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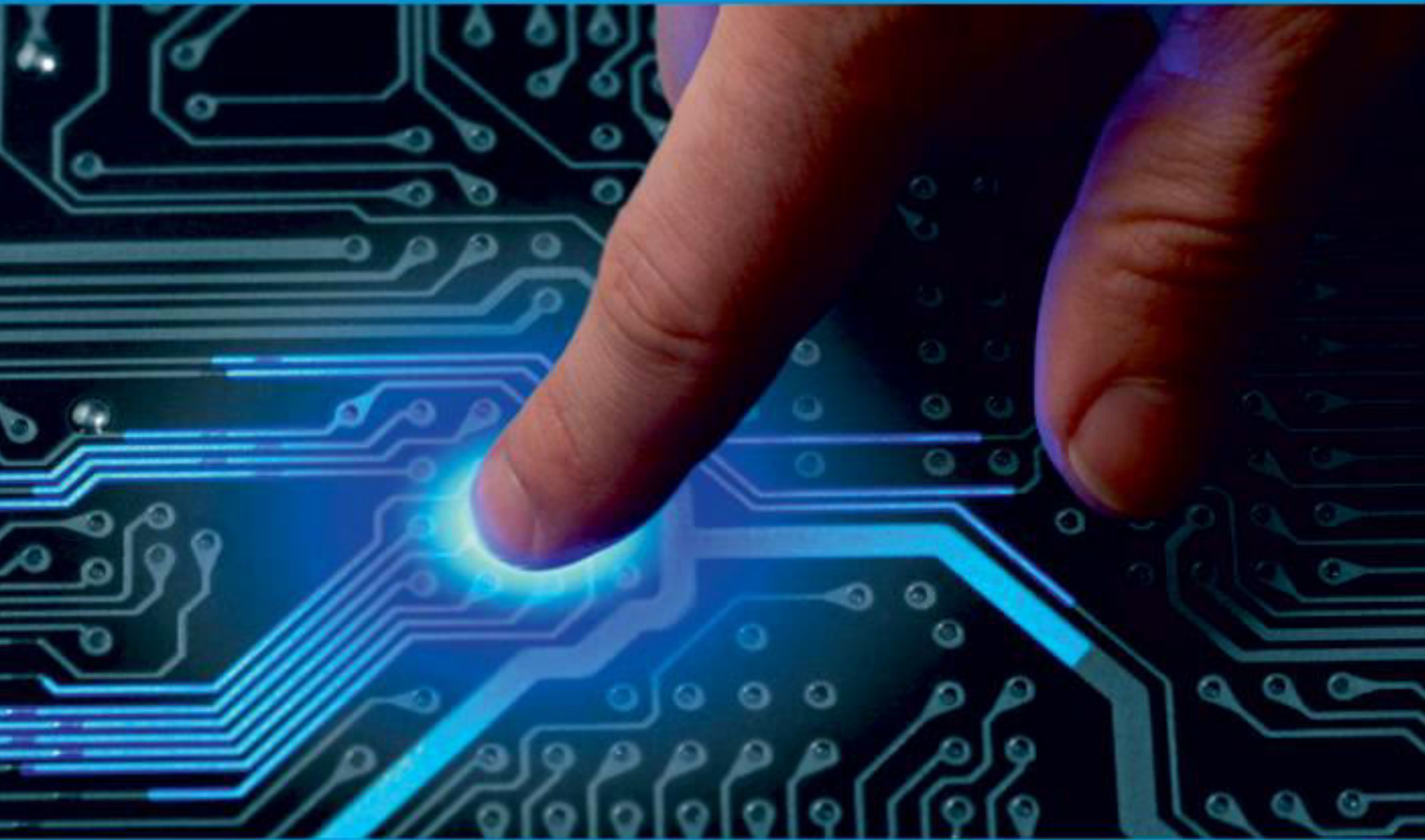

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Industry 4.0

Pratik Tawde, Prerana Jalgaonkar, Samidha Chavan, Kirti Gupta, Kalyani Pawar, Sangeeta Shirsat

Lecturer, Department of EXTC, Vidyalankar Polytechnic, Wadala, Mumbai, India

Lecturer, Department of Information Technology, Vidyalankar Polytechnic, Wadala, Mumbai, India

Lecturer, Department of Information Technology, Vidyalankar Polytechnic, Wadala, Mumbai, India

Lecturer, Departtment of EXTC, Vidyalankar Polytechnic, Wadala, Mumbai, India

Lecturer, Department of Information Technology, Vidyalankar Polytechnic, Wadala, Mumbai, India

Lecturer, Department of Computer Engineering, Vidyalankar Polytechnic, Wadala, Mumbai, India

ABSTRACT: Industry 4.0 is a strategic initiative recently introduced by the German government. The goal of the initiative is transformation of industrial manufacturing through digitalization and exploitation of potentials of new technologies. An Industry 4.0 production system is thus flexible and enables Individualized and customized products. The aim of this paper is to present and far-ciliate an understanding of Industry 4.0 concepts, its drivers, enablers, goals and limitations. Building blocks are described and smart factory concept is pre-scented. This paper presents a review on the advances of robotic and automation technology in achieving industry 4.0. Many companies, research centers, and universities acknowledge that robotics and automation technology is the basis of industrial manufacturing and an important driver for Industry 4.0. The current status of Industry 4.0 readiness of the German companies is presented and commented. Finally it is discussed if Industry 4.0 is really a disruptive concept or simply a natural incremental development of industrial production systems**.**

KEYWORDS: Industry 4.0, Cyber-Physical Systems, Enterprise-Resource- Planning, Manufacturing Execution System.

I. INTRODUCTION

Professor Klaus Schwab, Founder and Executive Chairman of the World Economic Forum and author of The Fourth Industrial Evolution describe an industrial evolution as the appearance of "new technologies and novel ways of perceiving the world which triggered a profound change in economic and social structures."

The first industrial evolution began with the mechanization and mechanical power generation. It brought the transition from manual work to the first manufacturing processes; mostly in textile industry. It is characterized by use of water and steam to mechanize production, an improved quality of life was a main driver of the change.

The second industrial evolution was triggered by electrification that enabled industrialization and mass production.
The third industrial evolution is characterized by the digitalization with introduction of electronics, IT and automation. In manufacturing this facilitates flexible production, where a variety of products is manufactured on flexible production lines with programmable machines.

The fourth industrial evolution is the IoT, robotics, Augmented Reality (AR) Virtual Reality (VR) and Artificial Intelligence (AI) are changing the way we live and work.

It began at the turn of this century and builds on the digital evolution. It is characterized by a much more global and mobile Internet, by smaller and more powerful sensors that have become cheaper, and by artificial intelligence and machine learning

The world is at the cusp of the fourth industrial evolution. It is current and developing environment in which disruptive technologies and trends such as the Internet, AI, IoT, Autonomous Vehicles, 5G Telephony, Nanotechnology,

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BioTechnology, Robotics, Quantum 3D printing, Cloud Computing and the like marked the era of 4^{th} industrial evolution.

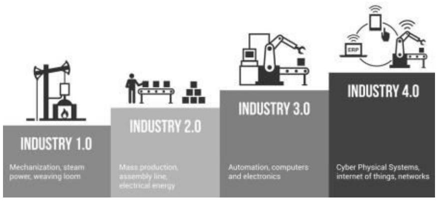

Fig:The industrial evolutions from 1 to 4

First Industrial Evolution: Agrarian societies to Mechanized production.

The first industrial evolution, began in the 18th century involved a change from mostly agrarian societies to greater industrialization as a consequence of the steam engine and other technological developments. It is marked by a transition from hand production methods to machines through the use of steam power and water power. It is started with use of steam power and mechanization of production. It is also called as the Age of Mechanical Production. Its effects had consequences on textile manufacturing, which was first to adopt such changes, as well as iron industry, agriculture, and mining. What before produced threads on simple spinning wheels, the mechanized version achieved eight times the volume in the same time using Steam power.

The use of it for industrial purposes was the greatest breakthrough for increasing human productivity. Instead of weaving looms powered by muscle, steam-engines were used for power. Through the advent of the steam engine, the focus has shifted from agriculture to textile manufacturing. But with steam power, those agrarian societies gave way to urbanization.

Developments such as the steamship or the steam-powered locomotive brought about further massive changes because humans and goods could move great distances in fewer hours. The world began to rely on steam power and machine tools, while steamships and railroads revolutionized how people got from A to B and what emerged as the new center of community life? Ultimately, advancing industrialization created a middle class of skilled workers. Cities and industries grew more quickly than ever before, and economies grew along with them.

Second Industrial Evolution: The Age of Science and Mass Production

The Second Industrial Evolution better known as the technological evolution is the period between 1870 and 1914. It began with the discovery of electricity and assembly line production. Henry Ford took the idea of mass production from a slaughterhouse in Chicago. The pigs hung from conveyor belts and each butcher performed only a part of the task of butchering the animal. Henry Ford carried over these principles into automobile production and drastically altered it in the process. By the early part of the 20th century, Henry Ford's company was mass producing the groundbreaking Ford Model T, a car with a gasoline engine built on an assembly line in his factories.

While before one station assembled an entire automobile, now the vehicles were produced in partial steps on the conveyor belt - significantly faster and at lower cost. It was made possible with the extensive railroad networks and the telegraph which allowed for faster transfer of people and ideas. It is also a period of great economic growth, with an increase in productivity. It, however, caused a surge in unemployment since many workers were replaced by machines in factories.

Things started to speed up with a number of key inventions. Think gasoline engines, airplanes, chemical fertilizer. All inventions that helped us go faster and do more. But advancements in science weren't limited to the laboratory. Scientific principles were brought right into the factories. Most notably, the assembly line, which effectively powered mass production.

People follow the jobs, and the early 1900s saw workers leaving their rural homes behind to move to urban areas and factory jobs. By 1900, 40% of the population lived in cities, compared to just 6% in 1800. Along with increasing

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urbanization, inventions such as electric lighting, radio, and telephones transformed the way people lived and communicated.

Third Industrial Evolution: Digital Evolution

The Third Industrial Evolution called the digital evolution involved the development of computers and Information Technology (IT) since the middle of the 20th century. This began in the 70's of the 20th century through partial automation using memory-programmable controls and computers**.** Since the introduction of these technologies, user can now able to automate an entire production process **-** without human assistance. Known examples of this are robots that perform programmed sequences without human intervention.

The third industrial evolution or Industry 3.0 occurred, after the end of the two big wars, as a result of a slowdown with the industrialization and technological advancement compared to previous periods. It is also called digital evolution. The global crisis in 1929 was one of the negative economic developments which had an appearance in many industrialized countries from the first two evolutions.

The production of Z1 (electrically driven mechanical calculator) was the beginning of more advanced digital developments. This continued with the next significant progress in the development of communication technologies with the supercomputer. In this process, where there was extensive use of computer and communication technologies in the production process. Machines started to abolish the need for human power in life.

Beginning in the 1950s, the third industrial evolution brought semiconductors, mainframe computing, personal computing, and the Internet—the digital evolution. Things that used to be analog moved to digital technologies, like an old television you used to tune in with an antenna (analog) being replaced by an Internet-connected tablet that lets you stream movies (digital).

The move from analog electronic and mechanical devices to pervasive digital technology dramatically disrupted industries, especially global communications and energy. Electronics and information technology began to automate production and take supply chains global.

Fourth Industrial Evolution: Cyber Physical Systems, IoT and Networks:

The Fourth Industrial Evolution is characterized by the application of information and communication technologies to industry and is also known as **"**Industry 4.0**".** It builds on the developments of the Third Industrial Evolution but considered as new era because of the explosiveness of its development and the disruptiveness of its technologies.

Origin of Industry 4.0 concept comes from Germany, since Germany has one of the most competitive manufacturing industries in the world and is even a global leader in the sector of manufacturing equipment. Industry 4.0 is a strategic initiative of the German government that traditionally supports development of the industrial sector. In this sense, Industry 4.0 can be seen also as an action towards sustaining Germany's position as one of the most influential countries in machinery and automotive manufacturing.

The basic concept was first presented at the Hannover fair in the year 2011. Since its introduction, Industry 4.0 is in Germany a common discussion topic in research, academic and industry communities at many different occasions. The main idea is to exploit the potentials of new technologies and concepts such as:
1. Availability and use of the internet and IoT.
2. Integration of technical processes and business processes in the companies.
3. Digital mapping and virtualization of the real world.
4.'Smart' factory including 'smart' means of industrial production and 'smart' products.

Besides being the natural consequence of digitalization and new technologies, the introduction of Industry 4.0 is also connected with the fact that, many up to now exploited possibilities for increasing the profit in the industrial manufacturing are almost exhausted and new possibilities have to be found. Namely the production costs were lowered with introduction of just-in-time production, by adopting the concepts of lean production and especially by outsourcing production to countries with lower work costs. When it comes to the decreasing costs of industrial production, Industry 4.0 is a promising solution.

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Advantages and reasons for the adoption of this concept including:
1. A shorter time-to-market for the new products.
2. Improved customer responsiveness.
3. Enabling a custom mass production without significantly increasing overall production costs.
4. More flexible and friendlier working environment.
5. More efficient use of natural resources and energy.

Production systems that already have computer technology are expanded by a network connection and have a digital twin on the Internet so to speak. These allow communication with other facilities and the output of information about themselves. This is the next step in production automation. The networking of all systems leads to "cyber-physical production systems" and therefore smart factories, in which production systems, components and people communicate via a network and production is nearly autonomous.

The advent of 5G telecommunication technologies will make real-time downloads possible. This will enable a whole host of things, such as a majority of driverless cars plying on the roads, and talking to each other using the IoT. The autonomous vehicle, enabled by 5G technology, will result in a lower demand for automobiles and release parking space for parks. When combined with an increasing population of non-polluting electrical vehicles, it will benefit the environment.

The electrical vehicles will be powered by renewable energy, and the use of fossil fuel would reduce. The cost of solar panels is likely to drop.Real-time speeds using 5G would allow devices to be connected and to communicate with each other through the IoT. Thus cars on the road will talk to each other, avoiding accidents. Machines in factories will talk to each other, leading to productivity gains.

II.BENEFITS OF INDUSTRY 4.0

The main benefits of industry 4.0 are:
1. Improved Efficiency and thus Productivity:Industry 4.0 technologies enable you to do more with less. That is, user can produce more and faster while allocating resources more cost-effectively and efficiently. User production lines will also experience less downtime because of enhanced machine monitoring and automated/semi-automated decision-making. Overall Equipment Effectiveness will improve asfacility moves closer to becoming an Industry 4.0 Smart Factory.Multiple areas of user production line will become more efficient as a result of Industry 4.0-related technologies. These efficiencies are less machine downtime, the ability to make more products and make them faster. Other examples of improved efficiency include faster batch changeovers, automatic track and trace processes, and automated reporting. New product introductions also become more efficient as does business decision making and more.
2. Increased Knowledge Sharing and Collaborative Working: Traditional manufacturing plants operate individually and in isolation. This results in minimal collaboration or knowledge sharing. Industry 4.0 technologies allow your production lines, business processes, and departments to communicate regardless of location, time zone, platform, or any other factor. This enables, for example, knowledge learned by a sensor on a machine in one plant to be disseminated throughout other organization.

Best of all, it is possible to do this automatically, i.e. machine-to-machine and system-to-system, without any human intervention. In other words, data from one sensor can instantly make an improvement across multiple production lines located anywhere in the world.

3. Flexibility and Agility: The benefits of Industry 4.0 also include enhanced flexibility and agility. For example, it is easier to scale production up or down in a Smart Factory. It is also easier to introduce new products to the production line as well as creating opportunities for one-off manufacturing runs, high-mix manufacturing, and more.
4. Better Customer Experience: Industry 4.0 also presents opportunities to improve the service you offer to customers and enhance the customer experience. For example, with automated track and trace capabilities, you can quickly resolve problems. In addition, you will have fewer issues with product availability, product quality will improve, and you can offer customers more choice.

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5. Cost Reduction:Becoming a Smart Factory does not happen overnight, and it won't happen on its own. To achieve it, you need to invest, so there are upfront costs. However, the cost of manufacturing at your facilities will dramatically fall as a result of Industry 4.0 technologies, i.e. automation, systems integration, data management, and more.

Primary drivers for these reduced costs include:

a) Better use of resources
b) Faster manufacturing
c) Less machine and production line downtime
d) Fewer quality issues with products
e) Less resource, material, and product waste
f) Lower overall operating costs

6. Better return on Investment:Industry 4.0 technologies are transforming manufacturing across the world. The benefits of Industry 4.0 and potential return on investment are what is truly important, though. To stay competitive and equip your production lines for the future, the time to think about the next stage of Industry 4.0.
7. Machine downtime reductions: Predictive maintenance in Industry 4.0 means that equipment failure will be identified before it occurs. Systems can spot repetitive patterns that precede failures, notify teams and have them schedule an inspection. Such systems also learn over time, becoming capable to spot even more granular changes and help continuously optimize production process.
8. Improved supply/demand matching: Cloud-based inventory management solutions enable better interactions with suppliers. Instead of operating in "individual silo", user can create seamless exchanges and ensure that user has:

a) High service-parts fill rates;
b) High levels of product uptime with minimal risk;
c) Higher customer service levels.

By pairing user inventory management system with a big data analytics solution, user can improve his demand forecasts by at least 85%. User can also perform real-time supply chain optimization and gain more visibility into the possible bottlenecks, protruding your growth.

III.CHALLENGES IN IMPLEMENTATION OF INDUSTRY 4.0

1. Economic
a) High economic costs
b) Business model adaptation
c) Unclear economic benefits/ excessive investment.
2. Social
a) Privacy concerns
b) Surveillance and distrust
c) General reluctance to change by stakeholders
d) Threat of redundancy of the corporate IT department
e) Loss of many jobs to automatic processes and IT-controlled processes, especially for blue collar workers
3. Administrative/policy:
a) Lack of regulation, standards and forms of certifications
b) Unclear legal issues and data security
4. Organizational/ Internal
a) IT security issues, which are greatly aggravated by the inherent need to open up those previously closed production shops
b) Reliability and stability needed for critical machine-to-machine communication (M2M), including very short and stable latency times
c) Need to maintain the integrity of production processes
d) Need to avoid any IT snags, as those would cause expensive production outages
e) Need to protect industrial know-how (contained also in the control files for the industrial automation gear)
f) Lack of adequate skill-sets to expedite the transition towards the fourth industrial evolution
g) Low top management commitment
h) Insufficient qualification of employees

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Comparison I3.0 with I4.0

Sr. No	Feature	I4.0	I3.0
1	Characterized by	A fusion of technologies across physical, digital and biological spheres. Physical– Autonomous Vehicles, 3D Printing, Advanced Robotics, New Materials etc. Digital–IoT, Block chain, AI etc. Biological – Molecular biology and genetics, application of engineering principles to biology, , 3DBio printing etc.	Digital evolution. Rise of telecommunications technologies, computers and IT
2	Technologies used	For smart automation technology used are Cyber physical systems, IOT, IIoT, smart factory, **Cloud,** Big Data Analytics, and AI.	For automation technology used is mainly PLC's and Robots.
3	Automation level	in Industry 4.0 machines work autonomously without the intervention of a human	Industry 3.0 the machines are only automatized.
4	Impact	The impact of the fourth industrial evolution is global and is on all the aspects of human life i.e. Economy, Business, Governments, Society, and Individuals.	Impact is limited to geographical and manufacturing industry only
5	Efficiency, Productivity and performance	By combining machine-to-machine communication with industrial big data analytics, I4.0 is driving unprecedented levels of efficiency, productivity, and performance.	Due to limitation of technological advancements lower Efficiency, Productivity and performance
6	Implemented by	Cyber physical systems, IoT, Smart factory, Big data, Cloud, Cyber security.	Production, planning and control, IT support, ERP, MES and data management.
7	Scope	Real time, Interconnected global system.	Not real time and global in nature
8	Example	if the CNC Milling machine is in the Industry 4.0 the tool changes are automatic at the same time the spindle speeds and all other parameters essential to carry out the process are recorded by the hundreds of sensors present in the machine and the optimum settings are done on its own based on the large amount of data there is to compare and optimize the process. i.e. No human intervention	If a CNC Milling machine is in the era of Industry 3.0, the tool changes can be done automatically but the speed at which the spindle should run is to be observed by the operator and the corrections should be made by him. i.e. Human intervention/ assistance.

IoT Layered Architecture:-

The IoT is a technology which is currently emerging and it can be viewed as a network of objects connected via. Internet, which aims to increase the availability of Internet at anyplace and any time through integration of the physical objects (embedded with software, sensors, actuators etc.) into the information network which enables these objects to collect data and exchange it.

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IoT is the ability to connect, communicate with, and remotely manage an incalculable number of networked, automated devices, from the factory floor to the hospital operating room to the residential basement. It is a scenario in which storage, computing and communication technologies are embedded in everyday objects. Processing, storage and communication capabilities attached to an object turns object into a service for which users pay per use.

Since the IoT was proposed in 1999, it has been in continuous development and expansion, but there are no uniform definition standards. The IoT concept broadly refers to RFID, infrared sensors, GPS, laser scanners and other information sensing devices, according to the agreed protocol, to achieve any time, any place, any object information exchange and communication in order to achieve intelligent identification, locate, track, monitor and manage a network. The IoT has full perception, reliable transmission, intelligent processing and other features.

IoT was making extensive use of, and made throughout the wisdom industry, wisdom agriculture, intelligent transportation, smart security, environmental protection, wisdom health care, government livelihood management, intelligent home, food safety and so on. Although the IoT industry has been in rapid development in recent years, there is still no large-scale applications in reality. There is no uniform construction standards, norms things access and integration management platform.

The three-layer framework of IoT is widely considered and it is consisting of perception layer, network layer and application layer. Although the three-layer framework describes the architecture of the IoT from the technical level, but not fully shows the characteristics and reference of the IoT. Now some applications require the closed-loop system, and the IoT is an open-loop global network system, so its application and promotion still faces many difficulties and challenges. To overcome this five layer architecture of IoT is proposed.

The Five-Layer Architecture of IoT:
Architecture of IoT is consisting of perception layer, network access layer, network layer, application support layer and presentation layer, as shown in figure 4.14.

Perception/Edgelayer: The perceptual layer is the foundation of IoT, is the interface between the layer of physical world and information world. It uses radio frequency identification technology, bar code technology, sensor technology, positioning technology, or other information sampling technology to complete the information collection, and with the help of controlling the objects of perception by the actuator, implement the interface control between the physical space and information space. Its main components include two-dimensional code label, code reader-writer, RFID tags and RFID reader-writer, cameras, and all kinds of sensors. So, the IoT perception layer has the main functions of information perception and original data collection, necessary auxiliary complete downward at the end of the control object. Therefore, the main function of perception layer of IoT is information and data collection, when necessary, assist to complete the control objects of perception.

Network access layer: The network access layer is mainly composed of the base station node and the network access gateway. Itcompletes the network control and the data fusion of each node in the perception layer, or forward the information from the above layers (The network transmission layer or the application layer). When the perception layer's nodes complete networking, the perception layer's nodes need to upload data, and send the data to the base station node. The base station node will receive the data, and complete the connection with the network transmission layer by the access gateway. When the application layer and the network layer needs to downlink data, the base station node sends data to each node in the perception layer after the network access gateway receiving the data from the network transmission layer, then complete the forwarding information and interaction between the perception layer and the network transmission layer. The current access methods in the network access layer mainly include WIFI, Ad hoc, Mesh, ZIGBEE, industrial bus. Itcollects the information by various cognitive tools, or to preliminary process and network access.

Network transmission layer: The network transmission layer is mainly used to realize the transmission and exchange of information provide the basis transmission network for the necessary of applications and services within a wide range, including the satellite communication network, the mobile communication network, the optical fiber communication network and the local independent private network and so on. It is a problem in the network layer that

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the neutral access and seamless integration between different network and means of communication, and how to form the transmission and exchange capacity with end-to-end. This layer normally uses TCP and UDP protocols

Application support layer: With the support of the information technology, cloud computing technology, middleware technology, database technology, expert system and so on, the application support layer complete public intelligent analysis and storage of data information, realize information processing, and all kinds of intelligent application sharing and exchanging. This layer normally uses HTTP, MQTT, CoAP protocols.

Application presentation layer: The application presentation layers task is the development of a variety of applications of IoT base on the data processing of the application support layer, and uses the technology with multimedia, virtual reality, human-computer interface to build the interface of intelligent application between the IoT and the user, implement present and application of all kinds of intelligent information.

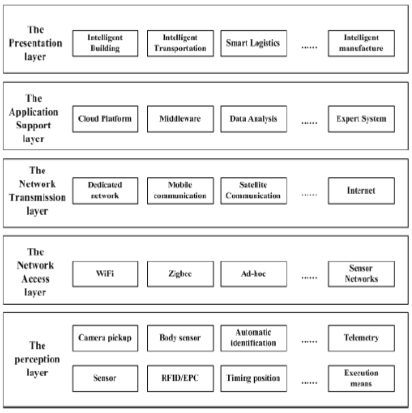

Fig :Five Layer Architecture of IoT

IV.INDUSTRIAL IOT (IIOT)

Industrial domain is different from consumer domain. It has specialized communications protocols, security requirements, QoS and device life cycles. Initially, IIoT applications referred to any application that relied on an Internet- (or Intranet-) capable sensor and actuator networks. Many web, industrial automation, embedded and wireless sensor network applications are usually grouped under the umbrella of IIoT. While IoT has maintained its position covering domain of home automation and consumer electronics, IIoT extended it to include industrial domain with all its implications. The key enabler of both is connectedness (networked).

The IIoT integrates with a wider array of communication protocols. IIoT based low power wireless networks may require real-time performance with time triggered variations of IEEE 802.15.4. Hence, IIoT applications must handle changes in and introduction of new communications protocols. Security is an important aspect for networked systems, such as IIoT. The open connectedness of IIoT applications make them vulnerable and require protection from various threats.

The traditional security triad of confidentiality, integrity and availability still apply to the IIoT, and now privacy must also be included. Traditionally, industrial computer networks rely on network segregation with highly controlled network access or an “air gap” between factory floor and IT networks. This includes using firewalls to control what connections are allowed to pass between network segments, for example network traffic entering and leaving the factory may be fully denied.

IIoT applications have monetary consequences and could expose commercially sensitive information. Authenticity terms and conditions must be taken seriously. IIoT applications operating in continuous production require QoS agreements and monitoring. QoS refers to the non-functional requirements of an application. The QoS concerns could

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be battery life time, bandwidth, round trip delay, redundancy, backup, resilience, recovery or more. QoS is an important issue for IIoT therefore it must comply stricter limits.

The life-cycles of IIoT applications differ to those of IoT. By comparison IIoT applications must pass thorough testing, simulation, validation and verification prior to deployment. The deployment environment of IIoT applications requires integration with areas, such as legacy systems and devices, simulators, intelligent robotics, big data, analytics and augmented reality etc. In addition, IIoT must not introduce cyber security vulnerabilities to other areas, such as robotics. Therefore, a software architecture style must account not only for IIoT but also the surrounding domains.

Comparison of IoT and IIoT

Sr. No.	Parameters	IoT	IIoT
1.	Devices	IoT includes devices located in consumer or commercial settings: offices, business, homes.	IIoT includes devices located in industrial settings: factory floor, automation control, HVAC, energy grid.
2.	Reliability	Moderate requirements: ease of use, short product life cycles.	Stringent requirements than the consumer IoT: Hi-reliability, harsh environments, high product life cycles.
3.	Security	Require identify and privacy.	Requires robust security protecting against access.
4.	Function	Synonymous with functions that benefit end users-human life style.	Provide basic operational roles and requirements many are independent of human intervention.
5.	Availability	Function in environment of updates, add-ons, apps, charging and random rebooting.	Requires high availability and up time. Unscheduled patching and rebooting is not tolerated.
6.	Failure	Retry, replace.	Resilient, fail in place.
7.	Connection	Connects people to people or people to internet.	Peer-Peer and M2M.
8.	Protocol	For the most part is IP.	Based upon numerous protocols standards based and proprietary.
9.	Market	Green Field new device uptake is almost immediate.	Brownfield new device uptake must be phased in.
10.	Area of focus	Commercial or consumer convenience	Monitoring and managing systems for high stake industries- defense, Manufacturing, Health Care and others.
11	Focus development.	Smart Devices.	Sophisticated Machines.
12	Degree of application	Sensitive sensors, Advanced controls and Analytics.	Simple application with low risk impacts.
13	Scalability	Low scale networks.	Large scale networks.
14	Precision and Accuracy	Critically Monitored.	Synchronized to milliseconds.
15	Programmability	Easy off-site programming.	Remote on-site reprogramming required supporting new processes.
16	Output	Convenience	Economic Growth.
17.	Resilience	Not required.	Must be automated to support fault tolerance.
18.	Maintenance	Consumer preferred.	Scheduled and Organized.

Industry 4.0 Architecture:
Industry 4.0 is the German initiative that aims to bring about challenges of the fourth industrial evolution. It undertakes to bring together advances in digital technologies. Starting with a focus on the smart factory concept, it now includes

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concepts such as big data and analytics, CPS, cloud, fog and edge computing, IIoT, augmented reality, intelligent robotics, additive manufacturing, and simulation and cyber security. Each of these fields is being developed within their own areas, but combining the technologies together and creating a cohesive technological environment is a challenge.

Industry 4.0 has proposed the Reference Architecture Model for Industry (RAMI) 4.0. It is a reference architecture that joins life-cycle, software concerns and the automation pyramid into a cube view. Refer the RAMI Architecture as per reference number 10. It shows the need for recognizing the multi-dimensional relationship between engineering domains within industrial automation. RAMI 4.0 make explicit the need for all hierarchy components to share some burden of the software layer distribution. To address the standardization issue, a Reference Architecture Model for the Industry 4.0 was developed in Germany.

This is a meta-model so it describes the aspects that play an important role in the Industry 4.0 production system. It is based on the internationally accepted Smart Grids architecture model introduced in year 2014. Two additional bottom layers are added to address specific aspects of Industry 4.0.
The three dimensional RAMI4.0 should enable:

- Identification of the existing standards,
- Identification and closure of gaps and loopholes in the existing standards,
- Identification of overlaps in the existing standards.

The first dimension of the RAMI4.0 addresses two elements, type and instance. Aslong as an idea, a concept, or a product is still a plan and is not available/realized yet,it is called type.

The second dimension of the model deals with location, functionalhierarchy from the product to the connected world (as the last stage of Industry 4.0development with all enterprises, customers and suppliers connected).

The third dimensionof the RAMI4.0 model is organized in functional layers as follows

- An assets layer includes physical components such as robots, conveyer belts,PLCs, documents, archives, but also non-physical objects such as software andideas.
- An integration layer provides information for assets in a form that can be digitallyprocessed. It includes elements connected to IT such as sensors, integration to HMIand computer-aided control of technical processes.
- A function of the communication layer is standardization of communication usinguniform data format and predefined protocols. It also provides services for the integrationlayer.
- An information layer is processing and integrating available data into useful information.
- A functional layer includes formal descriptions of functions. Also ERP functions belong to this layer.
- A business layer includes mapping of the business model and links between different business processes.

Thus the vertical axis representing software concerns, the horizontal axis representing life cycle stages and the diagonal axis represents automation hierarchy.

RAMI4.0 is in Germany registered as DIN SPEC 91345 and it is as such a first compilation of the essential technological elements of Industry 4.0. It is perceived as a precondition for deployment of Industry 4.0 concept in practice and also as a model that requires international acceptance.

Case Study

Smart City Street Light and Monitoring

City Street light can be controlled through smart embedded device having sensing and computing power which will communicate central coordinator and command station through internet. Here streetlights are grouped together having sensing, computing and communication circuit on each streetlight lamp post. Each group connects to a group controller or coordinator through Bluetooth or ZigBee. Each controller further connects to command and control station through internet.

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The station receives data of each streetlight from a group in specific period or intervals. This data may be about status of these streetlights related to nonfunctional/ faulty lights, nearby traffic conditions, daylight whether cloudy, dark and normal and so on.

The station remotely programs the group controller to take appropriate action as per the condition of traffic or light. It also sends data related to faulty light and its location for remedial action. This way each group of city streetlight is controlled through coordinator, controller and command station through internet.

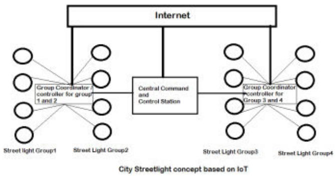

Fig :Street Light using IoT

Fig shows the concept of streetlight using IoT. Here lamppost hosts a streetlight, wireless sensor network (WSN) actuator and sensors. Sensors send messages about status of lamp, ambient light and traffic. Actuator makes light on or off.

When light is above threshold then lights are switched on. The WSN sensors deployed detects presence of traffic and its density. If traffic is not present the lights are switched off. This saves energy. Traffic density data is communicated to traffic signal monitoring service. The WSN transceiver also accepts data from other services such as Wi-Fi service, security service, traffic signaling service and retransmits to network of WSN and then to access points. Thus lamppost may act as information network or active node in service network.

Each transceiver at the lamppost receives and retransmits in real time. Events messages alerts, triggers and notifications from a number of services can transmit for service such as smart parking, traffic signaling, waste management, weather monitoring, air pollution control services, security services for home, banks and important public spaces, emergency services and hospitals.

Functions of control and monitoring service for city streetlights are

1. Measure light intensity and monitor city street lights.
2. Measure and monitor traffic parameters in real time intervals
3. Each WSN has program that configure and communicate with WSN network.
4. The WSN network connects a coordinator/controller which has data adaption, store, time, location, IDs stampings and gateway interfaces.
5. Communicates the WSN messages
6. These massages are transmitted at preset intervals to access points which are in turn connected to coordinators.
7. Coordinator generates and communicates alerts, triggers, messages and data after aggregating, computing, processing, filtering and compacting at data adaption layer.
8. Coordinator creates and uploads in real time a database which transfers to the cloud for processing and for cloud data store.
9. An OTP module at the cloud node provides OTP management and uploads connectivity programs for gateways.
10. Runs and monitors at data adaption layer for faulty or inaccessible sensor at periodic intervals
11. Integrates data and activates the alerts and triggers.
12. Cloud node provides platform for processes, analyze and visualization of data and database information. The node provides analytics and AI for optimizing, monitoring and control functions.
13. Cloud platform could be CISCO IoT, IOX and Fog, Nimbits, TCUO, AWS or Bluemix platform with Watson Analytics.

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Data flow diagram, architecture and reference Model for Smart City Streetlight Monitoring and Control for WSN networks.

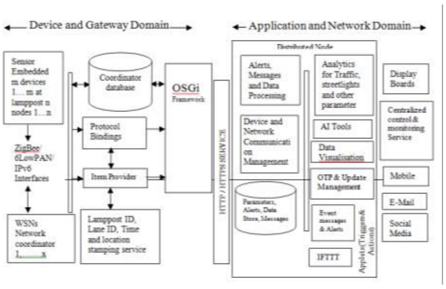

Fig :Data Flow Diagram

Fig, shows data flow diagram and domain architecture reference model for monitoring service. It is divided in two domains namely
1) Device and gateway domain
2) Applications and network domain.

Device and Gateway Domain: It has three major components i) Hardware ii) Software iii) Module component

Hardware: Hardware consist of m embedded devices n WSN node networks which communicate between them using ZigBee/6lowPAN/IPv6 protocol through x coordinators. Coordinator functions as data store, protocol binder, item provider and gateway.
Each lamppost deploys a WSN. Each node senses a set of sensors data. Sensor circuits can deploy Arduino boards with ZigBee. Each WSN interfaces with other WSN and forms a network of ZigBee devices WSN measures parameters such as i) light condition below or above threshold value ii) Nearby traffic presence or absence iii) traffic density iv) Lamppost status functional or not. Each lamppost need not measure traffic parameters. Each WSN configures the sensing device so that measurement may be activated or deactivated by the command from the coordinator and central monitor service. Nodes can be configured to measure parameter at different preset intervals. Similarly each WSN is configures actuator to make light on or off.

A group of WSN communicates among themselves using ZigBee and form a network. Each network has an access point which receives messages from each node using LPWAN. Each access point is associated with a gateway, which communicated with cloud using LPWAN.

Software: Open source IDE or IoT stack which include OSGi can be used for software development at devices and gateway domain. Each WSN, Lamppost, Lane, sensor node of WSN and coordinator is assigned a unique respective ID’s.

Modules: Each coordinator has three modules. i) protocol binding module ii) item provider module for communication of queried items, alerts, messages and data iii) time, lamppost Id, lane ID and location stamping service. The coordinator can use open source OSGi framework. A database at coordinator stores in associated streetlights, lanes and lanes subgroup data.

Application and Network Domain: Cloud platform for city streetlight monitoring service deploys a number of distributed nodes. Internet connectivity is achieved through HTTP/HTTPS services. The IP protocol network connects each coordinator with a distributed node.
The distributed node platform provides
1. Alerts, messages and data processing module.
2. Device, network and communication management module.
3. Analytic tools for traffic, streetlight and other parameters.

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4. Data storage for parameter alerts and messages.
5. AI tools
6. Data Visualizations tools.
7. Coordinator, networks and nodes update management using OTP.
8. Event messages, triggers and alerts for central control and monitoring services.
9. IFTTT for communication to mobile, email, social media, web services and applications.

V. CONCLUSION

In this paper, the background and development of the Industry 4.0 concept are presented. Although the concept is very comprehensive and complex, three main points can be identified:
The Industry 4.0 concept is not limited just to the direct manufacturing in the company but it includes also a complete value chain from providers to customers and all enterprises business functions and services.
The Industry 4.0 assumes broad support of an entire life cycle of systems, products and series, distributed both spatially and organizationally. The smart products are not smart only during the manufacturing process but they continue to provide the data about their state also during their lifetime. These data can be used for preventive maintenance; it can provide the manufacturer useful information about lifetime and reliability of their products.

The Industry 4.0 is a specialization of the Internet of Things applied to the manufacturing/industrial environment. It assumes a real-time data collection leading to the issue of handling and analysing huge data and cyber security.
Industry 4.0 is new industrial revolution of the 21st century, which enables companies to create smarter products and services by reducing costs and increasing efficiency, where the human factor is crucial for the application and the work is based on the existing literature in the area.

Smart Factory makes a solution which, due to the systems automated procedures, uncomplicated setup including simple, need-based installation and ultimately, high degree of scalability, can help companies in the manufacturing sector further optimize their processes and significantly boost their internal efficiency.

Five million workplaces could be lost due to digitalization in major industrialized nations. Also, it will quickly stop the market demand for the products made with outdated technologies due to lack of quality and such production would have to be shut down due to high costs and inefficiency.

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