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A comprehensive and investigative study of reference architecture of industrial internet of things and industry 4.0

AyushiTyagi[1],Dharamveersingh Chauhan[2],Mohd. Vakil[3]
[1,2,3]*Department of Computer Science And Engineering, R.D.Engineering College, Ghaziabad, India*

ABSTRACT:-
Due to an excessive interest and attention toward the digital transformation of the Modern Manufacturing Assets, a significant amount of research and study is required to build a sustainable system architecture that integrate the Industry 4.0 assets with the state of art Internet of Things concept, and to provide an easily implementable system. The system in need should not only work efficiently but also comply with Standard Cyber Securities practices. Multiple research papers and business review literatures are present to support various system architectures but a reasonable comprehensive and investigative reference is required to bridge a gap and provide a reference for future studies. Main objective of present work is to review reference architectures for Industrial Internet of Things and analyze them for suitability to support various Industry 4.0 architectures. For the same we put significant effort to review and research these existing architectures and come up with thoroughly developed analytical information. We also address their uses and technologies to support their implementation process. As a result, we observed that current technologies and their system architectures need more advancement to make it easy to implement, low cost solution.

Keywords: Industrial Internet of Things; Cyber Physical Systems; Industry 4.0; Reference architecture; Software architecture; Interoperability.

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I. INTRODUCTION:

The Internet of Things connects individual devices to the network as well as with each other. The main aim of IoT is to monitor, measure, trace, access and control the smart physical objects and things, anytime and anywhere using a dedicated and secure network. All the Internet of Things systems usually follow a Cloud based approach. These systems get the benefits of the strong computational capabilities of the Cloud. Recent development in the IoT can be viewed as how major technology companies have started shifting their business towards IoT. This way IoT has received a boost and subsequent advancement in technology as well as on reference architectures.

IIoT can be described as the interconnection of the machines, material handling systems and various measurement devices through the Internet. At the center of the IIoT is the network that uses various industrial communication modes such radio frequency, cellular data connection, Ethernet etc. The IIoT refers to integrating all areas of the industry with the network and with each other to share data and necessary information for achieving operational excellence. It can also be said that IIoT lead the world to the path of Industry 4.0 or Fourth Industrial Revolution starting from year 2000 onwards, which is a paradigm shift from the existing centralized DCS controlled manufacturing plants to barrier-free communication network among all the manufacturing facilities, resources and products. The supporting backbone of this digital transformation of the Industry 4.0 is the integration of the IoT to the industrial processes. The Industry 4.0 concepts can be collectively specified as CPS (cyber physical systems), IIoT, Big Data and Smart Factory. The major motivation that lead to the development of this work can be found in the fact that IIoT provides a vast area for future improvement and technical advancement and can play significant role in the future of the production systems. With the help of the IIoT and its capabilities modern machines can share information to make use of their resources in the most optimized way and saving the resources as well. The potential of IIoT is unlimited and if explored can lead to the most efficient systems ever developed. Industrial Internet of things not only provides the data monitoring and visualization tools but also comes out as a major tool of decision-making process.

Methodology: The methodology applied in this work consists of systematic review of the selected and relevant literatures, taxonomies a variety of resources like Google Scholar, IEEE, Sci-Hub, Springer, Taylor and Francis etc. Lots of academic literature and practical studies were extensively consulted to find the IIoT resource and framework technologies and their relation to with the Industry 4.0. While the current academic literature offers limited information to the existing and emerging IIoT developments, our major concern was on Industry 4.0 and its recent developments. In order to develop a conceptual and inter-related model for the integration of IIoT in the Industry 4.0, a more qualitative and empirical study for the new Industry 4.0 architectural reference model was required.

IIOT Reference Architecture: Reference architecture is a reference document or a framework, which provides guideline for the development of system, solution and application architectures. It assist in developing a common and widely acceptable definition for the system to be developed, its compositions, sub-systems, design patterns, and a common vocabulary for the implementation and comparing available options for the application. For Instance, reference architecture for an IoT solution for the residence states that all residential houses need to provide IoT enabled devices connected through the network and can share the necessary information. Along with sharing the information, multiple controls and analytics will be required, which comes under the compliance of data and information security. The reference architecture,, will provides a common framework, around which the solution can be developed with the guidelines and reference taken from the reference architecture. It also enables the identification of the most important issues across its applications in many different use cases. The reference taken architecture allows designs to follow the reference architecture without any unnecessary, arbitrary restrictions. The Industrial IoT reference architecture is developed by the Industrial Internet Consortium (IIC). The IIRA, also known as the Industrial Internet Reference Architecture for Industrial Internet of Things systems specifies a framework comprising various viewpoints to help and assist in the development, documentation of the IIRA. Reference architecture uses a common as well as widely acceptable vocabulary and a framework to describe usage, functional and implementation viewpoints. The Industrial Internet Reference Architecture technical document is aimed to address two primary purposes. First, it serves the purpose of providing a foundational framework for all other technical documents for IIOT references.secondly, it provides guideline for the development, documentation and deployment of IIoT systems.

An architecture framework contains all the information for identifying the fundamental architecture, constructs and specifies the concerns, various stakeholders involved, viewpoints, model kinds, corresponding rules and all the conditions of applicability. IIoT System architects and designers can use this architecture framework to discover, describe and organize point of concerns of the system; they can further use architectural representation to clarify, analyze and resolve these concerns. At the centre of the ISO/IEC/IEEE Architecture description standards are various viewpoints like usage, functional etc. A viewpoint consists of the all the related conventions that defines the description and analysis of system of the interest. A viewpoint frames one or more concerns or topic of interest. A stakeholder could be an individual, a team, an organization or multiple classes, having an interest in a system concern and in the same way, an interest in the viewpoint of the system. To help the tasks of explaining, analyzing and 28 resolving the point of concerns, one or more modeling construct is required which can be defined as the model kinds for each viewpoint. The model constructs of the viewpoints and their related stakeholders, concerns and model kinds can be named and grouped as the architecture frames. On the basis of the approach defined by the ISO/IEC/IEEE Architecture Description standard, the concept of describing, analyzing and resolving, the set of specific concerns in each viewpoint is explained as the architecture view for each viewpoint. Applying the model kinds defined in each viewpoint to describe, analyze and resolve the concerns helps in the formation of architecture models that creates the respective architecture view. The architecture views along with their architecture models can be considered as the representations of the architecture. This is how the ISO/IEC/IEEE Architecture Description works. Figure 3.1 explains the content of a standard architecture description and the relations between the related terms and concepts therein. The architecture description guides the system architect to develop an architecture based on the application.

Functional Viewpoint: The functional viewpoint basically emphasis on the functional components of the IIoT system. It also consider the structure and inter-relation of the components, and the functional interfaces and interactions between them. It establishes the relation and interactions of the system with external elements in the environment to support the usages and activities of the system. As if we bring these control systems online with the help of Industrial Internet, the control will always remains essential part of industrial systems. The control here is the process of automatically doing the operation, based on sensory inputs received to achieve process objectives. Many control systems used today are of low-latency controls to physical systems in close proximity, without a network connection to other systems. Due to this, it is difficult to create local control network, let alone perform all the operations. The inclusion of IT into the OT has primarily emerged due to a need to connect larger control systems and devices and establish control over hierarchies of machines along with scheduling and optimization of resource consumption. There was also a requirement to move toward controls that can digitally simulate the physical world. This requirement led to new approach such as machine learning, possible to apply to OT. The combination of IT and OT brings a great possibility of advancement to a system. But the main obstacle is safety and resilience. Many process-critical OT applications are so critical that certain levels of software reliability that are acceptable in the IT are not sufficient for OT.

Reference Architecture Model for Industry 4.0: Reference Architecture Industry 4.0 (RAMI 4.0) is a reference architecture model, developed by members of the Industry 4.0 platform, the group of the German Companies: BITCON, VDMA & ZWEI, and was introduced into standardization in Germany with the DIN SPEC 91345:2016 and in 42 international network through IEC/PAS 63088:2017. It explains a reference model for the architecture of technical components; also known as assets, and also enable their description and life cycle and their assignment to technical and organizational hierarchies to be defined in DIN-SPEC 91345:2016-04. A three-dimensional model which represents the Industry 4.0 space as described in the figure have some features of the model of the Smart Grid Architecture Model, which was developed by the European Smart Grid Coordination Group (SG-CG) and is now accepted worldwide. It was adapted and extended to meet the Industry 4.0 requirements. The function layer is described as:

• Description of various functions.
• Platform for horizontal integration of the various functions.
• Run-time and modeling environment for services to support business processes.
• Run-time environment for technical & applications functionality.

Rules and decision-making logic are developed in the Functional Layer. Remote access and horizontal integration occurs within the Functional Layer. Such type of access is in particular used to call up information, processes which are only relevant to subordinate layers. For examples, include flashing of sensors/actuators or the reading of diagnosis data. This maintenance- related temporary remote access is not relevant to permanent functional or horizontal integration.

Specification of the Industry 4.0 component model: The initial condition for the implementation is that different objects come from different vendors with different communication abilities and protocols have to be implemented as Industry 4.0 components. Fig.5.3 shows how a physical object or machine of production becomes an Industry 4.0 component. The object or thing as mentioned is a standard technical component of a machine, 47 machine, software etc. may be without any Industry 4.0 component’s features. Only when the object or thing is enveloped by an administration shell or data container, they can be described as an Industry 4.0 component. The administration shell considers both the virtual representation and technical functionality of the object. Below are the examples of implementation of Industry 4.0 functionality of the object to become the Industry 4.0

• An entire machine can become an Industry 4.0 component using control system for example PLC.
• A supplier develop a component considering the an Industry 4.0 component,
• A terminal block can be considered as an Industry 4.0 component
• Also the software supplied can be an asset in a production machine.

In the component model, there are few requirements based on the VDI/VDE GesellschaftMessundAutomatisierungstechnik, 2015): development works of the Industry 4.0 components, these are as follows:

• Such network must be structured in a way that connections between any end components are possible.
• The components should follow a common semantic model.
• Industry 4.0 component should meet requirements with different areas, i.e. office floor and shop floor“
• The Industry 4.0 compliant communication data of the component should be kept either in the object itself or in a IT system.

II. CONCLUSION AND FUTURE SCOPE :

The contribution of this paper is two-fold. Firstly, the paper developed a method for aggregating evidence on the emerging advancements in the field of IIoT in relation to I4.0. The paper combines approaches to incorporate existing standards into new design model for I4.0. Secondly, the paper captures some of the best practices in industry and develops a reference architecture using a step-by-step process design. This analysis includes reflection on how automation and AI could lower the cyber risk from the IIoT integration into the I4.0 future architectures.

The paper presents the first I4.0 architecture model that integrates the recent academic literature on IIoT integration into I4.0 with the state-of-the-art practical initiatives that are currently at work in world's leading I4.0 initiatives. Research on CPS requires development of testbeds to validate the proposed solutions. In scenarios where current testbeds have limited deployment capabilities for complex computation, the model design should be further validated through case studies.

The architecture model for the integration of the CPS-IoE-5C into I4.0 requires further validation and delimiting, possibly through application to real world case studies. The process of implementing I4.0 is an evolutionary process, and as such, it would require flexibility in adapting the proposed framework to synchronise changes in the system complexities. This study proposed a new overarching I4.0 architecture model, and the holistic approach in this study can hardly be verified with the aforementioned methods. Nevertheless, these alternative approaches could be applied to validate individual components of the architecture model proposed.

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