# Industrial Edge Computing - Application in Smart Manufacturing


Alexander Metzler
TU Berlin, Berlin, Germany,
Department for Open Communication Systems

Farah Nasir
TU Berlin, Berlin, Germany,
Department for Open Communication Systems



***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 the gathering and exchanging of data between devices and applying reasoning based 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 business functionalities are currently being implemented using centralized clouds. Some of the key problems for the manufacturing domain are latency, as some processes on the shop floor require real time decision making and therefore real time communication, the energy consumption of the devices at 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. latency concerns can be greatly reduced. This paper surveys current trends in industrial edge computing by identifying key technologies for the I.4.0 use cases, outlining 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. However it is also shown, that to maximize the true potential of edge computing in the manufacturing domain, existing plants have to be radically transformed to meat the requierements for an efficient system.**



***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 real 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]

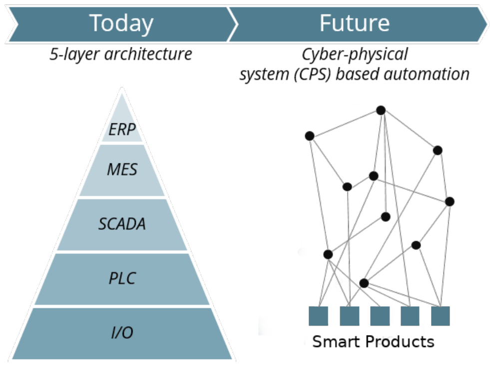



Fig. 1: Comparison between the traditional 5-layer automation Hierarchie and the future production architecture based on CPSs

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 lie in the ability to analyse running processes efficiently as well as to apply reasoning on 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

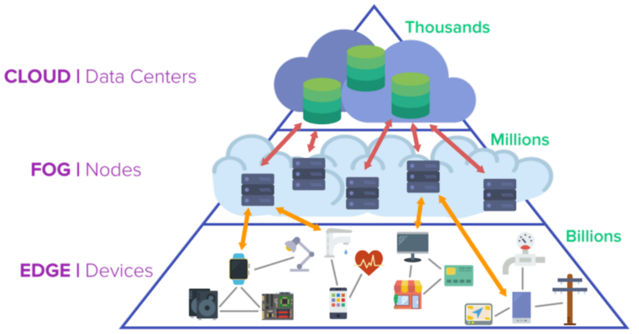



Fig. 2: Example of the division between Edge/Fog and the Cloud

the shop floor, as many thousand sensors and machines are part of the shop floor, and therefore requiring big data concepts. 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 altering the computational workflow. The term Edge refers to a cencept where the processing of data is not achieved at a centralized node, but where the logic of the system is pushed towards 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 option to differentiate these terms is depicted in Fig.2, where the Edge layer refers to the devices themselves 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 limited the drawbacks of tradinitional approaches.

This paper surveys the current trends in industrial edge computing, which leads towards smart manufacturing. It identifies key technologies in the manufacturing domain, 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. The rest of this paper is organized as follows. Section II provides an outline of the related work on this topic. Section III introduces key technologies used in the Smart Manufacturing and outlines advances in the field of 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. Smart Manufacturing

Smart Manufacturing introduces various new technologies that are geared towards improving the efficiency of current production systems or changing them to create new value and expand existing business models. The main components in implementing this concept consist in the interconnection, collaboration and execution resulting in four layers which consist of the physical resource layer, the network layer, data application layer and the terminal layer [11].

The resource layer includes all devices that are part of the manufacturing life cycle (sensors, machines) and which enable intelligent manufacturing. Some of the key aspects of this layer are configurable units and controllers to provide the needed flexiblitity of the devices and the controlling processes that observe them. Another key problem consists in the implementation of a reconfigurable production line in order to adjust for capacity in real time as well as intelligent data acquisation, as the devices are using heterogenous protocols such as RFID, ZigBee and others.

The network layer on the other hand provides the means by which smart factories can operate as they require reliable, secure and fast communication. One of the most prominent solutions is Industrial Wireless Sensor Networks, which build on top of the general WiFi. Because many connectivity and communications technologies are used in the industrial domain, frameworks like OPC UA are used in order to abstract the various technologies away leading to an efficient and uniform communication and therefore allow to enable the implementation of Smart Factories. Other solutions include D2D (Device to Device) communication. One promising technology to implement the Smart Manufacturing effiencently is the implementation of edge technologies, as it provides the means by which network bandwith can be optimized and latency reduced.

The data application layer is used to infer knowledge where the semantic association between manufacturing data is established using ontology models. Other topics also include big data (sensor data, machine log and machine processing data).

In order to implement edge technologies into the current manufacturing domains, a hierarchical architecture is mostly choosen consisting of the device at the bottom, the intermediate layers implementing the edge concepts and the cloud at the top

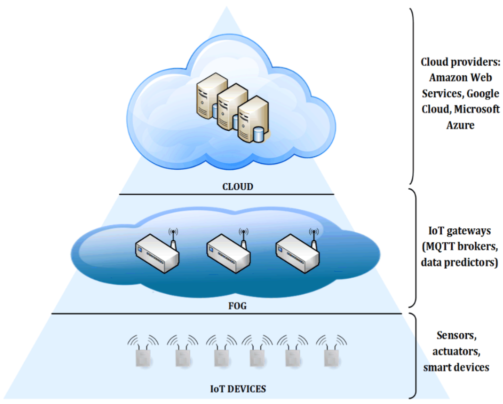
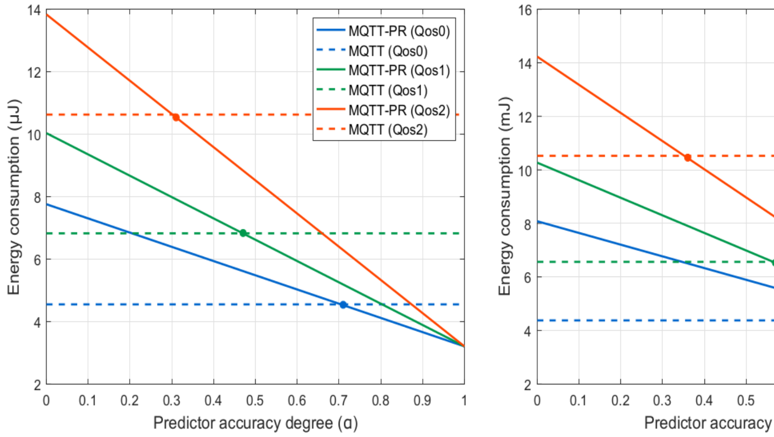



Fig. 3: Introduced architecture for the integration of fog capabilities




(a) WiFi link.

(b) 4G li

Fig. 4: Effect of different QoS levels on the energy consumption of the sensing devices

of the hierarchy. The most used communication protocal for such applications is the MQTT-protocol which implements a publish/subscribe approach, where publishers are pushing data to the broker and subscribers subscribe to different topics and receive information about those topics when a change when new data is available.

## IV. Implementations

As edge and fog technologies are by many seen as additions to pure cloud approaches and most current factory implementations are using central clouds, many works are based on a mix between Edge and Cloud technologies. One such approach was introduced by Peralta et al in order to reduce the energy consumptions by the devices at the shop floor. Their approach is based on a three layered architecture, where those layers are composed of IoT nodes at the lowest level, an intermediate fog layer with IoT-Gateways and a cloud layer for crucial decision making and logging. An example of this architecture is shown in Fig. ???.

The way by which the devices at the different layers are exchanging data is using the MQTT-Protocol, where the nodes are the publishers and the fog layer, consisting of IoT-Gateways, represents the broker towards the cloud side. The means by which this proposed work is improving device energy consumption is by limiting the amount of data that has to be sent from the devices to the Gateways by applying a prediction algorithm using machine learning concepts at the fog layer. After an initial traning process, where sensed data from the devices is being sent to the fog layer, the fog layer is able to make forecasts for the data. Since the devices only have to transmit the data if the prediction fails to meet a predifined threshold, the amount of data transmitted by the devices can be greatly reduced. When using MQTT the QoS level impacts the enery consumption aswell. This effect can be seen in Fig. ???

Another approach was introduced by Lin and Yang where the goal was to apply a cost effiecent deployment of fog computing into a logistics center use case. Similarely to above mentioned approach, they make the assumption that the implemented architecture consists of the device layer, fog layer and a cloud layer. However they also add an additional edge layer that is placed at the very edge of the network, providing a intermediate layer between the devices and the fog layer and enabling up to real time decision making. This architecture follows the following workflow. The devices are sensing data at the shop floor and forward them to the edge layer, where decision making is applied depending on the location. If a decision cannot be made at the edge layer it is forwarded to the fog layer, where the responds time is lower than one second. The transmition of data towards the cloud in this framework only happens for long time storage. In order to implement an efficient workflow the edge and fog devices have to be placed efficiently to provide the fastest possible implementaion.

## V. Discussion

As shown in this paper edge technologies are providing an efficient way to coup with the problems of current manufacturing system. As of now various works provide novel approaches to improve key drawbacks such as latency and energy consumption. However the current advances provide only limited application for real use cases. One major drawback lies in the need to restructure existing factories in order to implement the mentioned approaches.

## VI. 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

## References

[1] The European Commission, "Germany: Industrie 4.0," 2017.

[2] H. Lasi, P. Fettke, H.-G. Kemper, *et al.*, "Industry 4.0," *Business & information systems engineering*, vol. 6, no. 4, pp. 239–242, 2014.
[3] M. Hermann, T. Pentek, and B. Otto, "Design principles for industrie 4.0 scenarios," in *2016 49th Hawaii international conference on system sciences (HICSS)*, IEEE, 2016, pp. 3928–3937.
[4] C. Costa, C. Mendes, and R. Osaki, "Industry 4.0 in automated production," Nov. 2017.
[5] K.-D. Thoben, S. Wiesner, and T. Wuest, ""industrie 4.0" and smart manufacturing – a review of research issues and application examples," *International Journal of Automation Technology*, vol. 11, pp. 4–19, Jan. 2017.
[6] M. Riedl, H. Zipper, M. Meier, *et al.*, "Automation meets cps," *IFAC Proceedings Volumes*, vol. 46, no. 7, pp. 216–221, 2013.
[7] C. Shi, Z. Ren, K. Yang, *et al.*, "Ultra-low latency cloud-fog computing for industrial internet of things," in *2018 IEEE Wireless Communications and Networking Conference (WCNC)*, IEEE, 2018, pp. 1–6.
[8] A Kusiak, "Smart manufacturing must embrace big data," *Nature*, vol. 544, pp. 23–25, Apr. 2017.
[9] C.-C. Lin and J.-W. Yang, "Cost-efficient deployment of fog computing systems at logistics centers in industry 4.0," *IEEE Transactions on Industrial Informatics*, vol. 14, no. 10, pp. 4603–4611, 2018.
[10] W. Shi, J. Cao, Q. Zhang, *et al.*, "Edge computing: Vision and challenges," *IEEE Internet of Things Journal*, vol. 3, no. 5, pp. 637–646, 2016.
[11] B. Chen, J. Wan, L. Shu, *et al.*, "Smart factory of industry 4.0: Key technologies, application case, and challenges," *IEEE Access*, vol. 6, pp. 6505–6519, 2017.