Industrial Edge Computing - Application in Smart Manufacturing

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***Abstract*—Current advances in the manufacturing domain lean heavily towards the Industry 4.0 concept as it introduces smart, flexible and predictive manufacturing, thus resulting in more efficient production processes and new business opportunities. The main objective of I. 4.0 lies in interconnecting the entire shop floor, allowing to gather and exchange data between devices and applying reasoning on this data to improve production processes. However the I. 4.0 concept suffers from a number of drawbacks which greatly limit the use case scenarios, given that most functionalities are currently being realized with a centralized cloud approach. Some of the key problems are the importance of latency in the manufacturing domain, as some processes on the shop floor require real time decision making and therefore real time communication, the energy consumption of the used devices on the shop floor, as they have mostly limited resources, as well as the amount of devices that gather data, as this leads to a bottleneck on the back end of the network, thus making a centralized cloud approach either inefficient or impossible.**

A promising approach to tackle these problems is based on the usage of edge technologies to reduce the back end traffic by enabling a local processing step where the gathered data can be analysed locally and therefore e.g. the latency of the system can be greatly reduced. This paper surveys current trends in industrial edge computing by identifying key technologies and current advances in the integration of edge technologies in Smart Manufacturing as well as providing an overview of the benefits and drawbacks of these solutions.

It is shown that the integration of edge technologies can greatly improve the efficiency of current production processes by reducing the latency, improving the energy consumption of the devices on the shop floor and allowing a more efficient analysis of the data, resulting in a more robust implementation of the I. 4.0 vision.

***Index Terms*—IIoT, Industry 4.0, Fog, Edge, CPS**

I. Introduction

The term Industry 4.0 (I. 4.0), as it was introduced by the German government in an effort to kick start a new paradigm in the manufacturing domain, describes a model towards enabling smart, flexible and predictive manufacturing, therefore optimising existing production processes and creating new business opportunities. [1] I. 4.0, also stated as the 4th Industrial Revolution[2], consists of four essential principles: interconnection between various devices (sensors, control units, machines, etc.) on the shop floor, information transparency to enable the creation of digital twins (virtual representations of objects), assistance for human operators and the use of Cyber-Physical-Systems (CPS) to enable smart manufacturing by applying decentralized decision making at the lower levels of production, therefore incorporating communication technologies, Internet of Things (IoT) and Machine Learning approaches. [3]

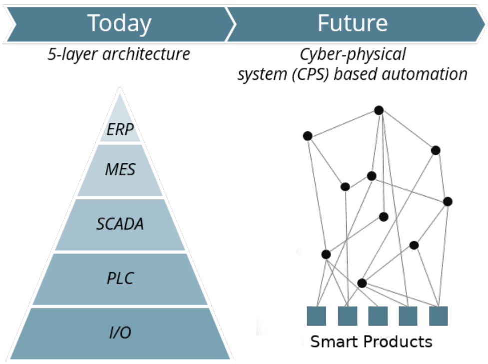

Fig. 1: Comparison between the traditional 5-layer automation Hierarchie and the future production architecture based on CPSs

The implementation of the I. 4.0 concept is thus transforming the current automation pyramid [4] towards Smart Factories [5], where not only the factories themselves, but where also the products are interconnected resulting in a decentralized/distributed ecosystem which is depicted in Fig. 1. The advantages of Smart Manufacturing over the traditional approach lie in the ability to analyse the running processes more efficiently as well as to apply reasoning to the data, which enables predictive manufacturing where machines can be controlled on a finer scale, resulting in individual maintenance scheduling on the shop floor and therefore in an improved production cycle.[6]

However the implementation of the I.4.0 concept currently suffers from different drawbacks, as the manufacturing context applies different limitations on the integration. One of the key drawbacks lies in the latency requirements of factories. [7] Depending on the domain, it may be required to provide up to real time communication between devices as even small latencies can lead to delays of the production/assembly lines or even outages. Another problem arises from the amount of devices that gather data and therefore the amount of data that has to be processed. [8] Even small devices can accumulate large sets of data over time, thus resulting in large datasets for the shop floor, as many thousand sensors and machines are part of the shop floor, and therefore requiring big data concepts.

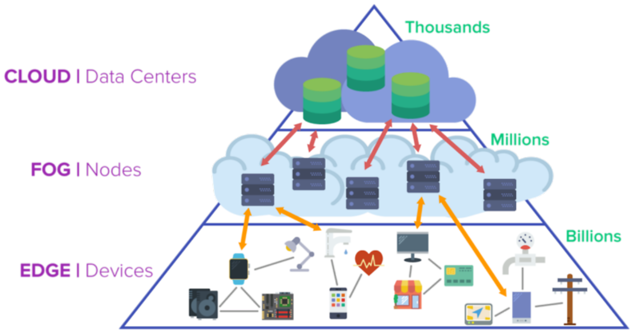

Fig. 2: Example of the division between Edge/Fog and the Cloud

Given that most current implementations rely on a centralized cloud approach(a key enabler of automation), this creates a prominent data stream and therefore a heavy load towards the cloud, resulting in a bottleneck and leading to inefficient processing of the data. Another major concern is the power consumption of the sensing devices. [9] As sensing devices are usually constrainted and in certain use cases located in places difficult to reach efficiently, it is of importance to define communication methods that reduce the energy consumption of the devices, thus improving the battery lifetime.

Edge technologies introduce a way to tackle the above stated problems by improving the computational workflow. The term Edge refers to concepts where the processing of data is not achieved at a centralized node, but where the logic of the system is pushed to the edges of the network and thus closer to the devices. [10] This concept is sometimes also referred to as FOG computing as these terms are not strictly defined and therefore used interchangeably. One way to differentiate these terms is depicted in Fig.2, where the Edge layer refers to the devices and the Fog layer represents a higher processing step. The addition of this processing step between the device layer and the cloud introduces a possibility to improve for example the latency of such systems.

This paper surveys the current trends in industrial edge computing, which leads towards smart manufacturing. It identifies key technologies, introduces concepts to integrate these technologies into existing production facilities as well as provides an overview on the benefits as well as drawbacks of these systems. This paper is therefore organized as follows. Section II provides an outline of related work on this topic. Section III introduces key technologies used for industrial edge computing, Section IV outlines integration concepts of these approaches and in Section V a discussion on the current state of industrial edge computing is provided. Section VI concludes this paper.

II. Related Work

Todo: Decide: Refer to other surveys that give an overview or to papers sighting works that implement edge technologies for smart manufacturing?

- Short outline of manufacturing as a whole (main goals) and the current trends.
- Outline existing concepts towards I. 4.0 (e.g using a centralized cloud) and state their limitations
- Outline existing works introducing Edge/Fog concepts that try to address the limitations and point out there pros & cons
- State the purpose of this work

III. Edge Computing in Smart Manufacturing

- Outline current key technologies in smart manufacturing including CPS, AS, etc.
- Outline possible concepts to integrate Edge/Fog computing capabilities into the I. 4.0 vision / current manufacturing context

IV. Evaluation

- Evaluate/State the advantages that can be obtained from the integration of Edge/Fog computing
- Identify and outline the drawbacks/difficulties and open problems
- Give a short summary stating the most promising technologies & concepts and highlight their potential towards a flexible & smart manufacturing landscape

V. Conclusion and Future Work

- Provide a short summary of the paper and the most important results (key technologies for the future)
- State what these technologies mean for smart manufacturing
- Outline possibilities for further work

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