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Novel Three- Tier Architecture for Implementing Industry 4.0

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Abstract - *The hype of technologies lead to the Industrial revolution by the shifting up of industries from Industry 3.0 to Industry 4.0. The Industry 4.0 describes the growing trend towards automation and data exchange in technology and processes within the manufacturing industry, including: The Internet of Things (IoT), The Industrial Internet of Things (IIoT), Cyber-Physical Systems (CPS), Smart manufacturing and so on. In this paper we have discussed about the technologies used for implementing Industry 4.0, and we have proposed unified 3-tier architecture for converting an industry to Industry 4.0. The role of a software engineer in Industry 4.0 and challenges were also briefed in this paper*.

Key Words: Industry 4.0, Manufacturing industry, Internet of Things, Industrial Internet of Things, Cyber Physical Systems.

1. INTRODUCTION

From the first industrial revolution (mechanization through water and steam power) to the mass production and assembly lines using electricity in the second, the fourth industrial revolution will take what was started in the third with the adoption of computers and automation and enhance it with smart and autonomous systems fueled by data and machine learning [1]. The implementation of Industry 4.0 involves lot of technologies; the key technologies are IoT, Big Data, Artificial Intelligence, Cloud Computing and so on. Existing architectures for implementing Industry 4.0 consists of many layers. In the proposed architecture, we have designed 3 layers based that acts as a core for implementing Industry 4.0.

In the implementation of Industry 4.0 the key roles of a software engineer are identified. Implementation challenges and technological challenges are present while implementing Industry 4.0 will be discussed in this paper.

2. OVERVIEW OF TECHNOLOGIES USED IN INDUSTRY 4.0

This section briefs the technologies involved in Industry 4.0 and significance of those technologies for the development of Industry 4.0.

2.1 Review of technologies involved in Industry 4.0

Table 1 will describes the papers related to the technologies involved in Industry 4.0

Table 1- List of Technologies with associated works

List of Technologies incorporated with Industry 4.0		
TECHNOLOGY	**DESRCIPTION**	**CITATION**
Internet of Things	The overlapping of IoT in Industry 4.0 is discussed in these papers	[2-4]
Cloud Computing	These papers talks about cloud computing and its importance in Industry 4.0	[5-9]
Big Data and Analytics	These papers will be focused on how big data is used and its role in Industry 4.0	[10-13]
Communication	The overview of communication protocols is briefed in this paper	[14]
Block Chain	This paper discusses the benefits of using block chain for Industry 4.0 smart manufacturing	[15]
Artificial Intelligence	These papers discuss about the collaboration of artificial intelligence and machine learning in Industry 4.0	[16-19]

2.2 Base technologies in Industry 4.0

2.2.1 Internet of Things (IoT) and Industrial Internet of Things (IIoT)

The IoT is a system of interrelated computers, machines, and objects that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. IoT in manufacturing industry is known as IIoT [20]. At industrial level, there is a need of interconnection and intercommunication of physical devices including: the sensors, machines and electronic devices. The IoT and IIoT play a vital role and acts as a backbone for the development of Industry 4.0.

2.2.2 Cloud computing

Cloud computing is one of the component for Big Data implementation in Industry 4.0. It is used for storing, analyzing, managing and monitoring the data. The SaaS (Software as a Service) is widely used as a platform for applications used in manufacturing industries.

2.2.3 Big Data and Analytics

The combination of using IoT and Cloud permits different equipment to be connected, collecting huge amount of data, which results in the Big Data storage. Analytics enables advanced predictive capacity, identifying events that can affect production before it happens. The combination of big data with analytics can help optimizing decision-making activities.

3. EXISTING ARCHITECTURES

This section presents the related works and existing architectures for the implementation of Industry 4.0.

3.1 RAMI 4.0

The authors [21] proposed the RAMI 4.0 architecture which is a Reference Architectural model for Industry 4.0. It is a service oriented architecture model and comprises of 3 dimensions that includes the combination of all technological elements, components and lifecycle for the implementation of Industry 4.0.

3.2 5C Architecture

The 5C architecture proposed by Lee et al. to build the CPS consists of 5 levels, namely the connection, conversion, cyber, cognition, and configuration levels [22]. The 5C architecture integrates cyber parts into physical world by enabling Industry 3.0 to Industry 4.0.

3.3 ISA-95 Model

The ISA-95 model divides production systems into 5 levels, enabling efficient interfacing and error-free integration of production systems [23].

It comprises of sensors and actuators at its base level followed by field level for network, control level for PLC, process control level for SCADA and Enterprise Resource Planning (ERP) as top layer.

3.4 SWETI Platform's Layered Architecture For Industry 4.0

Semantic Web of Things (SWeTi) platform's layered architecture for Industry 4.0 depicts each layer and its components and its functionality from device layer to application layer [24].

The Device layer will consists of physical devices. Followed to the device layer, the edge layer comprises gateway for establishing communication, cyber layer which is performs core operations in the system, data analytic layer which performs the operations and analytics using Artificial Intelligence and Machine learning algorithms and so on. At the top of the architecture the application layer is present which gives abstractions for decision making.

3.5 8C CPS Architecture

The 8C CPS is an improved version of 5C architecture. The architecture will consist of three facets in addition to 5C architecture components. The facets are Coalition, Customer and Content [25]. It addresses vertical integration and cross-level relationship and is a helpful guideline to build the CPS for smart factories.

3.6 Advantech Industry 4.0 Architecture

Advantech is a leading computer manufacturing company has proposed architecture for Industry 4.0 consisting of four main components namely IoT sensing device, Edge Intelligence Servers (EIS), IoT Cloud platform and Solution Ready Platform (SRP) [26]. IoT sensing device comprises sensors and communication protocols. EIS comprises intelligent computers, servers and terminals. In the IoT cloud platform computing, data storage and data analytics can be done. The SRP will provide solutions such as automating industries, factory monitoring and so on.

4. PROPOSED ARCHITECTURE

Several architectures have been proposed to develop Industry 4.0 applications. They are either application-specific or technology-specific. No generalized architecture exists for implementing Industry 4.0. So, we proposed our 3-tier architecture for Industry 4.0 based manufacturing industries.

Figure 1 depicts the 3-tier architecture starting with the machines and devices at the Component layer and moving towards the application software in the Functionality/ Enterprise layer.

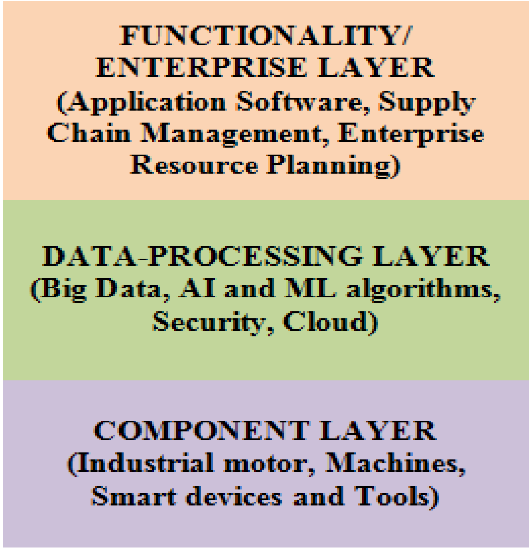

Fig-1:3-tier architecture for Industry 4.0 based manufacturing industries.

4.1 Component Layer

At the component layer, physical assets of a production industry are combined. The components such as the sensors, industrial motors, production machines which involve in industrial manufacturing process and the smart devices and tools which provide human-machine interaction are included in this layer.

4.2 Data Processing Layer

Next to the Component layer, is the Data Processing layer. In this layer, the technologies used for implementing Industry 4.0 applications are included. As the name implies, Data Processing layer processes the data generated by the component layer and converts it into information.

The technologies in the Data Processing layer focuses on all areas of a production industry which includes Big Data, AI and ML algorithms, Security and Cloud Computing.

The Big data and Cloud computing technologies are used so as to facilitate storing the data on cloud. The AI and ML algorithms provide extended human-machine interaction. Security concentrates on the secured storage of data

4.3 Functionality/ Enterprise Layer

The Functionality/ Enterprise Layer involve the application software, Supply Chain Management and the Enterprise Resource Planning resources.

5. IMPLEMENTATION OF INDUSTRY 4.0

The phased approach that couples each step with the innovative manufacturing practices and usage, and integration of new technologies to produce value-added products includes the following five steps [27].

Step 1: *Identifying Business Objectives*

Step 2: *Developing a Prototype*

Step 3: *Validation of prototype*

Step 4: *Replication of Prototype*

Step 5: *Total rollout*

The other implementation ideas and works are presented in Table 2.

Table 2- Implementation ideas with associated works

Implementation of Industry 4.0	
DESCRIPTION	**CITATION**
The conceptual framework for front-end and base technologies for the implementation of Industry 4.0 is discussed	[28]
The implementation of Industry 4.0 technologies in mining industry is discussed	[29]
A framework for implementing Industry 4.0 in learning factories is discussed in this paper	[30]
The roadmap for implementing Industry 4.0 and case study of steel industry is briefed	[31]
The Industry 4.0 Process Modeling Languages (I4PML) for requirement analysis phase is discussed	[32]
A decision-making framework for manufacturing technology selection by incorporating technological, social and business considerations is discussed	[33]
This work presents model based validation and testing of Industry 4.0 plants	[34]
Mapping of traditional automation to Industry 4.0 technologies is discussed in this work	[35]
Three possible stages of Industry 4.0 manufacturing is explained in this paper	[36]

6. ROLE OF ENGINEERS IN IMPLEMENTING INDUSTRY 4.0

The role of engineers [37] in implementing Industry 4.0 applications is described as follows:

6.1 Software Engineering Roles

The software engineer plays a vital role in implementing Industry 4.0 in production industries, as the entire manufacturing system is automated.

- Production Planner and Scheduler
- Robot programmer

- PLC programmer
- SCADA HMI engineer
- Quality engineer
- Cloud/edge engineer

6.2 Other Engineering Roles

The other engineering roles include:

- Production designer
- Production specialist/technologist
- Transportation system designer
- Transportation system integrator
- Robot work cell designer
- System integrator
- Pneumatic system engineer
- Project manager
- Simulation engineer
- Operator

7. CHALLENGES

Industry 4.0, involves many aspects combining the strengths of latest technologies, also faces some difficulties and challenges. Some of them are given below.

7.1 Technological Challenges

The various manufacturing units of an industry are automated and integrated as a whole to facilitate smart manufacturing. As we do so, the distinct challenges we face include collaboration, data sharing, Interaction and automation [38].

This intelligent manufacturing also requires intelligent equipments, self configurable robots and integration networks [39] to enhance the efficiency in manufacturing.

7.2 Social and Economical Challenges

As digitization is employed in manufacturing industries, it may lead to reduction in number of employees and the industries will have to invest in staff in order to equip them with latest technologies [40]. Further, the manufacturing industries have to invest a huge amount in converting a current production industry into intelligent manufacturing systems.

7.3 Scientific Challenges

Industry 4.0 faces challenges in scientific aspects also. It includes the production of smart devices, interaction between different systems, modeling, integration and testing of different physical, hardware and software platforms and digital manufacturing [41].

7.4 Engineering Challenges

There is a need to develop certain technologies related to recognition [42]. The automated devices and machines should be able to recognize the objects, implement the functionalities assigned and interact with the other sources in production process.

7.5 Security Challenges

Major security challenges include the loss of information or manipulation by third parties [42]. Various types of risks associated with the technologies adopted should be analyzed and appropriate measures should be taken at its earlier stages.

7.6 Big Data Challenges

The major automated components of Industry 4.0 include sensors and PLCs (Programmable Logic Controllers). Data collection, data pre-processing and data transmission needs much concentration as it involves complex and heterogeneous data [43].Data integration is a challenging task as it involves integration of multiple types of data in an automated production environment.

Real time access to big data can be achieved in Industry 4.0 but, if there is a delay in processing the data by remote devices, may create problems for next devices to complete its task in scheduled time.

As the data is growing exponentially, we have shifted from local storage to cloud storage. The risk of data loss or data manipulation is high. So, we have to concentrate more on data security and privacy.

8. CONCLUSIONS

In our work, we presented a overview on Industry 4.0 and its underlying technologies. With reference to the existing architectures which were either application oriented or technology oriented, we proposed our 3-tier architecture which would help industries to fit-in their machineries and technologies at specific layers to implement smart manufacturing. After that, the overview of implementing I4.0, various engineering roles in this implementation and the challenges were addressed.

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