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IMPLEMENTING INTEGRATED SYSTEM NETWORKS WITH 5G TECHNOLOGY IN THE GERMAN CAR INDUSTRY

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Abstract: *German car manufacturers' digitization initiatives encompass projects that aim to build integrated system networks supported by 5G technology. Here, the results of scientific research are presented in which IIoT ("Industrial Internet of Things") projects have been analyzed with regard to their suitability for 5G implementation, respectively the efficiency of the new technology within an integrated system network. The researched IIoT projects originate from a so-called press shop which is the part of the manufacturing plant in which automotive sheet metal components are formed in a metal press. On the basis of the insights drawn from the IIoT project analysis, it is shown that the implementation of a 5G-supported system network can transmit, bundle, and visualize huge data volumes, can moreover make the production process more efficient, and finally can improve collaboration and quality. A special focus is on the organization of information, which will improve significantly, since 5G allows real-time communication.*
Keywords: *digitization, automation, network building, management of information, 5G technology*

INTRODUCTION

For many decades, the German automotive industry has been a key industry branch contributing considerably to the country's wealth. For example:

- 4% of all jobs are associated with automotive manufacturing (Statistisches Bundesamt 2019);
- around 506 billion € in revenues were generated in the car industry in 2022 (Statista 2023);
- and around 70% of the value creation from German automotive suppliers occurs in the country itself (Bundesministerium für Wirtschaft und Klimaschutz 2023).

While these figures underline the importance of the industry branch for the BIP, the question whether this performance has always been achieved with the latest technological equipment is absolutely justified. At least at the beginning of the new millennium, the German car industry was still underdeveloped in regard to the degree of automation in their facilities. "Manual work still plays a major role in three quarters of the researched companies, and production is either based on it or strongly depends from it in a hybrid system. Less than a quarter of the researched productions are fully or highly automated" (Spath 2013).

Regarding the current status of digitization and automation in production, Volkswagen at Wolfsburg is a good example. "To date, Volkswagen's press shop is still a conventional production area. Large coils of sheet metal are shaped into vehicle parts, it is noisy, every stroke is noticeable" (Volkswagen AG 2022, 45). Nevertheless, digitization and network infrastructures more and more play a part. Andreas Ellermeier, head of Volkswagen's press tool construction department, says: "Processes such as trim and coining steel manufacturing now are increasingly being automated […]

Press tool construction which is the central pillar of classic vehicle production finds its way from a traditionally manual environment into the digital world […] Now we are about to march towards digital and autonomous press tool production" (Volkswagen AG 2022, 44). So it is easy to see that "[…] the world of real hardware and that of virtual production is bridged by the digitized process chain" (Volkswagen AG 2022, 44).

These hybrid models are in use in other Volkswagen facilities as well. For instance, their " […] Condition Monitoring Team […] safeguards access to data and provides technical expertise. Together they are installing a network solution, in order to productively implement machine learning models. They prefer a hybrid system in which machine learning models nearly run in real time on shop floor level, generating forecasts. Additionally, we create connectivity with our digital production platform, in order to perform post-trainings for aged machine learning systems" (Volkswagen AG 2022, 45).

The Volkswagen examples prove that car makers have understood, since all of them have meanwhile taken measures to digitize or automize production. In this context, the author of this article was able to scientifically accompany a variety of IIoT projects (cf. *Table 1*), originating from the press shop of a renowned car manufacturer headquartered in Southern Germany. The goal of the research was to evaluate these projects in regard to their 5G upgrade potential and to the expected efficiency of 5G technology within an integrated system network.

RESEARCH METHODOLOGY

A press shop is that part of the plant where sheet metal is inserted into a press where the material is shaped into components that eventually form the cars' bodies. The facility provides the ideal setting for this kind of research as it not only represents an "automotive mini-cosmos" in which all aspects of digitization can be studied in a nutshell, but is also one of those areas, where manufacturing is still characterized by principles of traditional craftsmanship so that the introduction of new technologies allowing data collecting and state-of-the-art digital data evaluation is considered to be revolutionary. Qualitative analysis was used to explain the circumstances of the case and to describe what is needed for developing an efficient integrated system network, while quantitative methods were used to evaluate statistics, perform calculations, and prepare scoring models on the basis of self-developed mathematical formulas. With the help of these scoring models, a total of nineteen IIoT projects were ranked according to their feasibility and to the expected efficiency of 5G technology within an integrated system network.

RESULTS

A VARIETY OF PROJECTS: The researched IIoT projects ranged from "Automatic maintenance order" to "Consistent online data use" or "Enterprise resource planning on digital terminal devices" to more technical applications such as "Inline crack detection". The generation of data, that for instance are collected by newly installed sensors, their evaluation and visualization, and finally the impact of the transformed processes on the company's information management were the main aspects of the research. The potential of implementing 5G technology in IIoT projects is huge, since the latest generation telecommunication standard is extremely fast and can transmit immense data volumes in real time. So when 5G potential was measured with the help of scoring models, it was no surprise that particularly "Big Data" and "Network" related projects made it to the top (cf. *Table 1*). In detail, these were the parameters that characterized 5G opportunities:

- the higher the frequency of data, the more the system will benefit from the implementation of 5G technology which in turn will significantly accelerate the information flow;
- the more data sources, the higher the data complexity and the greater the need to process the data with 5G that is low in failure rates and latency;

- the greater the need to evaluate the data in real time – for example, in order to be able to prevent or to quickly react to machine failure – the more the implementation of 5G in IIoT concepts will make sense.

THE IMPORTANCE OF NETWORK BUILDING: In the context of network building, the insight that "Big Data" and "Network" related projects are best suited for 5G upgrading and promise the optimum of 5G efficiency speaks for itself. So in order to fully benefit from the implementation of 5G technology and moreover to achieve the desired synergy effects, it is necessary to bundle the technological efforts in a comprehensive system network that eventually will guarantee a significant optimization of the information management. Because by harmonizing the individual information sources, by consolidating the extracted information and by providing information in a convenient, preferably visualized form, an integrated system network will allow managers, operators, or workers to react immediately after receipt of the respective information, which brings the organization of information to the next level and improves decision quality.

Table 1. Nineteen IIoT projects were scored according to their feasibility and to the expected efficiency of 5G technology within an integrated system network. (Own graphic)

Strategy	Project Name	Overall project feasibility	Expected 5G efficiency
360° network	ERP on digital terminal device	138	138
Big Data	Unidor monitoring	108	138
Big Data	Material parameters measurement	108	138
Big Data	Online quality data	138	123
Big Data	Drawing process management	108	108
Digital process chain	Remote Maintenance	92	108
Smart supply chain	RFID tags for block storage	77	108
360° network	Automatic maintenance order	92	108
360° network	Consistent online data use	138	108
Big Data	Digital control of milling machines	108	92
Big Data	Condition monitoring	108	92
Smart supply chain	Component traceability	92	92
Big Data	Steinbichler working packages	123	77
360° network	Paperless factory	62	77
Agile production systems	Light guide system	62	77
Big Data	Inspection by notch sensor	77	62
Agile production systems	Sarissa QualityAssist	62	62
Big Data	Inline crack detection	77	62
Agile production systems	3D printing in tool manufacturing	62	62

NETWORK BUILDING IN A PRESS SHOP: If equipped with sensors and upgraded with 5G, a sheet metal press is a very good and reliable source of valuable data. The respective management of information is exemplarily shown in *Figure 1* for one machine, but it is also easy to imagine how this unit can be expanded to an entire press line, all the more, since the implementation of 5G technology is scalable (cf. *Figure 2*). All the data generated at every process step are collected in a data pool located in “The Cloud” which is in a position to store huge data volumes so that external control of the press is possible. With the help of data mining, the structurally extremely diverse data are processed, evaluated and partly sent back to the production facility in order to take over controlling functions. It begins with the delivery of the coils when the material parameters and the supplier’s production data are recorded and counterchecked by the data mining system. During the insertion of the sheet metal, a camera examines the roughness of the material and the oil film thickness, while the mechanic material characteristics such as tensile strength are measured by the so-called bulge tester. All the gathered data go to the data pool where the information is compared with standard values so that the machine automatically adapts to the input variables. From time to time, the data mining system might issue a message such as “The oil film is below tolerance level in a certain area.” Now, a signal is sent to press control with the order that a certain area has to be re-lubricated before this section of the sheet metal can be transformed to an automotive component. From inline production, temperature values, information about power consumption or the current number of strokes can be passed on to the data pool. When so-called thin film sensors are attached to the cutting shears they can report if the tool is still sharp enough. This is an example of how condition monitoring combined with sensor technology and 5G provides operators with a perfect overview of the facility’s condition and the state of its tools, a benefit which helps to reduce or even avoid machine stoppage.

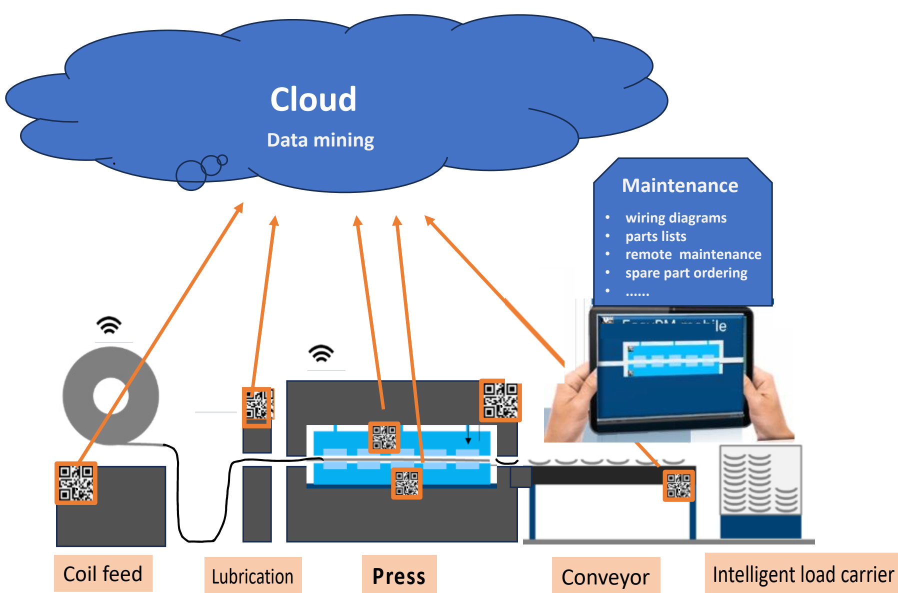

Fig. 1. Schematic illustration of a sensor-equipped sheet metal press delivering information to the data pool in “The Cloud”. With the help of 5G, information can not only be retrieved in real time, but can also be conveniently visualized on digital terminal devices. (Own graphic)

TOWARDS TOTAL CONNECTIVITY:

The importance of network building in the automotive industry was emphasized by Jürgen Prokop, CEO of Trumpf, a leading German manufacturer of machine tools offering “ […] machines for bending, punching, combined punch and laser processing, and also laser cutting and welding applications. Diverse automation solutions and a range of software for digitally connected production solutions round off the portfolio” (Wikipedia, n.d.). Prokop said: “For sheet metal manufacturers, connecting production processes and machines in a network will be the decisive competitive edge” (Mücke 2020).

German car manufacturer Mercedes-Benz seems to have acted on it, since they have turned many of the above-mentioned concepts into reality in their “Factory 56”, a digitized manufacturing unit which comes close to the idea of a smart factory. Particularly in regard to 5G implementation, they are proud of their achievements: “The use of state-of-the-art 5G network technology allows Mercedes-Benz Cars, among other things, to optimize existing production processes […] with the help of new features. These include, for example, the data linking or product tracking on the assembly line. With a separate own network, all processes can be optimized and made more robust, and if necessary, adapted at short notice to prevailing market requirements. Furthermore, the mobile communications standard links production systems and machines together in an intelligent manner, thereby supporting the efficiency and precision of the production process” (Daimler Communications 2019).

However, under the motto “360-degree networking – from the supplier to the customer”, the automotive company makes clear that their vision of connectivity goes beyond the conventional IIoT concept: “[…] networking not only happens inside the factory. A significant feature of ‘Factory 56’ is the all-round networking across the entire value-added chain – from development and design to suppliers, production and customers. […] For […] production, 360-degree networking means quick and transparent communication across all units. Digital tools are used for development and production: for example, production processes are visualized and optimized by ‘Virtual Reality` (VR) before a real production hall comes into existence [… and] workstations and processes can be virtually tested and designed ergonomically” (Mercedes-Benz Group AG, 2023).

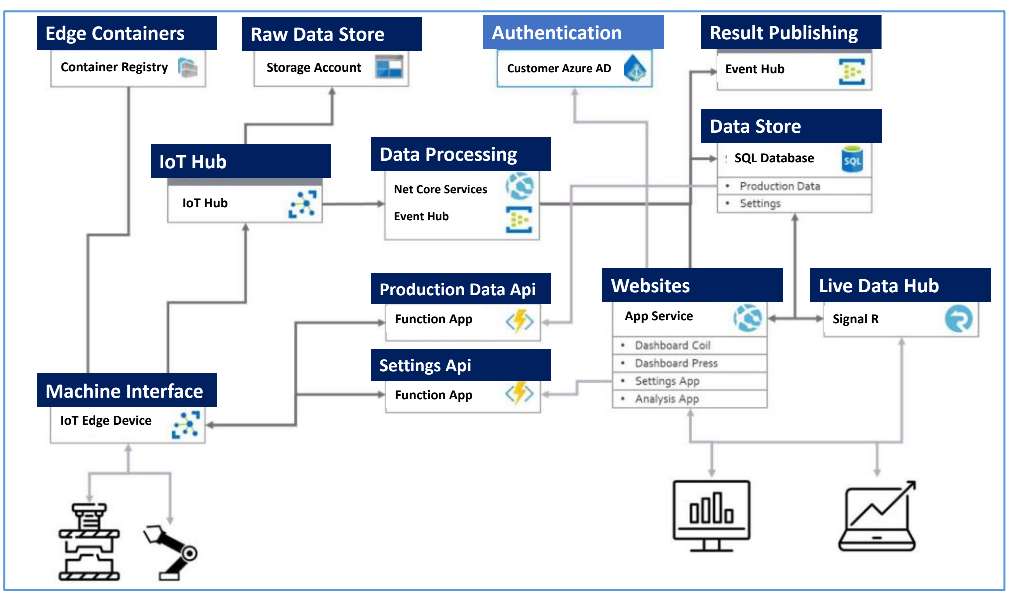

Fig. 2. Example of an integrated system network with extended functions, implemented in an automotive press shop. (Source: evopro systems engineering AG 2023)

SUCCESS MONITORING:

For the time after the implementation of an integrated system network, it is recommended that key performance indicators are defined. They serve as measurement parameters for the assessment of efficiency, productivity and capacity of the network. These criteria could be helpful:

- Throughput rate: the number of products that can be manufactured in the press shop per time;
- Downtime: the time during which the network is not available due to disturbances or technical problems;
- Production quality: the quality of manufactured products, as measured according to the defect rates or quality standards;
- Response time: the time needed to react to requests or orders that turn up in the network
- Network latency: the time lag that occurs when data are transmitted in the network;
- Data transmission speed: the velocity with which data can be transmitted in the network.

CONCLUSION

It became obvious that the implementation of an integrated system network supported by 5G technology is suited to facilitate a more efficient and less cost-intensive production. At the same time, information management will benefit, since the system allows instant data availability and real-time evaluation and communication. All of these achievements will entail better collaboration, optimized production processes, improved quality and more efficient utilization of resources. Eventually, the automotive company might thus become more competitive and innovative. When planned carefully, an integrated system network is easily scalable and allows many other applications and enhancements (cf. *Figure 2*) than those that were hitherto described.

In an integrated system network, the majority of data are generated by components of the facility itself (cf. *Figure 1*), i.e. they are recorded by sensors etc. that feed the information into the cloud-based data pool. However, it could be helpful if data from external sources were added such as statistics or survey results, in order to supplement the company-own information with relevant subjective outside assessments or third-party experience. Finally, the evaluation of the collected data shall result in the measurement of the achieved improvements and their impact on efficiency and productivity which – if the evaluation is positive, an outcome which is to be expected after all what has been said here – will be another proof of the integrated system network's benefits.

REFERENCES

Daimler Communications (2019). *Mercedes-Benz Cars and Telefónica Deutschland establish the world's first 5G network for automobile production.* [viewed 27 January 2024]. Available from: https://group.mercedes-benz.com/innovation/produktion/5g-netz-produktion.html.

Evopro systems engineering AG (2023). *Anbindung sämtlicher Maschinen- und Prozessdaten.* [viewed 23 January 2024]. Available from: https://www.evopro-ag.de/wp-content/uploads/2020/06/evoTrQ_Datenverarbeitung.pdf.

Mercedes-Benz Group AG (2023). *"Factory 56".* [viewed 26 January 2024]. Available from: https://group.mercedes-benz.com/innovation/produktion/factory-56.html.

Mücke, K. (2020). Digitalisierte Blechfertigung 30 Prozent effizienter. *Schweizer MaschinenMarkt.* [viewed 23 January 2024]. Available from: https://www.maschinenmarkt.ch/digitalisierte-blechfertigung-30-prozent-effizienter-a-985378/.

Spath, D. (ed.). (2013). *Produktionsarbeit der Zukunft – Industrie 4.0.* Fraunhofer Verlag, Stuttgart.

Statista (2023). *Automobilindustrie Deutschland.* [viewed 28 January 2024]. Available from: https://de.statista.com/themen/1346/automobilindustrie/#topicOverview.

Statistisches Bundesamt (2019). *Automobilindustrie: Deutschlands wichtigster Wirtschaftszweig mit Produktionsrückgang um 7,1% im 2. Halbjahr 2018.* [viewed 27 January 2024]. Available from: www.destatis.de.

Volkswagen AG (2022). *360° Transformation der Fertigung.* [viewed 27 January 2024]. Available from: https://www.volkswagen-newsroom.com/de/publikationen/magazine/360-transformation-der-fertigung-833.

Wikipedia (n.d.). *Trumpf.* [viewed 23 January 2024]. Available from: https://en.wikipedia.org/wiki/Trumpf.

ВНЕДРЯВАНЕ НА ИНТЕГРИРАНИ СИСТЕМНИ МРЕЖИ С 5G ТЕХНОЛОГИЯ В ГЕРМАНСКАТА АВТОМОБИЛНА ИНДУСТРИЯ

Резюме: *Инициативите за цифровизация на германските производители на автомобили обхващат проекти, които имат за цел да изградят интегрирани системни мрежи, поддържани от технологията 5G. Тук са представени резултатите от научно изследване, в което са анализирани проектите за IIoT („Индустриален интернет на нещата“) по отношение на тяхната пригодност за внедряване на 5G, респективно ефективността на новата технология в рамките на интегрирана системна мрежа. Изследваните IIoT проекти произхождат от т.нар. пресов цех, който е част от производственото предприятие, в което се формират автомобилни листови метални компоненти в метална преса. Въз основа на прозренията, извлечени от анализа на IIoT проектите, е показано, че внедряването на поддържана от 5G системна мрежа може да предава, обединява и визуализира огромни обеми от данни, освен това може да направи производствения процес по-ефективен и накрая да подобри сътрудничеството и качеството. Специално внимание е отделено на организацията на информацията, която ще се подобри значително, тъй като 5G позволява комуникация в реално време.*
Ключови думи: *Дигитализация, автоматизация, изграждане на мрежи, управление на информацията, 5G технология*

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