# Industrial IoT techniques and solutions in wood industrial manufactures

Zoltán Pödör, Attila Gludovátz, László Bacsárdi, Imre Erdei and Ferenc Nandor Janky

***Abstract*—The world of Industrial IoT (Internet of Things) generates different challenges for every company. For the small and medium-size enterprises these challenges involve material and special human resource constraints. For these enterprises, the complex solutions may not be feasible due to financial reasons, so individual solutions and individual IT support must be provided for them. Still, generally accepted architectural principles, protocols, data analysis solutions are available as building blocks for solutions tailored for smaller enterprises.**

**In order to offer good examples for such individual solutions, this paper presents various infocommunication technologies and environment as a complex infrastructure background. This setup has already been used in two different wood industrial companies to improve the effectiveness of their productivity.**

***Index Terms*—IoT, Industrial IoT techniques, sensors, energy management**

## I. INTRODUCTION

IoT, Industrial IoT, Industry 4.0, Big Data; we often meet these expressions if we look into the processes and technical implementations of the modern producing companies. In our accelerated and digitized world, the pretension is getting bigger to reduce the costs and make the production more efficient. Sensors, various IT solutions and applications can help us in this process. Today, these devices can measure everything and digitally transmit the measured data, even without the construction of a wired network. The different solutions process the collected data and the results can be used to control machines or to support managerial decisions.

Nowadays, the conception of Industry 4.0 is becoming increasingly popular [1], which is a determining phase of the industry's development; this is why the present age is labeled as the fourth industrial revolution. The information technology and the automation domains closely interweave, and the result appears in the most various production processes.

With the advent of the Industrial Internet of Things (IIoT) and the Industry 4.0 concept [2], the usage of advanced automation within various devices created the need for all sorts of sensors in significant numbers. The data provided by sensors do not only serve the above mentioned, efficiency and optimization goals, but also facilitate the decision support.

Besides its on-the-fly processing, this data have to be stored properly in order to reduce the required post processing effort. This, however leads to a big challenge in several use-cases, since it is not uncommon that sensors provide data under a few milliseconds interval that has to be transmitted, stored, analyzed and displayed appropriately.

In order to tackle such challenges, there is a need for complex physical and software infrastructures, that are capable of receiving and storing great deal of online data, and providing the opportunity to access and process data, besides generating reports and results, as well. There are many relational or non-relational database based solutions that offer efficient data handling and data storage [3]. However the SensorHUB has been developed – by BME AUT – specifically for treating different kind of sensor data while providing the afore mentioned services [4]. Clearly, there are other, commercially available solutions. Among others, these include AWS IoT by Amazon [5], Azure IoT Suite by Microsoft [6], Google Cloud IoT Core [7], ThingSpeak by MathWorks [8], ThingWorx by PTC [9], Watson Internet of Things by IBM [10], and the Arrowhead Framework [11]. The main reason we have chosen SensorHUB is its appealing flexibility, beside the close regional support.

The current paper covers industrial examples from two different Hungarian wood factories referred to as *Company 1* and *Company 2*. Furthermore, the different Industrial IoT solutions of these companies are introduced. These are already used in their live production systems.

The paper is organized as follows. In Section II, we introduce relevant and modern IIoT and Industry4.0 solutions and technologies that address the small and medium sized enterprises. These can be used for taking steps towards the main goals of Industrial IoT and Industry 4.0: create, retrieve and use important digital data connected to production and the utilization of machines). These are the basic steps to create an IoT based, digital industrial environment. Furthermore, an overview is given about the most important questions and problems related to Industrial IoT. Moreover, the main tasks, components and expectations of the Industrial Internet are introduced through a wood industrial company.

Other IIoT and Industry 4.0 related questions are discussed in Section III, through an industrial example at another company. We demonstrate a hardware and software environment, and the manufacturing process at a wood industrial company. The aim is to reduce the cost of energy used in the industrial processes. We have implemented an integrated system, through which one can collect, store, analyze data, and create executive summaries. The *mFi mPorts* and *mFi Current Sensors* of UBIQUITI [12] were used in a furniture factory to handle and process the collected current measurement data of six different machines in this factory.

In Section IV, we describe the infrastructure and technologies used for the implemented data collector system that begins with the Current sensors and ends with the SensorHUB structure and a mobile application. The focus of the expanded structure is to determine the electricity consumption and utilization ratio of the examined machines. These results allow us to improve utilization, since the increase in electric energy consumption of a machine may indicate a mistake or a potential problem in the future.

## II. Brief overview of Some modern technologies in the Industry 4.0 concept

In this section, we demonstrate several approaches and techniques, which are related to the Industry 4.0 subject.

### *A. The main objects of Industrial IoT and Industry 4.0 concept*

Industry 4.0 means integration between individual systems in the industrial manufacturing environment and the company's other IT systems in order to manage entire value chains along with product lifecycles. An Industry 4.0 system uses modern information technologies to achieve cooperation between the integrated data-collection, data-processing and information visualization sub-systems. Industry 4.0 is about *making* things smartly, over the whole value chain – from planning through creation to the actual logistics of the manufactured product. The definitive reference model of this concept is RAMI4.0 [13].

On the other hand, Industrial IoT is about making things *work* smartly [2]. It is a cross-domain initiative, influencing various sectors, including energy, healthcare, transportation, the public sector, as well as manufacturing. It is more about industrial applications of the IoT and CPS (Cyber-Physical Systems) concepts; and does not include those value chain- and lifecycle-models that are core elements of the Industry 4.0 concept.

When IoT systems have purposeful, direct effect on the physical world – especially through modeling the world through their digital twin – and use the control information in a feedback-loop, the system is often referred to as CPS. Such systems and their physical environments are closely connected to each other.

In a manufacturing environment, the Cyber-Physical System's tasks are among the followings [14]: to find the bottleneck of the production, to determine the causes of the manufacturing faults, to change the configuration of the machines, to discover the utilization of the resources, to give information to the participants of the production, and to make a forecast of failures and optimize the working hours of the operators.

IIoT CPS systems are much more effective compared to traditional systems due to the following reasons: distributed operation, integrated software and hardware solution, which collects data and gives information in a feedback loop. By using this information, the operation of the system needs less intervention.

The tangible results delivered by the system are the following: increased productivity, better quality, quick readjustment of the parameters of the manufacturing machines, individual, special production, better resource utilization, transparency, maintainability, and less production outage.

The components of the system and their characteristics are the following. (1) Sensors and actuators: there are lots of devices and manufacturers (suppliers) and these actuators make local calculations; (2) Communication network: it contains many solutions, for example TCP/IP Ethernet, Wi-Fi, or another wireless sensor-network; (3) Information processing infrastructure: the cloud systems (mainly private solutions) are really important and popular. The earlier "dedicated server" conception is not scalable to this information infrastructure level; (4) Security sensitive environment: there are some important expectations, for example real time and fault-tolerant working.

### *B. PTP, IEEE 1588 Standard [15]*

The clocks of the computers are not accurate, and they skew even when comparing to each other. The clocks can be synchronized via the network, but it is a major challenge to set always the same and exact time on all of the clocks. The monitoring of the relatively slow processes requires accurate clock synchronization [16]. In case of energy systems, the convention is within the 1 μs error range. The special GPS-based systems stay very closely to the realization of clock synchronization with such accuracy. Unfortunately, they have some disadvantages. The solution cannot be applied in every device because of their technology and price or cost.

The typical industrial example – as one of our partner companies use as well – is periodic clock synchronization within a long time-range. This means that the machines and the computers connect to the common network, and their clocks synchronize every day.

### *C. Real-time Ethernet*

The Audio-Video Bridging standard (part of the IEEE 802.1 standard) was created in 2011. It guarantees the stable and high bandwidth, low-delay and time-synchronized voice and image transmission through the Ethernet layer. This protocol focuses on the clock synchronization and on the image and voice recording and replaying [17]. Otherwise, every client machine would record the contents based on their own clock.

At Company 1, this workflow can be adapted into the production process, as a part of the quality assurance. Now, they apply such solution, which determines the colors and faults of timber boards after the shaving process. This application evaluates the quality parameters before the subsequent manufacturing processes. We have developed and implemented this system, and this standard supports a part (real time monitoring) of our workflow in the video analysis task at the factory.

### *D. System management*

The Industrial Internet of Things concept cannot be used without an up-to-date system management solution. From the viewpoint of classical IT, the general system management tasks include the registration of machines, the monitoring of the usage of resources, capacity planning, diagnostics etc. These can be extended with the configuration and monitoring

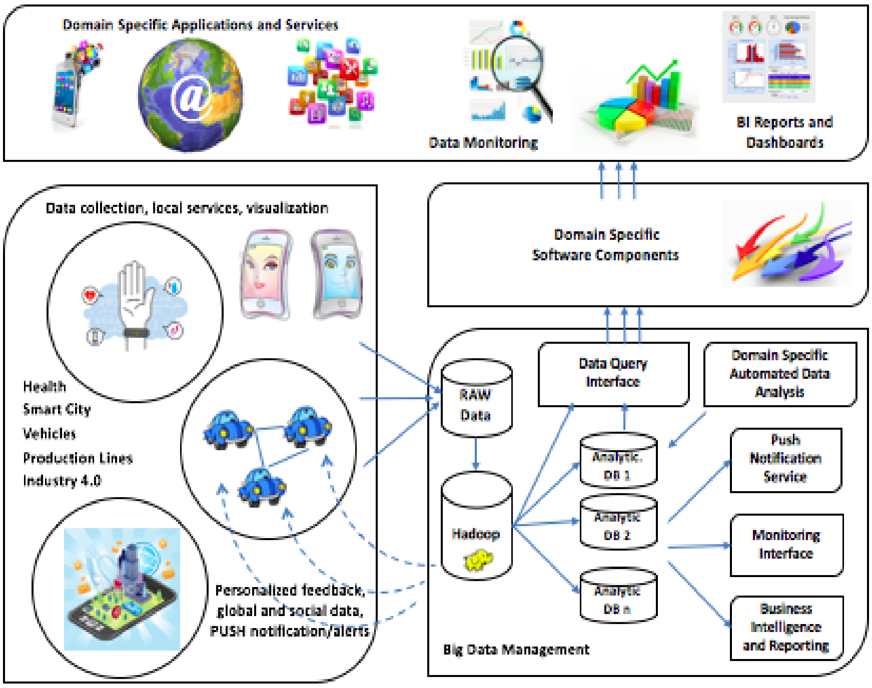



Fig. 1. The architecture of SensorHUB framework [4]

of the real-time processes. The usage of earlier solutions, such as CLI (Command Line Interface), or SNMP [18] is still necessary because of compatibility reasons, but these are not sufficient, because we want to know everything about the manufacturing. The new technological solutions' installations are imperative (Netconf [19] and Yang [22]). There are several open source solutions on the market (NeDi [21], Cacti [22], Nagios [23], etc.), which, on the other hand require wide and deep competences to use effectively.

At Company 1, the used server solutions' management applications control the system management processes (see Section III.A).

### E. Security

Security is a major topic in the field of Internet of Things; challenges arise at various levels [24]. Sensors have different kind of security issues than the communication architecture has, not to mention challenges at the data centers or the feedback loop. Covering these have to be taken care of, which also require various competences and continuous upgrade of procedures and tools.

The qualification conditions regarding authorization and authentication may also cause problems: the security protocols are changing and getting better, therefore, the re-qualification is necessary, because of the mentioned expectation.

IIoT systems do not require the availability of the complete system over the Internet. Moreover, the main system can be decomposed into virtual networks, which have different security-level.

At Company 1, the security-critical systems are defended with firewalls, protocols and restrictive actions. The last level machines can be reached from the outside world via the Internet. The company's intranets are working side by side in separate ways. The cloud solutions are not typical compared to other companies, especially in the area of high security expectations [25].

### F. A special example: the SensorHUB

The SensorHUB [4] is a distributed IoT framework developed by BME-AUT. It provides a unified architecture platform for secure storage and processing of various data. The architecture of the system is shown in Figure 1. The secure data management associated with flexible expandability creates a robust implementation that can be used in different areas of economy (automotive industry, vehicle manufacturing, healthcare, etc.).

The basis of SensorHUB is a distributed data management technology, Hadoop [26]. Contrary to the fact that traditional relational databases often result in slow processing for large data sets, distributed file system databases provide a significant improvement in processing time.

Hadoop is an open source framework that helps to store and process large amount of data in a distributed environment. The distributed environment means that in a client-server communication process the client requests need at least two servers to process them. The system provides scalable, fault-tolerant storage. The HDFS (Hadoop Distributed File System) detects and compensates the different hardware anomalies and files are decomposed into blocks, and each block is written to more than one server. Hadoop uses the MapReduce programming model for accessing its distributed file system.

The SensorHUB contains several domain-specific applications. These applications are ready to be used, they are just waiting the necessary data from the SensorHUB. At the same time, the system provides an opportunity to the development of the user's application.

## III. THE CREATION AND INTRODUCTION OF THE PROTOTYPE SYSTEM

In this section, we describe how we applied IIoT and Industry 4.0 techniques at Company 1, which is a wood production company based in Hungary.

The 4th industrial revolution motivated the preparation of the prototype system. Machines, production devices and workpieces integrate in a huge information network, which will be the network of the other networks. Every machine and workpiece knows their own role in the system, and their needs in the given processes.

Our prototype system is an extensive data collecting, data processing, display and controlling system, which is integrated with Internet technologies into the customer company's industrial environment. This system is closely related to the physical embedded environment, furthermore, it provides information and also optimizes the processes.

### A. *The system's environment*

In order to create an effective model system, we had to know the possibilities of the company, and also the potential of the hardware and software components. Furthermore, we had to cooperate with the elements during the data collecting, data transmission, analysis and displaying.

*1) Storage: MySQL and Microsoft SQL (MSSQL) Server*

Features of data storage are: (1) various equipment's function on various internal intranet networks, (2) the data are stored on different physical servers, (3) the corporate governance system and the supervisory system automatically cooperate with different types of database management systems. The MSSQL server, which serves ERP (Enterprise Resource Planning), is situated in the international IT center (headquarter). The whole process is shown by Figure 2.

*2) Data collection and storage: Movex ERP and Movex Operator*

The services of the standard system are not always enough, if an exotic problem or task has to be solved. The company, which develops the Movex ERP, made a sub-system, which supports the production of Company 1. The Movex operator watches the performance of the production machines and archives the related data to the central database (MSSQL) with the help of data collecting sensors.

*3) Analyzing and representation: QlikView*

QlikView is a business intelligence application used to generate professional queries. The resulting business reports of the queries aid the decision making process.

*4) Data collection, representation, supervision: Vision*

During real-time monitoring, the system makes incremental data backups every 10 minutes.

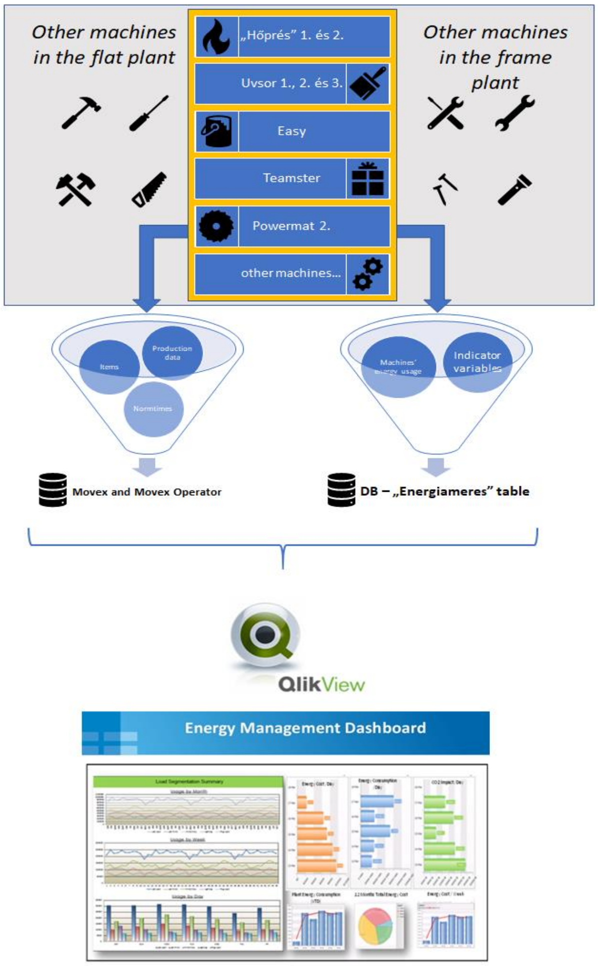


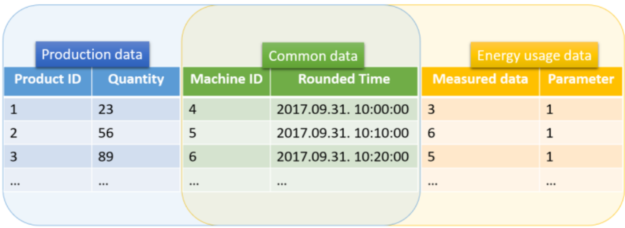

Fig. 2. The data stream from the sources to the analyzing and reporting tool

### B. *Architecture and processes: a summary*

Our main task was the interconnection of data sources (energy consumption and production data). The interconnection is based on the identity of production machines. It is important to compare historical data (e.g., data of the past shifts, hours or weeks), and based on the result of comparison, better decisions can be made. Furthermore, it is also important that we can try to predict and prevent future downtimes, problems and higher energy consumption. This concept is illustrated in Figure 2. In this figure, one can see, that we are collecting the data from different sources (manufacturing machines, environmental sensors etc.). The data is going to the company's ERP system (middle-left side of the Figure 2.) and to the database management system. Then, the initialized procedure is measuring the data from both sides.

The connection between the data is based on the common parameters: machine ID and the rounded time (see Figure 3.).

Then, based on the data analysis, a lot of questions can be answered about the manufacturing process. After the analysis, result reports are created (dashboards, tables, diagrams); this process is operating in real time. For example, we can show to the managers how much was the energy waste of a machine in the last shift. Such indication of wasting energy could mean that the machine is working without manufacturing. Thus, we can make optimizations in the operation of the factory.



| Production data | | Common data | | Energy usage data | |
|---|---|---|---|---|---|
| Product ID | Quantity | Machine ID | Rounded Time | Measured data | Parameter |
| 1 | 23 | 4 | 2017.09.31. 10:00:00 | 3 | 1 |
| 2 | 56 | 5 | 2017.09.31. 10:10:00 | 6 | 1 |
| 3 | 89 | 6 | 2017.09.31. 10:20:00 | 5 | 1 |
| ... | ... | ... | ... | ... | ... |

Fig. 3. The connection between the production and the energy usage data (with several sample rows)

## IV. Sensor network and the related infocommunication infrastructure

In this section, we show a detailed example about the data collection infrastructure and system which was placed at a furniture company referred as Company 2. The aim of this system was to introduce a basic Industrial IoT structure and reduce energy costs using the collected data.

There are six different analog machines in this factory. They are not suitable to generate digital data about the production or the condition of the machines. We need sensors which can be adapted into these machines to be able to provide important data and information about the operation of the machines.

Our aim was to establish a cheap, but trustworthy structure as shown in Figure 4., in order to measure the electricity consumption of the machines and to store this data for a later processing.

The UBIQUITI Networks Company produces the mFi Current sensors, which were attached to these machines, the sensors are directly connected to the mFi mPort with cable [12]. MFi mPort is an interface and monitoring function that connects to the mFi sensors. It uses special, proprietary software, the so called Controller Software to handle the sensors. These sensors can measure the current intensity in Amper and can send them to mPorts. The mPorts identify the sensors based on the ports, where the sensor is connected, because the sensors do not have their own MAC address. All sensors can have an ID, which is defined by the user. An mPort can treat only two Current Sensors, so three mPorts were utilized, because at Company 2, six mFi Current sensors were used in six different machines.

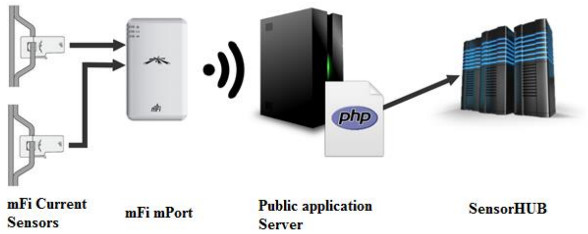



Fig. 4. The developed data collector structure for the given IIoT environment

The sensors and mPorts are placed next to the machines in the factory, but the application server is in Sopron at our University. The mPorts and the server communicate with each other through a wireless network. The mPorts have special, proprietary software (the so called Controller Software) to collect and visualize the data.

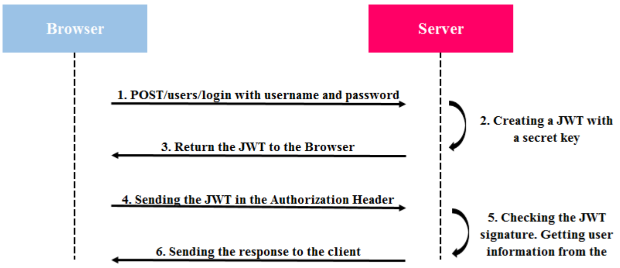
The Controller Software has limited possibilities to store the collected data; it has only an 8 Mbyte memory card, and the data cannot be directly retrieved. Still, on the Management area, we can give rules and triggers to define what the software has to do in case of an occurrence of a given event. The Controller Software's POST-URL method was used to transmit the collected data, when the sensor measures an Amper value above -1. This rule makes it possible to convey all measured Amper data to a given URL address. The POST-URL function has the following rules:

- The Controller Software automatically sends the name of the actual rule, the sensor ID, the measured data.
- The Controller Software creates automatically the HTTP header, and cannot treat cookies. This is due to the fact that the direct data sending to SensorHUB is not possible.
- The measured data cannot be directly converted to another unit, so we can only send in Amper.

Since the Controller software is not capable to directly connect to the SensorHUB, it was necessary to develop a data writer script between the Controller Software and SensorHUB. This is a PHP script, which receives the above mentioned data from the Controller Software using the POST-URL function to a given HTTP address. Then it transforms the data to JSON format, because the SensorHUB has a NoSQL based database.

Finally, the script sends the adequately prepared JSON data to the SensorHUB Upload Service based on the JSON Web Token (JWT) as it is illustrated in Figure 5 [27].

To realize the data upload using the given appID and secret key (given by SensorHUB), we need a token from SensorHUB "auth service" function, which can be used during a 24-hour time interval to send data to the SensorHUB.




Fig, 5. The JSON Web Token to send the collected data to the SensorHUB

The collected data is visualized on an Android mobile application. Earlier, personal computers were the primary tools to display data and results, but this situation has changed [28]. Due to the rapid development and spread of the smart phones and the costs of the decreasing data traffic, the smart phones overtook the desktop computers and notebooks among the average users whose primary purpose is to obtain the information.

To get the right data from SensorHUB infrastructure, it is important to give the time interval that can be selected using date-, and timepickers. Presently, the current data of 6 machines are available directly from the SensorHUB. A sample of the result is illustrated in Figure 6.

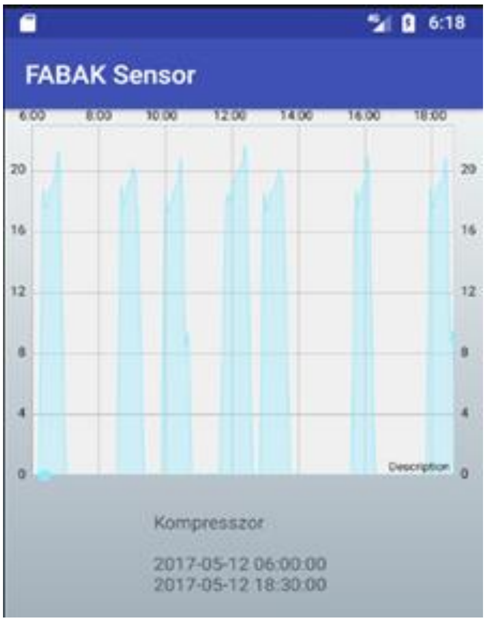



Fig. 6. Displaying IoT-related Amper data for a compressor in a Hungarian mobile application

The current form of the application offers easy and simple integration of further developments. As an example, the monitoring of values and sending threshold limit alerts in SMS, or to the given e-mail addresses, if needed.

## V. CONCLUSION

With the help of Industrial IoT applications, we can rethink the known production methods and help to achieve the main goal of the market: having bigger income with lower cost i.e. maximize the profit.

In this paper, we presented two different examples for Industrial IoT applications-related systems from the wood industry.

The first example shows us a prototype system for managing the data (collecting, storing, analyzing and representing processes) at a wood industrial company. We can continuously analyze the data with help of the prototype system. Information can be retrieved about past events, as well as about estimations on possible future events, which are provided by using forecasting procedures. Furthermore, we can focus on real-time events by defining different alarm limits, in order to prevent unexpected outages in production, or excessive energy use in the plants.

The second example introduces a simple and cheap infrastructure based on sensors and SensorHUB system, which is capable of collecting, sending, storing and processing the sensor data. The developed mobile application makes it possible to filter and visualize the collected data, and it can serve as a basis of a decision support system.

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