First Steps for a 5G-Ready Service in Cloud Manufacturing

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Abstract— One ambition of Industry 4.0 is that all physical, virtual and human entities shall be able to communicate among each other. This approach provides a huge potential in case of further merging of production processes and further, offers the possibility to combine facilities from different local sites to one system. As an outcome, the production processes can be controlled from a remote fixed or mobile terminal to control and therefore have access within the production line. Especially for customers it is highly convenient to have a transparent insight in the running production process and the actual status of his orders. Moreover, to be able to change orders during running manufacture.

Nowadays the industrial environment has changed a lot as the customers' demands have increased enormously. For instance, mass production must be smarter and all kind of data and information has to be handled. Furthermore, individual customized solutions are desired by clients. To react on the changing demands new solutions are necessary. Connecting all types of entities and equip the facilities with sensors to react on individual demands require a high reliability and security with a dynamic bandwidth, especially when production facilities have to work autonomously.

With the upcoming fifth generation of mobile communication (5G) many required demands in the industrial environment can be satisfied. This means that 5G will have a deep impact in Industry 4.0 as it will be able to handle shortages concerning data handling, real-time demands and controlling hundreds of connected devices.

BIBA's research topics lies in the field of production and logistics. With the new technology, the focus of research aims to examine requirements, constraints and the benefits of 5G for the industrial environment. By means of two use cases, one in production, the other one in logistics, the possibilities of 5G will be examined. The present paper will indicate the first steps by showing the use cases and first thoughts about the potential for future production facilities using cloud manufacturing.

Keywords— Smart Factory, cloud manufacturing, 5G-ready application

I. INTRODUCTION

With the help of the internet in the last years, the real and virtual world is growing together which is commonly known under the term the Internet of Things (IoT). Parallel to the existing models virtual mapping are created. The future ongoing especially in production and logistics for the German industrial environment is described as Industry 4.0. It includes cyber-physical systems, cloud computing as well as the the Internet of Things. With the idea of connecting physical, virtual and human entities and give them the possibility to communicate among each other, it allows a system to make decentralized decisions. Hence, one of the goals of Industry 4.0 are an extensive connected production line with a high individualization of flexible products. In addition, intelligent real-time monitoring and decision-making shall be able to control and optimize the production processes [1].

Especially IoT requires a large amount of sensors to receive the required data and information. Therefore, a high increased data transfer, the storage and analysis of the data has to be handled. Next to the common fixed and wired facilities, mobile devices and individual solutions have to be involved for a more convenient way to manage and supervise running production and logistic processes. Nevertheless, the high demands lead to more and more complex systems with very high requirements, which can only be handled partly at the moment.

With the upcoming 5th generation (5G) in telecommunication, it shall satisfy the demands. High data rates, edge computing and secure transmissions are some of the benefits of 5G. Now 5G is still in development and general standards are not defined yet. However, the actual plan foresees first test devices for the year 2020 and the beginning of commercial use in in 2025 [2].

The main challenging requirements for later use cases are low latencies, very high availabilities and reliabilities as well as energy efficiency. Also for comprehensive availability data and information must be stored decentral e.g. by using cloud services. Further, a flexible and dynamic end-to-end connection has to be provided to insert dynamically the customers' needs. Finally, a secure end-to-end data transmission must be guaranteed, especially when data is stored in a cloud.

Depending on the later applications, three implementation groups are arised and now under development:

1. Enhanced Mobile Broadcast (eMBB) which is offered for high device connectivity and high mobile data rates
2. Massive Machine Type Communication (mMTC) which is offered for Industry 4.0-applications and intelligent logistics. Especially for the demand of hundreds of thousands connected devices and a high-energy efficiency to extend the battery life time of sensors and actuators.
3. Ultra-Reliable and Low-Latency Communication (ULRRC) is used for highest connectivity and quality of services and real-time data transfers. Relevant in smart manufacturing which highest and precise time critical requirements [3]

Especially mMTC and ULRRC are interesting as these implementation groups belong to the scope of production and logistics.

II. Approach

The main goal in this research topic is to connect existing facilities to one complex production line and handle the production process with mobile end devices. Moreover, it aims to develop the implemented production processes to a cloud manufacturing system. This also means that the production environment has to be digitize to achieve a seamless connection. Based on the existing infrastructure two facilities will be used for further research concerning the new technology 5G in an industrial environment.

In the Industry 4.0 vision, future collaborative business settings are among others characterised through the improvement of the ways in which data in manufacturing processes are processed and integrated into the entire manufacturing supply chain. Data emerging from equipment, control systems, products, legacy systems, complex industrial designs and distribution networks needs to be shared, analysed and processed seamlessly under real-time constraints and in a secure way. As such, data can be communicated between globally distributed production sites and actors in the value chain (e.g. suppliers, logistic companies). A way of achieving this goal from a technical point of view is by the adaptation of existing infrastructures and related requirements with emerging high-bandwidth and data-rate communication solutions.

Considering the production environment, BIBA with its focus on production and logistics is examining two use case scenarios in this field. The first one addresses logistic processes. For an optimized system, all participants such as production sites, transportation, supplier, maintenance services and remote controls have to be connected with each other. In addition the data must be accessible for all participants which can be done by using cloud services to store and handled the data [Fig. 1].

The second scenario addresses the manufacture within a production site itself. Here, similar to the logistic concept, the participants such as automated assembly processes, human-robot collaboration, warehousing and packaging [Fig. 1] have to be connected and be able to communicate with each other as well (on-site connectivity). In addition, cloud services for data handling will be useful.

Considering the related requirements and concepts a merging of both scenarios is highly interesting. Combining both brings a complex production line and offers the possibility to have insight and access in the complete process. These use case scenarios address a new scenario of connected manufacturing facilities, which are embedded in a lab infrastructure and shall be supported by cloud services for data handling. Main challenges are expected by the diversity of multiple stakeholders, which are typically running different technologies and management solutions. One aspect of the use case scenarios is that the customer will have the possibility to get a deeper look inside the customer's order. After making the order, the customer can track the different steps from achieving the raw components, following the delivery, the production itself and finally the warehousing [Fig. 2] It shall be possible for the customer to have constant access to every detail about the whole delivery process, with answers to questions such as: "Where are the raw components?", "When does the delivery arrive?", "When is the expected time for finishing the order?".

As a representative for the industry, the requirements, constraints and benefits of 5G in the field of Industry 4.0 will be researched. Nevertheless, the high demands of a complex

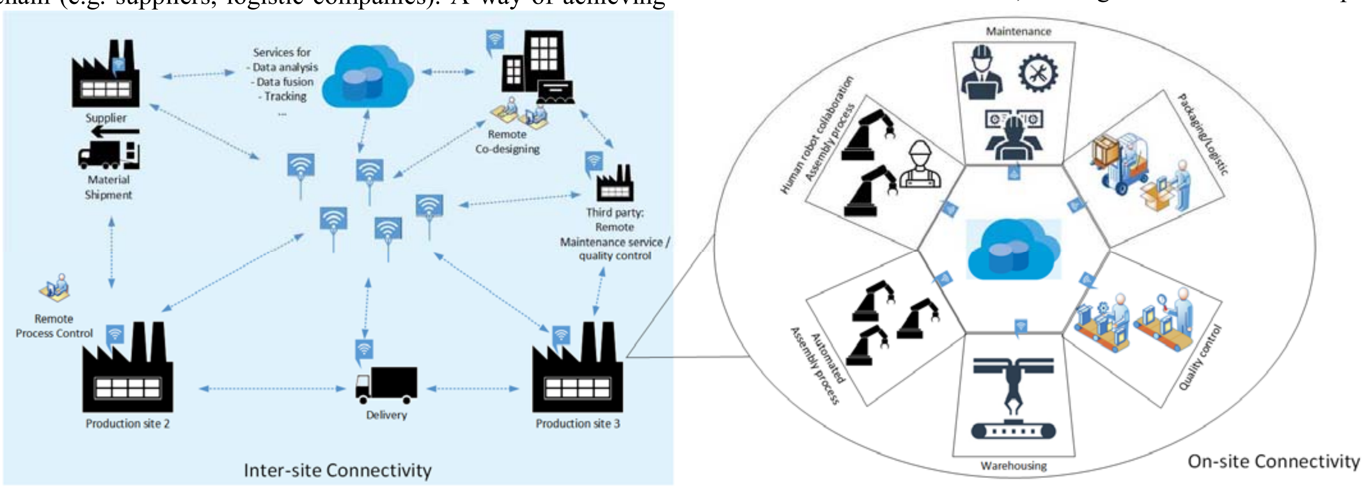

Fig. 1. Logistics and manufacture concept

production line with multiple facilities, hundreds of entities and thousands of sensors cannot be fulfilled with the existing infrastructure. By means of two use cases a 5G-ready application shall be developed which shows a combined logistics and production process which can be monitored and handled via a dash board. By scaling to an equivalent dimension, the requirements and technical approaches will be examined and evaluated.

III. USE CASES

The idea behind both use cases is a combined production line as a prototype in cloud manufacturing. The demonstration scenario will start with three independent customer orders for different automotive parts. One aspect is that the customers having the possibility to get a deeper look inside their order. Every customer will be able to monitor the status of the customer's own order and interact directly with the assembly process. During processing, orders can be reconfigured (e.g., change the color of a component, choose another cable type) and the customer has the opportunity to cancel or create orders. In addition, the scenario will include the case of a workstation failure and provide Service Consumers with the new delivery time of their orders.

The first scenario describes a logistic scenario where three customers can make their orders on a mobile end device by using an application, which shall be ready for 5G at the end of the project. The scope for this use case shall begin with the order and achieving/delivering the raw components, send them to the manufacturing facility and finally warehousing the complete products [Fig. 2]. The logistic chain consists of several facilities, which are available at BIBA [4]. For example, for transportation an existing truck shall be used, for the manufacturing /assembly a cyber-physical production system and for warehousing a high rack system are available. Besides, a dashboard for every customer shall be provided, so that each customer can see the actual process of his own order. After making the order, the customer can track the different steps. It shall be possible for the customer to have constant access to every detail about the whole logistic process. Following this scenario, every customer can only access its own order. Also, it shall be possible to set a priority for an order (e.g., it has to be finished within a certain time). For the logistic chain, all orders (from the customers) are running parallel. Therefore, a negotiation of the products and components is required to fulfil the orders in an optimal way. For this use case, the facilities have to be linked with a smart object and require clear service provisioning and real-time capability of the overall communication network. This encompasses interfacing to existing legacy systems of OEMs, as well as interconnecting suppliers or logistics service providers. Network slices shall be used for the customers' orders. As it is already very complex, this use case mainly focuses on the part of delivery in the supply chain. In this mentioned scenario, a truck shall be used. It has to be equipped with tracking and communication devices such as a GPS transmitter. The data shall be stored in a cloud environment where the client can trace, via a terminal or smart device, the client's own order. Besides, by using network slices, every client has only access to his/her own order. This also means that separated and flexible resources are required, depending on the orders. A further challenge considered in this scenario will be what will happen during interferences. In case of interference, much higher bandwidth is required as the communication between the products rises enormously.

The second use case describes a scenario within the manufacturing process. Here, the customers are able to see the actual manufacturing status. In the new supply chain's competitive markets, enterprises must provide customers with a range of information services in real-time, tracking capabilities, as well as product customization alternatives in product configuration. In the new environment, customers want to know at all times the status of their orders and the relative delivery date. They want assurances that their particular needs can be incorporated into product configuration. The aim is the prototypically development of a cyber-physical production system, that deals with the environment's requirements. For a real-life demonstration an existing prototype will be used as a production environment for automotive assembly. The demonstrator will consider a production/assembly process of mass customized products, e.g. fabrication of automotive parts and will focus on a production scenario in which mass customized automotive parts are ordered by a customer and produced by the different production facilities into the production plant. The internally distributed production facilities form a network by means of being connected to the intranet/Internet and the ability to communicate with each other using defined interfaces and protocols. For configuring and ordering the customized product, a cloud service is provided. With this service, the customers are able to develop customized products by selecting from a number of components and options, e.g. the color/size of the automotive part and additional characteristics [5].

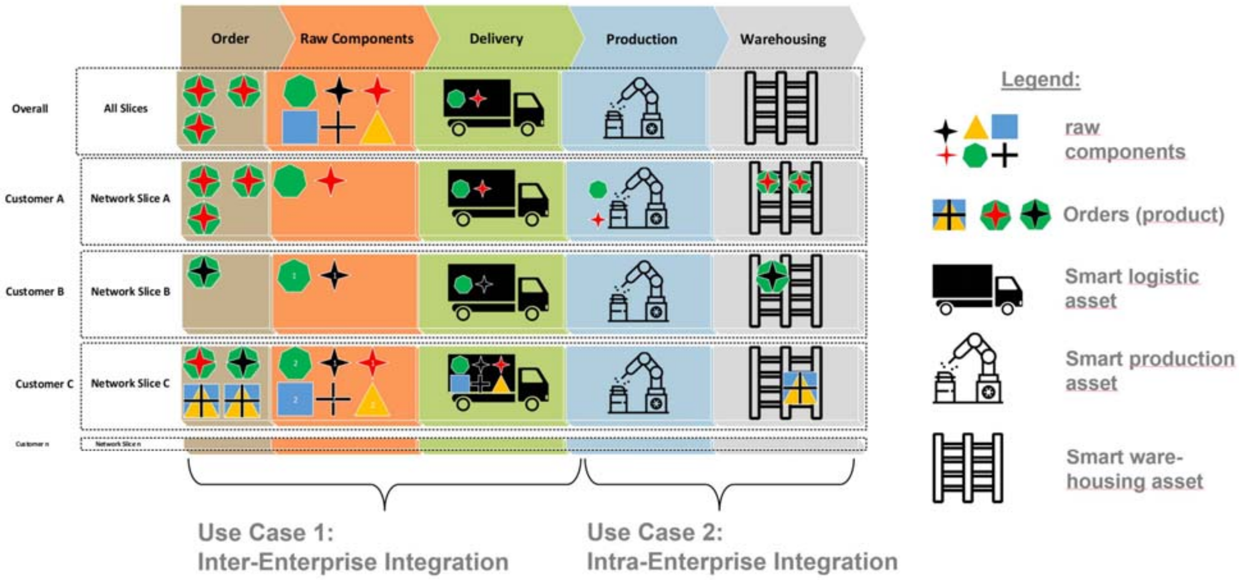

Fig. 2. Combined Use Case Scenarios

After the configuration of the expected product is completed, the customer's order is forwarded to a provider that automatically plans and deploys the necessary production steps to the production plant. For this step, a local production facility (e.g., production facility A for assembling, production facility B for painting) is selected. During the production of the automotive part, the different facilities are monitored for diagnosis to enable further optimization of the production process and, if necessary, reasoning about possible reconfiguration measures in case of failures. In order to implement the selected scenario, novel software paradigms and architectural approaches will be applied for the production facilities that include workers, machines, tooling, components of final products, products and for the customer interfaces. The adoption of systems based on a multi-agent architecture has proven its utility in several works. Multi-agent systems have been widely investigated for providing a support for modularization, decentralization, autonomy and reusability, and are increasingly adopted in order to realize different functionality required to enhance production automation and control. Most applications of software agent concepts for production systems address different reconfiguration issues of the production system to handle modules'/workstations' breakdowns or structural changes of the system, or to realize distributed production planning. Based on task descriptions to realize a certain production process, software agents that control production system's components and monitor the state of products will be implemented. Decision options for reconfigurations of the production system will be realized by redundant control functions offered by different modules. Therefore, the users can reconfigure the automation system's behavior of inner logistic systems online. The reconfiguration of a production automation system to compensate components' or workstations' breakdowns under varying throughput conditions will be developed. Each machine or workstation is equipped with an IoT module for edge computing to guarantee 5G requirements. To complete the assembly of automotive parts, many processing steps have to be carried out and many product types are available. The diverse assembly parts (raw components) are illustrated in [Fig. 2]. This scenario includes the flexibility to change the sequence of the assembly steps. The aspect of flexibility is taken into consideration by offering many workstations for assembling a specific component.

Since both use cases are addressing the acquisition of huge production data, cloud resources have to be offered for data processing and storage (Cloud Infrastructure Providers). To enable real-time interaction of the costumer with the production plant, dashboards have to be implemented. The collaboration with 5G Application Software developers will ensure the implementation of generic robust and secure interfaces, which will be later available on application marketplaces. The integration of those types of services into industrial applications, such as the addressed scenario, could be the role of Service Providers.

As the single use cases are already very complex, both are examined and developed separately now. As both are part of a supply chain, where a client order a product and can follow the production process back to the single components, these two scenarios will be merged to one scenario at a later time in this project.

A. Challenges

To achieve a reliable connection between the different stakeholders, the network infrastructure has to manage different technologies and management solutions with low latencies, safety, and separate logistic/order chains. Furthermore, tracking of the components for traceability is required. At least, the transportation service needs a GPS transmitter. In order to achieve the goals and ensure the defined requirements for an industrial environment, many actors/stakeholders have to be involved during the implementation and testing of the expected prototype. Since the use case addresses the acquisition of huge production data, national cloud resources have to be offered for data processing and storage (Cloud Infrastructure Providers). For enabling a real-time interaction of the costumer with the production plant, dashboards have to be implemented. The collaboration with 5G Application Software developers will ensure the implementation of generic robust and secure interfaces, which will be later available on application stores. The integration of those types of services into industrial applications, such as the addressed scenario, could be the role of Service Providers.

A further challenge is to achieve a highly flexible automatic logistic production chain. In detail, the idea is to give three customers the possibility to track, change and prioritize their own orders. This includes information about when, where, and real-time monitoring. All the data shall be stored in a cloud service [Fig. 1]. As each item belongs to a different customer, there shall only be access to that customer's certain order. This requires a very flexible system where all facilities and products – respectively, components – have to interact with each other. In normal mode, the communication between the products will be set with the order. By using network slices, every order shall receive enough bandwidth so that the logistic chain process can communicate and run smoothly. A challenge related to scenarios whereby interferences occur is how to react on this. The communication between facilities, products and components will increase. For example, for a small order the exchange of information requires much more bandwidth than during the normal mode.

These approaches lead already to numerous requirements and questions that has to be answered clearly in advance.

B. Requirements on 5G in Industry 4.0

So far, the following requirements for both industrial approaches can be determined:

- **High reliability** to guarantee the (and avoid failures) data transmission which has an impact on the quality of services.
- **Low latencies**, especially during manufacturing, to guarantee a seamless collaboration between the entities.
- **Real-time monitoring** for a transparent view on the production processes.
- **Cloud services** for storing and handling data. This gives the possibility that independently from each customer's position access to the system and production status is available.
- **Separated** slices for a secure and isolated order for each customer.
- **Tracking/tracing** to fulfill the demands in logistic concepts, especially for real-time monitoring.
- **Flexible bandwidth** will be very useful in a mass production scenario where hundreds of entities communicate with each other. In case of an failure the system's participants have to continue with its tasks which leads to a much higher communication between the participants and this results in a much higher required bandwidth.
- **Security**. By using a cloud service and guarantee the safety of the data, for each client a secure end-to-end connection is required.

IV. Summary and Outlook

So far both scenarios are settled. Both Use Cases are separate but in preparation to merge to one combined automated logistic production scenario. Furthermore, the parameters for the requirements using 5G in an industrial environment are examined and listed. The next steps in this research topic will be the preparing of both use cases to be able to use a 5G architecture. In addition, the GUI for mobile end devices and dashboards will be developed so the above-described scenarios for logistics and production can be realized.

For future projects, an integration of further existing facilities in this production-logistics scenario is considered.

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