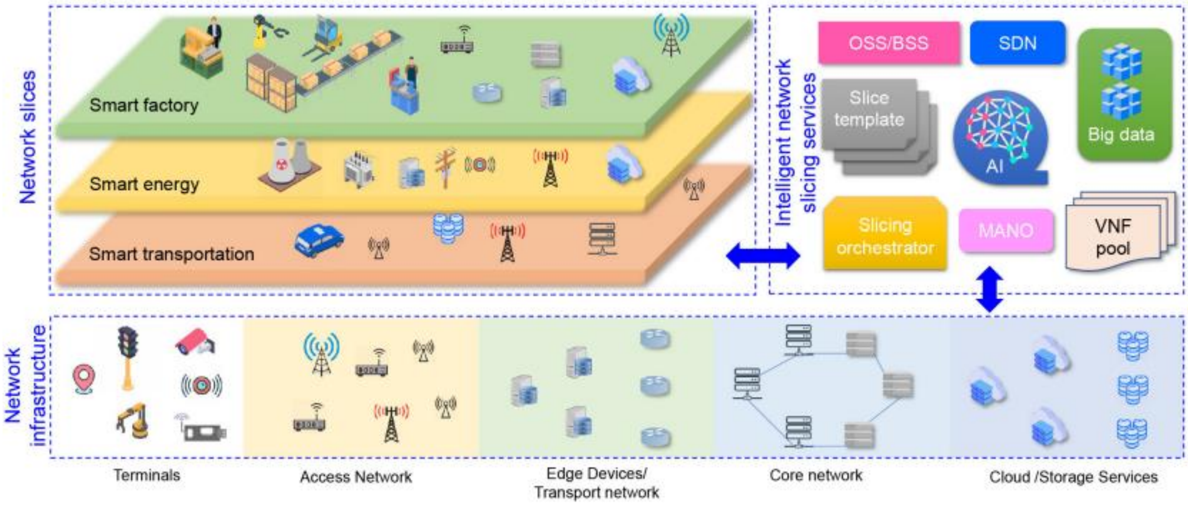

Figure 9. Intelligent network slicing management architecture for smart factories, smart energy, and smart transportation

Machine vision combines artificial intelligence, edge computing, and high-resolution smart cameras [47]. AI-based machine vision systems can identify defects and mistakes in packaging and labeling and, depending on the situation, can also take the necessary action. Standard machine vision can detect issues but cannot classify them or respond appropriately. AI-based machine learning becomes increasingly effective when more images are acquired, the problem is identified, and the proper course of action is then taken. Industry production and processing depend on automatic optical inspection (AOI), which is based on machine vision. Research has demonstrated that AOI increases competitiveness in addition to product quality and productivity [18]. A typical AI-based machine vision setup is shown in Figure 9 with a smart camera that is equipped with the necessary sensors and AI integration software. The camera is also connected to a cloud storage of similar images. The system as a whole gets ready to take pictures. The working distance is automatically altered by zooming in and out as necessary. This technique is known as pre-processing automation. As the photo is being shot, the image processor is processing it. The pictures are prepared at this step by undergoing a number of changes, such as converting color images to grayscale and standardizing their sizes. The information gleaned from an image is afterwards examined by a number of algorithms in order to create predictions. A large number of subpar elements will be disregarded by the algorithm during picture processing.

2.3. Automated Optical Inspection (AOI) in smart manufacturing

High-quality quality control is one of the most important components of every production facility in the era of Industry 4.0. This is because evaluating the products before they are sold is an efficient way to reduce supply chain delays and to maintain high quality standards. Due to its non-destructive methodology, the AOI technique is the one that is utilized for exams the most often. (NDT). The human eye is capable of picking up electromagnetic waves with wavelengths ranging from 390 to 770 nanometers (nm), and this range is called the human visual spectrum. On the other hand, video cameras may be modified to be able to detect a much larger range of wavelengths.

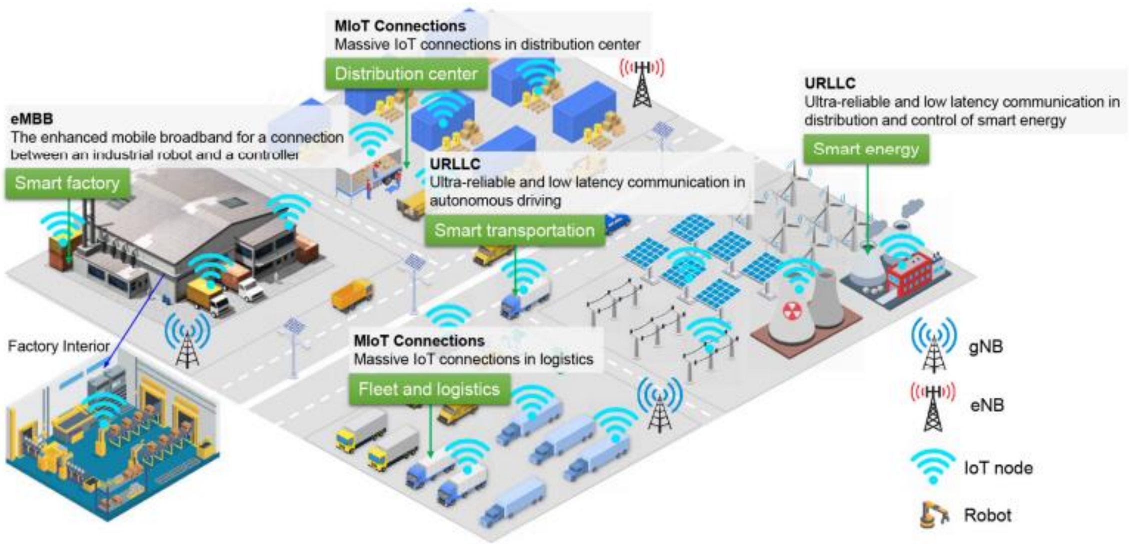

Fig. 10. Critical requirements of IIoT applications.

2.4. AI-Powered AOI

Electric and electronic device designs have evolved over time, making it more challenging to examine them using conventional AOI techniques for quality control. A large amount of image data from successful and unsuccessful products is collected by an AI-based AOI system. The built-in algorithm of the AI software can efficiently decide where and what to look for thanks to the ruleset-based approach [10]. More precisely scanned items are more prevalent. The capacity of high-resolution AI-powered cameras to conduct quality checks at any point along the production line and discover flaws in real-time makes it simpler to locate the causes of flaws in the early phases of production [27]. In order to enhance the effectiveness and speed of the detection process, manufacturers have lately introduced machine learning and deep learning technologies to AOI systems in their smart factory production lines [19]. As a result, AOI enabled by AI enhances yield and manufacturing processes while drastically decreasing the amount of human labour [18].

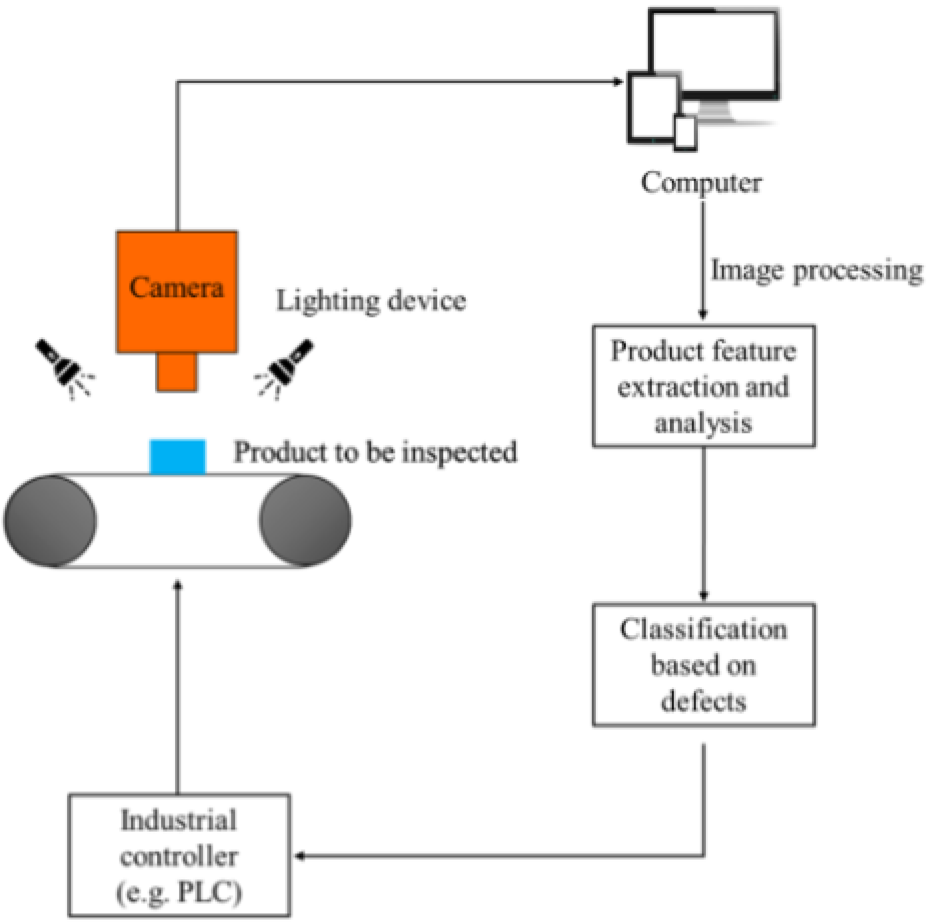

Fig. 11. Schematic diagram of a basic AOI system

2.5. challenges with smart manufacturing

There are always major security threats, regardless of how complex a system is. Even after using state-of-the-art technology in numerous factories to achieve smart manufacturing, businesses still face a number of challenges. There will always be new risks since the foundation of smart manufacturing is a degree of technical complexity, integration, and automation that is much beyond that of traditional manufacturing processes. Additionally, the lack of agreement on security is unsettling. The rise in cyberattacks on intelligent factories demonstrates that even current systems are susceptible to a number of poorly understood security risks. Because of this, organisations are ill-prepared to handle contemporary security risks [13]. Small and medium-sized businesses (SMEs) in particular struggle greatly to overcome these obstacles because of their low financial resources [14].

2.6. Data security

Data security is necessary for the adoption of smart factories, where IIoT and IoT are commonly used to combine operational technology (OT), information technology (IT), and intellectual property (IP) [15]. In smart factories, a combination of physical and virtual technology enables interoperability and real-time operation. However, cyberattacks are a possibility. There is always a danger of a data breach when data is traded online. The misuse of this highly classified information exposes the industrial sector to significant risks on a daily basis. 65% of organisations, according to a poll, think that IoT technology mainly raises cybersecurity risks [16]. A single attack may completely shut down a smart factory, denying users access to real-time data monitoring, predictive maintenance, and supply chain management.

Therefore, impenetrable cybersecurity is very necessary for smart infrastructures. In a 2019 report by Deloitte and the Manufacturers Alliance for Productivity and Innovation (MAPI) on risks related to smart factories, it was found that 48% of the factories surveyed viewed operational risks, such as cybersecurity, as their greatest threat—one that could easily disrupt production, business, and the market.Along with smart manufacturing practises, manufacturers should provide cybersecurity to all employees. Organisations should adopt layered security measures to protect all networks and react quickly to outside assaults on IT and OT systems [19].

2.7.System Interoperability and Integration,

Machines in smart factories often include contemporary technologies. However, compatibility issues between older and newer devices could exist. The hardest problem is establishing machine-to-machine (M2M) connectivity. For instance, modern production systems enable several devices connected simultaneously and work best with IPv6 connections, which may not be the case with older models of the equipment [14]. The two primary problems with autonomous machine interactions in the context of smart manufacturing are the pervasive M2M connections and machine understanding [20]. The absence of a clear understanding of the return on investment (ROI) of the new technology also deters firms from making sizable expenditures [11]. Furthermore, smart manufacturing is not necessarily improved by the most latestIIoT and AI technology. If their real experience providing solutions is researched, it will be much more important to build a successful smart factory in addition to bringing new technology hardware and software [22]. The use of these technologies ought to enhance the interoperability of systems. The ability of machines to interact with one another is influenced by the factors listed below: Even when different versions of software are developed by the same manufacturer, compatibility and data transfer are problems. Other problems include inconsistent data formats, misunderstood terminology used to communicate data between devices, and IoT connections.

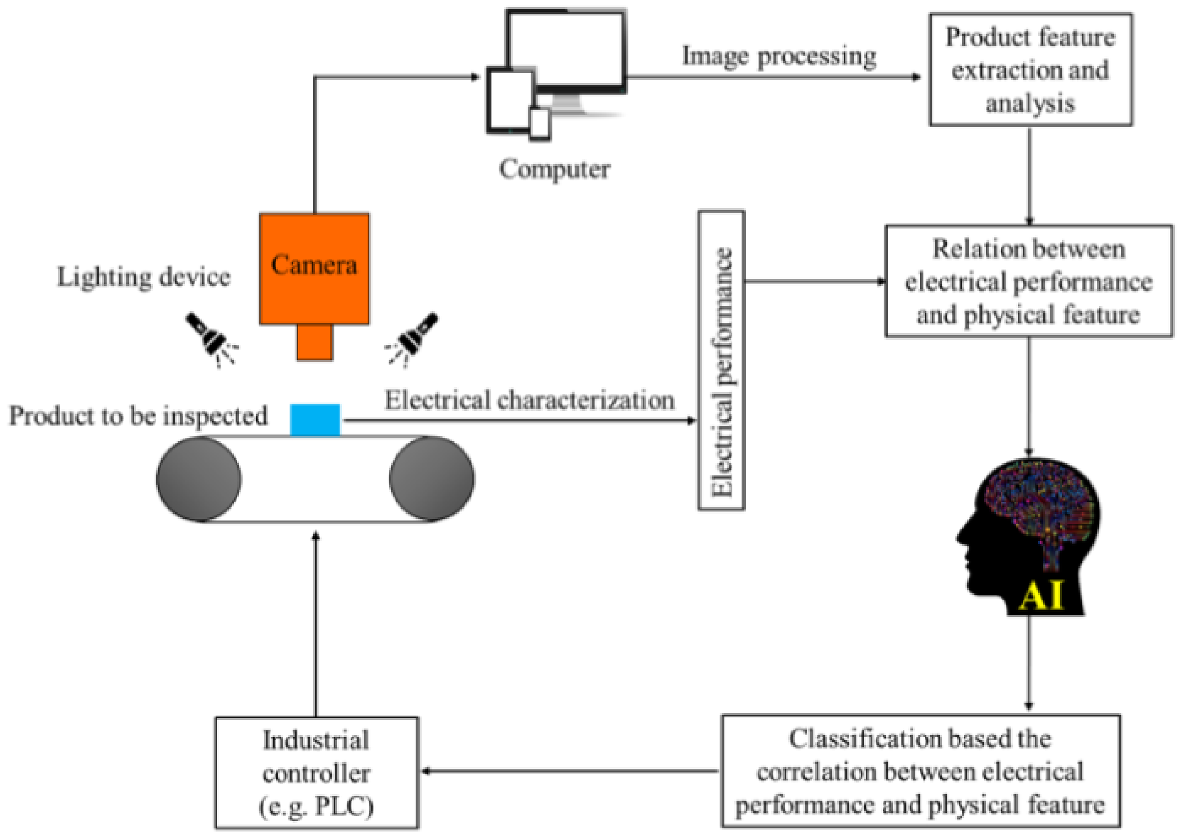

fig. 12. Schematic diagram of an AI-powered AOI system

Smart manufacturing is a key paradigm for the fourth industrial revolution because it holds the promise of personalisation according to the end user, improved product quality, and higher factory efficiency. The evolution of industrial manufacturing technology and the current status of smart manufacturing, a crucial element of Industry 4.0, are both examined in this article. The influence that AI technologies have on the whole manufacturing process has been emphasised, and we have also gone into great depth regarding a variety of smart manufacturing technologies. Current problems are also mentioned, which may provide academics and professionals inspiration for next research projects.

Manufacturers are deciding to completely automate their factories in order to save labour expenses and increase productivity. AI-powered quality checking technology also significantly helps the market's capacity to sell the best quality products. Furthermore, innovative concepts like CPS, IIoT/IoT, additive manufacturing, and immersive technologies have significantly improved production processes that make use of smart manufacturing systems. Since these technologies are not often employed in the majority of industrial enterprises, the concept of smart manufacturing varies substantially from the real production system. This can be due to difficulties integrating smart manufacturing technologies, a lack of knowledge, and uncertainty regarding the returns on such investments. Although the adoption of smart manufacturing may be challenging at initially, it may have a significant positive impact on both enterprises and end users.

3. SMART FACTORY

Significant improvements brought about by the 5G network slicing enable the continued digitalization drive in the Industry 4.0 and smart manufacturing sectors. As a way to provide new services and improve operational performance, network connectivity is becoming increasingly crucial for manufacturers. To handle the many diverse traffic types, dynamic resource needs, and time-varying utilisation rates that are produced by the several applications, factory networks need to be flexible and isolated. The network slicing paradigm may create several logical network instances on top of a single network infrastructure by using NFV and SDN networking techniques.Each instance has the ability to have its own quality of service (QoS) specifications that may be tailored to fit the needs of specific use cases and commercial services.

3.1.Requirements and Architecture

A significant element of the transition to Industry 4.0 is the development of smart factories, where machines and sensors will produce enormous volumes of data that can be used to coordinate and receive feedback almost instantly [14]. The networks of smart factories may become more flexible and have a better QoS thanks to network slicing. By creating conceptually independent virtual networks, network slicing enables many industrial use cases with varied QoS requirements to be handled simultaneously over the same physical infrastructure [18]. However, there hasn't been any in-depth research on the design and management of network slices for smart factories. For smart factory verticals, network slice management must take into consideration the unique factory network architecture, a variety of resource types, a wide range of network domains, and stringent business specification needs, all of which necessitate well-defined management models and cunning strategies.

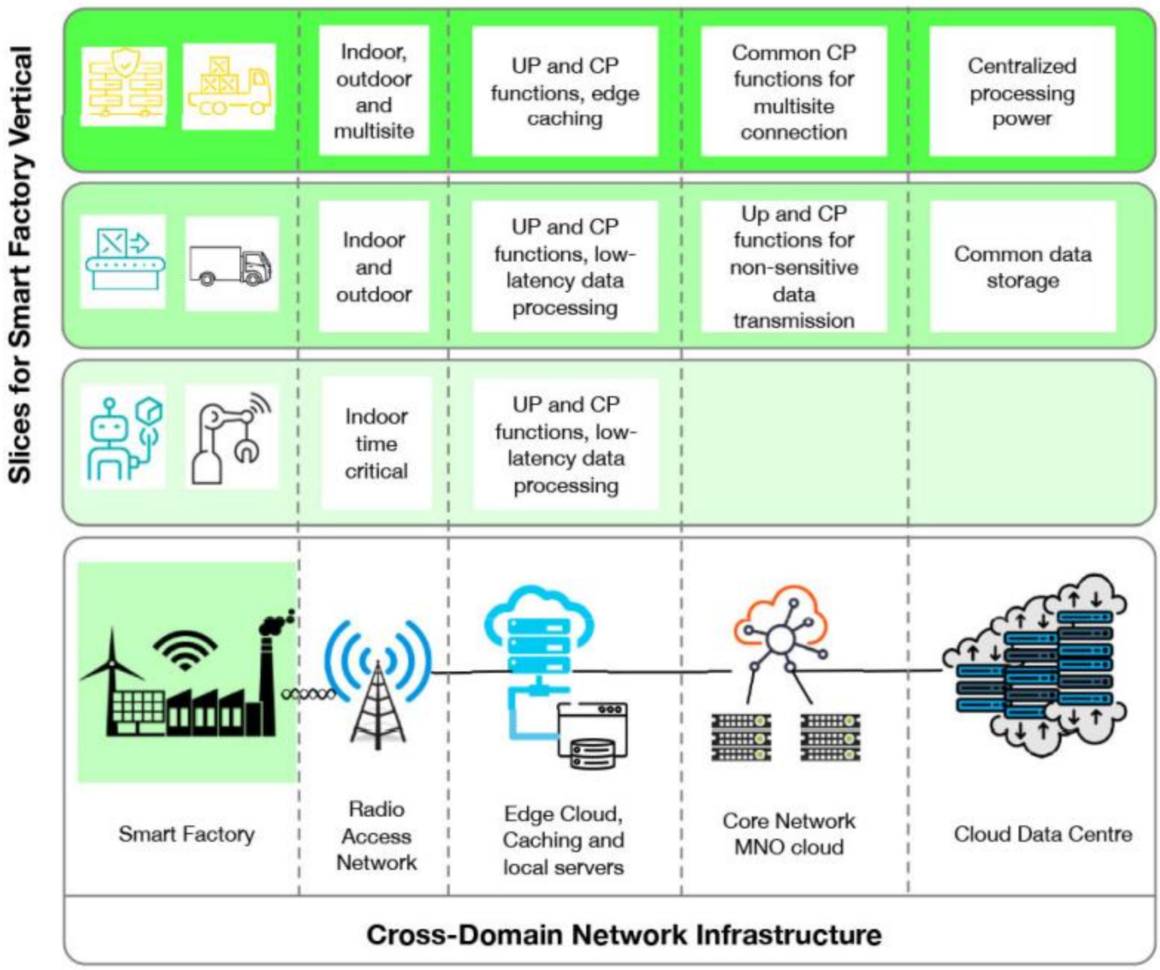

Figure 13. shows an example of End-to-End network slicing across several domains in the context of a smart factory.

4. CASE STUDY

This section presents a case study of an integrated IIoT-enabled smart manufacturing, smart energy system, and smart transportation system. In this case study, we examine an actual candy-wrapping production line in a smart factory that has reliable energy supply and management, effective logistics, and quick client delivery. As shown in Fig. 14, a three-part end-to-end network slicing with the manufacture of candy wrapping, energy supply and management, and logistics and delivery is necessary. Before demonstrating how multi-agent reinforcement learning may be used to manage the network slicing for this case study, we will go through each phase of this end-to-end network slicing in the parts that follow.

The candy-wrapping production line includes robot arms, sensors, an RFID reader, RFID tags, security cameras, a Raspberry Pi 3B, and a conveyer belt. A 5G base station and an industrial Ethernet with time-sensitive networking (TSN) [223] capabilities are used to connect them. It is significant to note that the 5G base station also contains the NVIDIA Jetson TX2 module, which serves as an edge computing node to process IoT data locally in the factory. To provide the connection required for data collection of candy-wrapping factory, a network slicing based on the TSNempowered industrial Ethernet and the 5G base station is created. The edge computer node will be virtualized, and the network slicing will get enough processing power to support the computation required for candy-wrapping production.

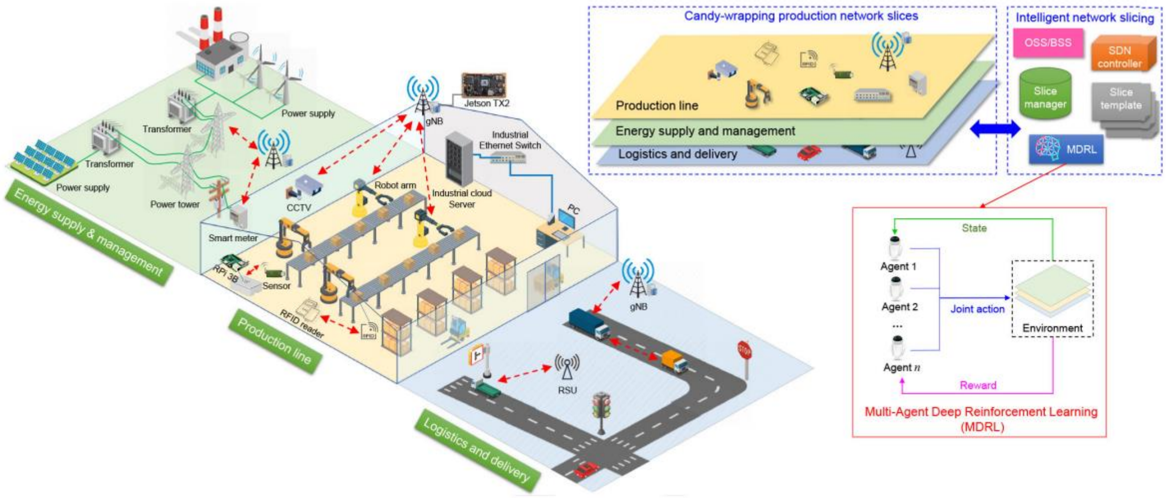

Fig. 14. Case study: A manufacturing line for packaging candies

5. Conclusion

The industrial industry may benefit from predictive maintenance thanks to the Internet of Things (IoT), which uses sensors to track data on a variety of metrics and monitor equipment performance. Machine learning algorithms may be used to analyse this data and forecast when a machine is likely to break so that maintenance can be planned appropriately. This proactive maintenance strategy may avoid unscheduled downtime, save maintenance costs, and increase the overall efficacy of the equipment. By seeing potential faults before they develop into significant ones, IoT-enabled predictive maintenance may assist manufacturers in switching from reactive maintenance to proactive maintenance. Because it enables proactive maintenance planning, lowers costs, and boosts operational effectiveness, predictive maintenance has grown in significance for the industrial industry. Because equipment may not always need repair at the specified time, the conventional maintenance strategy, which includes scheduling maintenance at defined intervals, sometimes results in excessive downtime and maintenance expenses. On the other side, predictive maintenance employs real-time data to monitor equipment performance and spot maintenance requirements before they become serious problems. IoT is essential for allowing predictive maintenance because it offers the connection and data analytics tools required. IoT sensors may be used to gather a variety of data, including temperature, vibration, energy use, and more, giving manufacturers a more complete picture of the health of their equipment. Manufacturers can forecast possible problems and respond appropriately by employing machine learning algorithms to analyse these data points and find trends and patterns. Manufacturers may save maintenance expenses by employing predictive maintenance based on IoT. Manufacturers may save downtime and excessive maintenance costs by planning maintenance for when it is truly required, rather than at predetermined intervals. Additionally, the expense of emergency repairs and replacements may be decreased by being able to anticipate breakdowns and plan maintenance in advance. IoT-based predictive maintenance may have a big impact on the industrial industry. Manufacturers may save costs, boost productivity, and decrease downtime by utilising real-time data to monitor equipment performance and anticipate maintenance requirements. The potential advantages of predictive maintenance are anticipated to become more apparent as IoT develops, enabling manufacturers to better their entire operations and optimise their maintenance methods.

6. References

[1] Devi, Munisha, and Nasib Singh Gill. "Mobile Ad Hoc Networks and Routing Protocols in IoT Enabled." Journal of Engineering and Applied Sciences 14.3 (2019): 802-811.

[2] Zou, Zhuo, et al. "Edge and fog computing enabled AI for IoT-an overview." 2019 IEEE International Conference on Artificial Intelligence Circuits and Systems (AICAS). IEEE, 2019.

[3] WHITE PAPER · INTERNET OF THINGS (IoT) · TECHNOLOGY, ECONOMIC VIEW AND TECHNICAL STANDARDIZATION · Version 1.0

[4] Yuan Ai, Mugen Peng, Kecheng Zhang, Edge computing technologies for Internet of Things: a primer, Digital Communications and Networks, Volume 4, Issue 2, 2018, Pages 77-86, ISSN 2352-8648

[5] Razouk, Wissam, Daniele Sgandurra, and Kouichi Sakurai. "A new security middleware architecture based on fog computing and cloud to support IoT constrained devices." Proceedings of the 1st international conference on internet of things and machine learning. 2017.

[6] R. Lu, K. Heung, A. H. Lashkari and A. A. Ghorbani, "A Lightweight Privacy- Preserving Data Aggregation Scheme for Fog Computing-Enhanced IoT," in IEEE Access, vol. 5, pp. 3302-3312, 2017, doi: 10.1109/ACCESS.2017.2677520.

[7] Çorak, Burak H., et al. "Comparative analysis of IoT communication protocols." 2018 International symposium on networks, computers and communications (ISNCC). IEEE, 2018.

[8] Jaloudi, Samer. "Communication protocols of an industrial internet of things environment: A comparative study." Future Internet 11.3 (2019): 66.

[9] Al-Sarawi, Shadi, et al. "Internet of Things (IoT) communication protocols." 2017 8th International conference on information technology (ICIT). IEEE, 2017

[10] H. Zorgati, R. B. Djemaa and I. A. B. Amor, "Service discovery techniques in Internet of Things: a survey," 2019 IEEE International Conference on Systems, Man and Cybernetics (SMC), 2019, pp. 1720-1725, doi: 10.1109/SMC.2019.8913969.

[11] Lalle, Yandja, et al. "A comparative study of lorawan, sigfox, and nb-iot for smart water grid." 2019 Global Information Infrastructure and Networking Symposium (GIIS). IEEE, 2019.

[12] R. S. Pukale, S. V. Bavache, S. N. Kashid, A. P. Sabale, P. P. Patil and P. H. Shinde, "Automatic meter reading of electricity by using power line communication," 2017 International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT), 2017, pp. 1-5, doi: 10.1109/IGEHT.2017.8094100.

[13] Ahmed, Tanvir, et al. "Automatic electric meter reading system: A cost-feasible alternative approach in meter reading for Bangladesh perspective using low-cost digital wattmeter and WiMAX technology." arXiv preprint arXiv:1209.5431 (2012).

[14] Kesav, O. Homa, and B. Abdul Rahim. "Automated Wireless Meter Reading System for Monitoring and Controlling Power Consumption." International Journal of Recent Technology and Engineering 1.2 (2012): 66-69.

[15] Shinde, Manisha V., and Pradip W. Kulkarni. "New development in energy meter reading system." International Journal of Scientific Research and Management Studies (IJSRMS) 1.4 (2014): 124-129.

[16] Štruklec, Gordan, and Vedran Bilas. "Wireless Automatic Water-meter Reading System." XVIII IMEKO World Congress-International Measurement Confederation. Pag. 2007.

[17] Q. Zhu, R. Wang, Q. Chen, Y. Liu and W. Qin, "IOT Gateway: Bridging Wireless Sensor Networks into Internet of Things," 2010 IEEE/IFIP International Conference on Embedded and Ubiquitous Computing, Hong Kong, China, 2010, pp. 347-352, doi: 10.1109/EUC.2010.58.

[18] Alcaraz, Cristina, et al. "Wireless sensor networks and the internet of things: Do we need a complete integration?." 1st International Workshop on the Security of the Internet of Things (SecIoT'10). 2010.

[19] Mekki, Kais, et al. "A comparative study of LPWAN technologies for large-scale IoT deployment." ICT express 5.1 (2019): 1-7.

[20] Zanella, Andrea, et al. "Internet of things for smart cities." IEEE Internet of Things journal 1.1 (2014): 22-32.

[21] Bhushan D. and Snehal S. "A Review Paper on Automatic Meter Reading and Instant Billing". International Journal of Advanced Research in Computer and Communication Engineering, Vol. 4, Issue 1, January 2015

[22] Amaxilatis, Dimitrios, et al. "A smart water metering deployment based on the fog computing paradigm." Applied Sciences 10.6 (2020): 1965.

[23] Lloret, Jaime, et al. "An integrated IoT architecture for smart metering." IEEE Communications Magazine 54.12 (2016): 50-57.

[24] Sliwa, Jan. "A Generalized Framework for Multi-party Data Exchange for IoT Systems." 2016 30th International Conference on Advanced Information Networking and Applications Workshops (WAINA). IEEE, 2016

[25] Datta, Soumya Kanti, et al. "oneM2M architecture based IoT framework for mobile crowd sensing in smart cities." Networks and Communications (EuCNC), 2016 European Conference on. IEEE, 2016.

[26] Joseph Boman et. al., "Flexible IoT Middleware for Integration of Things and Applications" in 10th IEEE International Conference on Collaborative Computing:

[27] Networking, Applications and Worksharing, 2014Sanchez, Tomas, et. al. "Adding sense to the internet of things—an architecture framework for smart object systems." Pers Ubiquitous Comput 16.3 (2012): 291-308

[28] Wadekar, Sayali, et al. "Smart water management using IOT." 2016 5th International Conference on Wireless Networks and Embedded Systems (WECON). IEEE, 2016.

[29] Singh, Manmeet, and Suhaib Ahmed. "IoT based smart water management systems: A systematic review." Materials Today: Proceedings (2020).

[30] Fagiani, Marco, et al. "A novelty detection approach to identify the occurrence of leakage in smart gas and water grids." 2015 International Joint Conference on Neural Networks (IJCNN). IEEE, 2015.

[31] Cherukutota, Neeharika, and Shraddha Jadhav. "Architectural framework of smart water meter reading system in IoT environment." 2016 International Conference on Communication and Signal Processing (ICCSP). IEEE, 2016.

[32] Fuentes, Henry, and David Mauricio. "Smart water consumption measurement system for houses using IoT and cloud computing." Environmental Monitoring and Assessment 192.9 (2020): 1-16.

[33] Arun, S., and Sidappa Naidu. "Design and implementation of automatic meter reading system using GSM, ZIGBEE through GPRS." International Journal of Advanced Research in Computer Science and Software Engineering 2.5 (2012).

[34] Shahanas, K. Mohammed, and P. Bagavathi Sivakumar. "Framework for a smart water management system in the context of smart city initiatives in India." Procedia Computer Science 92 (2016): 142-147.

[35] Mudumbe, Mduduzi John, and Adnan M. Abu-Mahfouz. "Smart water meter system for user-centric consumption measurement." 2015 IEEE 13th international conference on industrial informatics (INDIN). IEEE, 2015.

[36] Carrillo, Enrique, et al. "IoT framework for smart buildings with cloud computing." 2015 IEEE First International Smart Cities Conference (ISC2). IEEE, 2015.

[37] Sarraf, Rajan, et al. "IoT based Smart Quality Water Management System." international journal 5.3 (2020).

[38] Ray, Aritra, and Shreemoyee Goswami. "IoT and Cloud Computing based Smart Water Metering System." 2020 International Conference on Power Electronics & IoT Applications in Renewable Energy and its Control (PARC). IEEE, 2020.

[39] Antzoulatos, Gerasimos, et al. "Making urban water smart: the SMART-WATER solution." Water Science and Technology 82.12 (2020): 2691-2710.

[40] Baoding Zhang, Jialei Liu, "A kind of design schema of wireless smart water meter reading system based on ZigBee technology" in E-Product E-Service and E-

[41] Entertainment (ICEEE), 2010 International Conference on, Nov. 2010, pp 1-4Laubhan, Kevin, et al. "A low-power IoT framework: From sensors to the cloud." Electro Information Technology (EIT), 2016 IEEE International Conference on.

[42] IEEE, 2016Jovanovic, Philipp, and Samuel Neves. "Practical cryptanalysis of the open smart grid protocol." International Workshop on Fast Software Encryption. Springer, Berlin, Heidelberg, 2015.

[43] Kursawe, Klaus, and Christiane Peters. "Structural weaknesses in the open smart grid protocol." Availability, Reliability and Security (ARES), 2015 10th International Conference on. IEEE, 2015.

[44] Dlodlo, Nomusa, et. al. "The state of affairs in internet of things research."Electronic Journal of Information Systems Evaluation 15.3 (2012): 244-259

[45] Guest Editorial, "Special Issue on Internet of Things (IoT): Architecture, Protocols and Services" in IEEE Sensors Journal, vol. 13, no. 10, October 2013 Web Reference: