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# DATA TRANSMISSION FOR A SMALL-SCALED, CYBER-PHYSICAL MATERIAL HANDLING SYSTEM

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## Abstract

In the presented article, the initial situation, which leads to the development of a small-scaled cyber physical material handling system, is presented first. Therefore, apart from the general requirements of material handling systems, the reasons for a determination of new requirements are presented as well.
Since the developed system consists of multiple decentralized controlled conveyor elements, the data transmission principle inside the system will be described.

## INTRODUCTION

Future cyber-physical production systems (CPPS) must provide flexibility, real-time ability and networking capability to meet the progressively shortening production cycles. [1,2]
CPPS include adaptive, self-configuring and partially decentralized self-organised, flexible production facilities [3]. They consist of production machines, which are connected through industrial trucks, continuous conveyors and small-scaled material flow systems.
Small-scaled, flexible material flow components with an integrated control system and data processing offer a solution as a classical CPPS. Connected

with the modular matrix, these single modules are able to solve complex material flow tasks and promise cost advantages through a standardized design, as they allow an easier exchange of the module without complex assembly works.

## INCREASE OF FLEXIBILITY IN INDUSTRY 4.0 WITH THE SMALL-SCALE CYBER-PHYSICAL MATRIAL FLOW SYSTEM

In order to provide a failure-free cycle for production processes in the industry, the needed materials should be delivered in the right place, at the right time, and in the right quality.
The term "intra logistics" describes these processes and includes the organization, performance and optimization of internal material flows with the help of technical systems and services. Figure 1 presents the functional view of the material flow system, which was developed at the Institute of Transport and Automation Technology.

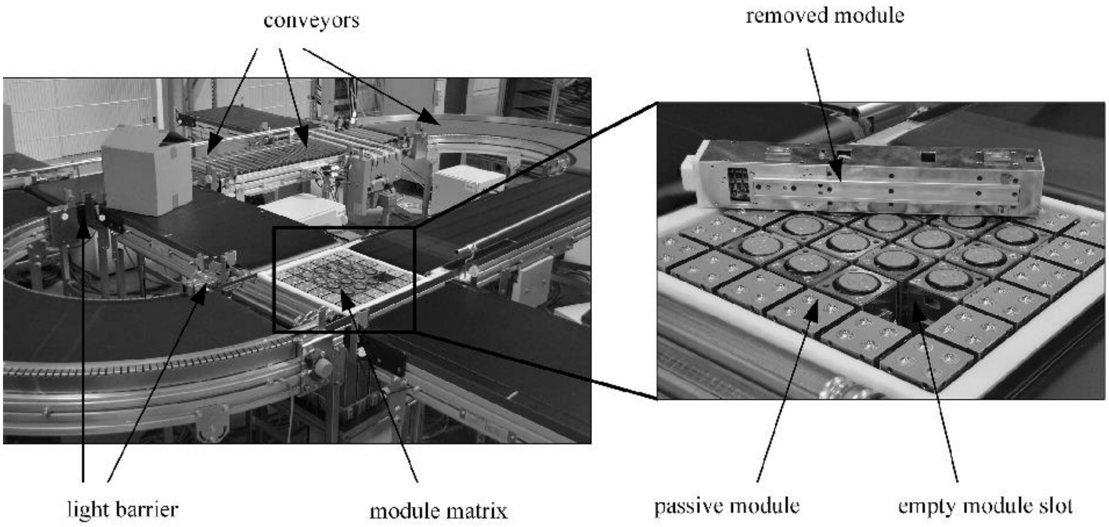


Figure1. Overview of constructed demonstrator [4]

When a packet appears, the first module receives the information to which destination port the packet should be delivered. The modules organize themselves in the following way that a route is planned and the packet is transferred through the matrix without collision. The size and shape of the matrix does not play any role, so that later changes of the topology are possible without any further programming efforts. The goal was to create a coalition of the basic functions of all material flow systems, which are currently on the market, in a single module.

In the developed modular matrix, each module has an integrated individual control and the ability to communicate only with its direct neighbors. A centralized control is not necessary in this case. There are multiple requirements for the networking of the CPPS and especially for the data transmission of small-scaled cyber physical material flow systems.

## DATA TRANSMISSION FOR A SMALL-SCALED CYBER-PHYSICAL MATERIAL FLOW SYSTEM

### Requirements

The fieldbus technology must allow the ability of recognizing the construction and arrangement of a production system and to derive the technologic image of production systems. In this context, the recognition of neighbourhoods is of main importance. Therefore, the topology of the fieldbus, which cannot exhibit neighbors in all directions, can vary. A further general requirement is a constant bitrate to meet the demand of real-time systems.

In addition, data communication for a small-scaled cyber-physical material flow system should meet the requirements of the intra logistic system. Apart from the robustness against disturbances and layout change, a real-time capability is an essential aspect. Information, which belongs to the product, has to be processed in a defined processing time and forwarded to the next neighbor. Therefore, the size of the intended information packages and the data bit rate of the intended fieldbus technology should be paid attention to.

For example, in a small-scaled cyber-physical material flow module with the intended speed of the conveyor of 2m/s and an edge length of 6 cm, the calculated processing time is maximum 30 ms (Fig. 2).

Processing time

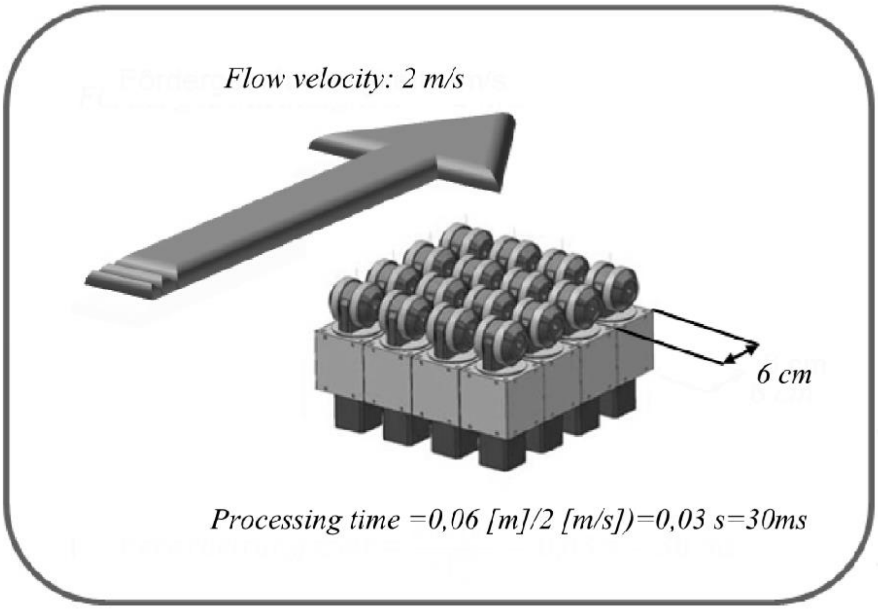


Figure 2. Processing time of information package

Furthermore, the requirements of the product-specialized data should be taken into account: the information flow is to be executed simultaneously to the production process. Therefore, the size of the products is important, so that the small-scale cyber-physical material flow system receives the information about the locating surface of the production materials. Thus, each conveyor module of the conveyor matrix is capable of making the decision to which output of the conveyor matrix a production material should be transferred. Nevertheless, this process chain cannot be rigid. It should rather be dynamically expandable to allow the intra logistic functions, which, in this case, can change the target temporarily.

The last requirement for the transported data is to be generally readable and interpretable.

## Application area

Often, each manufacturer of material flow systems supplies an individual communication protocol, for example, based on field buses. Therefore, the highest specifications of the Controller Area Network (CAN) can be observed as examples, which are ISO-TP, CANopen and DeviceNEt.

Open standards in the area of field busses, as for example OPC-UA, show that the same communication protocol can already be applied to different application scenarios today.

Field bus technologies, which meet the requirements of a real-time ability, recognition of neighbourhoods and topology-independencies and thus allow the networking of a small-scaled, cyber-physical material flow system, are already represented on the market. With the help of the field bus technology, it is therefore possible to get a digital image of the real system. This technology is applicable to all existing topologies, as, for example, ring or tree topology. Because of the data transmission bitrate, the CAN bus technology meets the requirements of real-time efficiency in the concrete example of small-scaled material flow technology through the fact, that the effective size of the intended information packages of circ. 1,75 kilobytes is not exceeded (Figure 3).

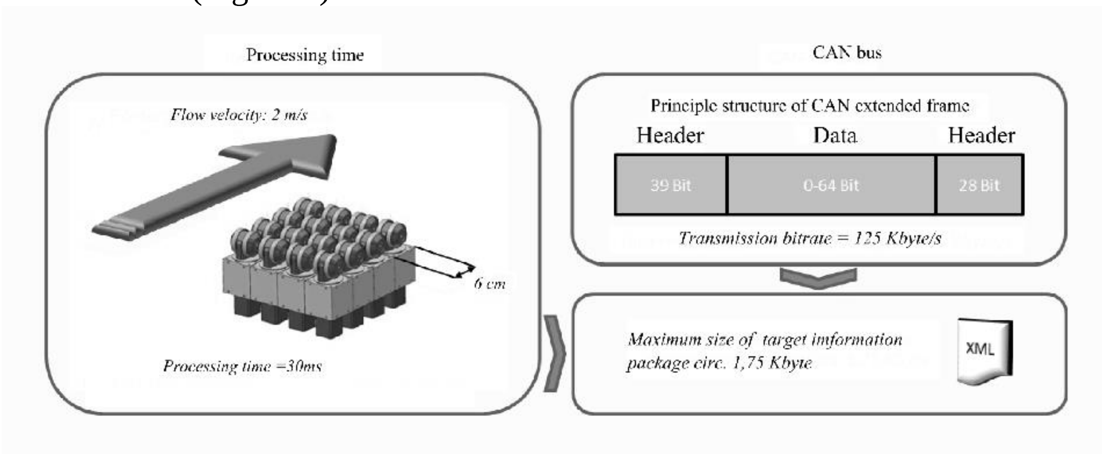


Figure 3: Maximum size of information packages in dependence to processing time and field bus technology

In order to convert the production information in information packages into readable existing technologies in the area of description languages, programs like open standard XML can be addressed. There, standard approaches for open data exchange formats are presented, as for example, Automation ML (DIN 2012). In equipment engineering contents, Automation ML establishes a communication interface based on the description language. As a software interface, it allows the exchange of data of equipment engineering about tool borders and reduces the transmission error. Nevertheless, Automation ML does not guarantee a constant size of the transmitted data as the history of the data sets is extensively built in itself (DIN2012). Thus, the size of the data is increased with each changing of data sets.

Finally, modern technologies in the area of communication interfaces provide first approaches to standardization, although not all requirements of the data communication in small-scale cyber-physical material flow technology are met, yet.

## Structure of description language for data communication

A description language as a base for the data communication between small-scale cyber-physical material flow elements can be equally interpreted by humans and machines. An example of the description language is hereby applied for a specific information package for a production resource. In the following the basic structure of the information package will be sketched to show the transferred data in respect to the transported packet and small-scale cyber-physical material flow technology.

The structure of the information package, which belongs to a packet, depends on the specification of AutomationML, to allow the compatibility to this standard. The structure is divided, as foreseen by AutomationML, into 2 areas – header information („AdditionalInformation“) and user data („InstanceHierarchy“) (Figure 4)

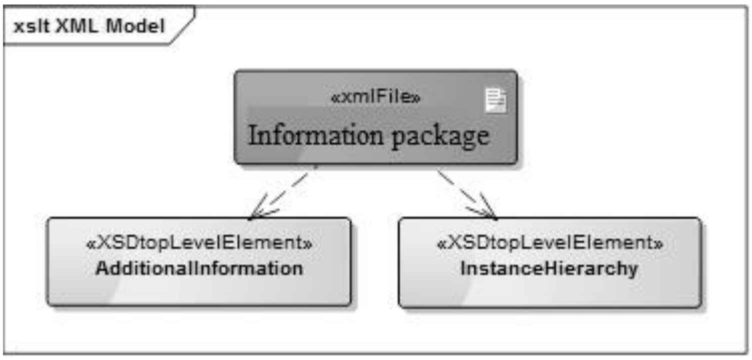


Figure 4: Structure of the information package

Figure 5 shows the structure of the header information. It contains the version number of specification of description language as far as XML-element of so-called “WriterHeader”, including the data of information packages as attribute. The “WriterHeader” consists of a defined number of XML-elements. The following elements are exemplarily presented in Figure 5: the “WriterName”, “WriterID” and XML-element “LastWritingDateTime”. According to the AutomationML specification, the XML-element “WriterName” describes the names of the organization resources, which changed the information package last. The “WriterID” is a biunique identification number of WriterName”. The “LastWritingDateTime” includes the time, at which the information package was changed last.

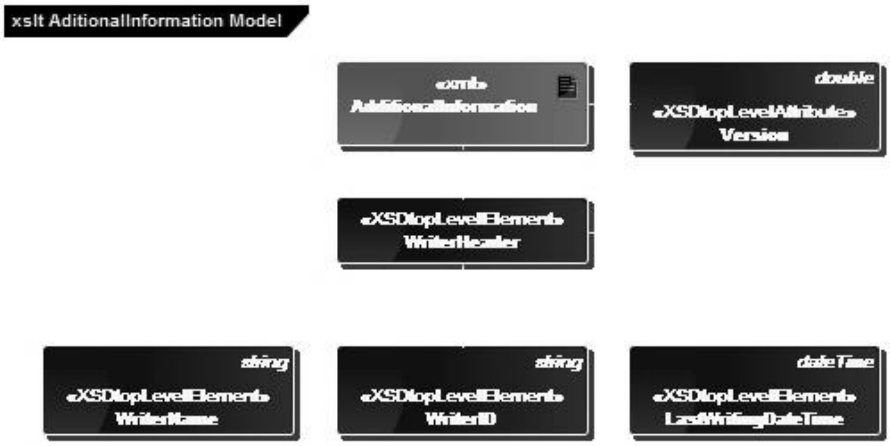


Figure 5: Structure of header information

Figure 6 shows the structure of the user data, which always includes an "InternalElement". In this case, an "InternalElement" describes the packet with the help of the XML-attributes "Name" and "IdentificationNumber". The "InternalElement" is a defined number of XML-element "Attributes", each describing a specific feature, as for example a mass of the packet. Belonging value, in this case the weight of the packet, is placed in a XML-Element value which is also placed there. On the other hand an "InternalElement" can contain "InternalElemente".


Figure 6: Structure of user data

Principally, the product-specific data and production-resources-specified data will differ. To keep the information package as small as possible for reasons of memory, only production-specific data will be transported. These will be divided into three categories – basic data, production order data, and process steps data, each area containing specific data to the package.

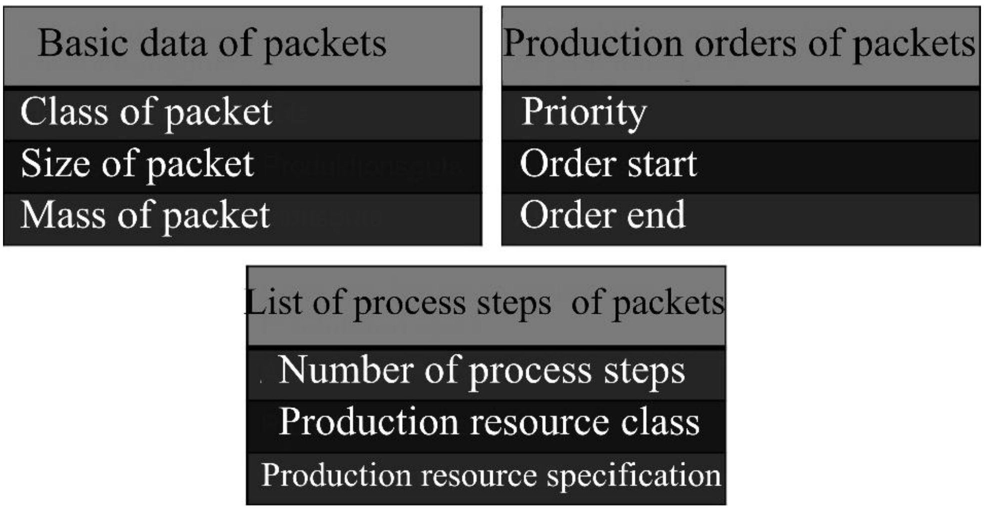


Figure 7: Data of information packages with examples

Production-resources-specified data orient themselves towards the described structure of the information packages. They are divided into three areas – basic data, identification data, and production order data, each area including specific data concerning the production resources (Figure 8). Thus, production-resources-specified data are represented in that way (all data to information technical imaging of production systems, as space orientation to the neighbour, as far as all data for the specification of production resources, as width of production resources)

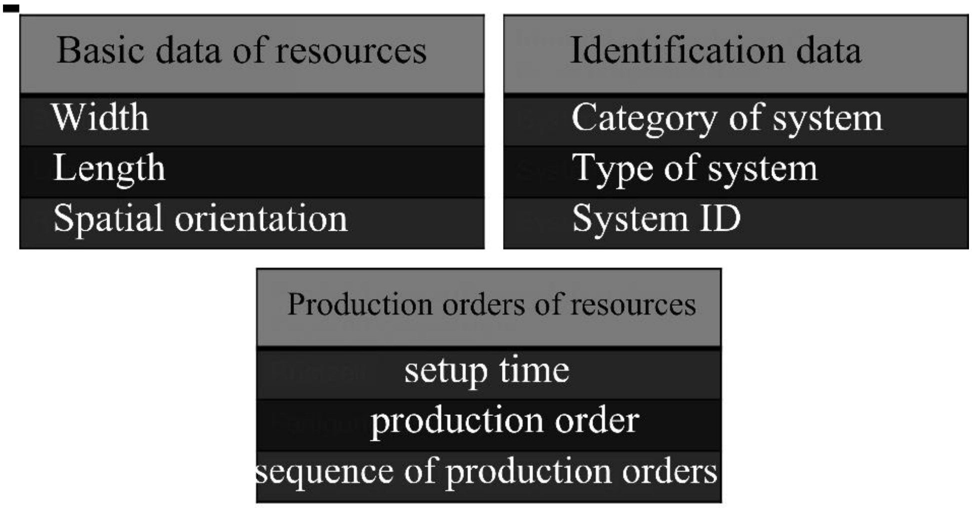


Figure 8: Data of production resources with examples

## TRANSFER TO INDUSTRIAL ENVIRONMENT

The previously presented approach explains information packages in the case of a small-scaled cyber-physical material flow system being validated in frames of the research project netkoPs on a developed demonstrator.

Concerning the information package, 3 central scenarios can be observed for this application case – setting of information package, transport of information package and modification of information package.

At the first appearance of a packet on the CPPS, the information package will be set, supported through an AutoID –process and supplemented with data from a database. The scanning of a matrix code, i.e. with the help of an industrial hand scanner, is used as an example of an AutoID Process (Figure 22).

So, the presented imagined information package migrates simultaneously to a specific packet through the CPPS. In certain situations, when a new highly prioritised packet enters the CPPS, it can be necessary, that its information package will be needed. In this case the priority of all other information packages, which are situated in the CPPS at this time, will be decreased, so that this new packet can be speedily transferred through the production. A further example of a dynamic changing of the information packages is used in the application case of the intra logistic function buffering. This requires a change in the list of process steps inside the information packages, in which buffering will be included as a process step.

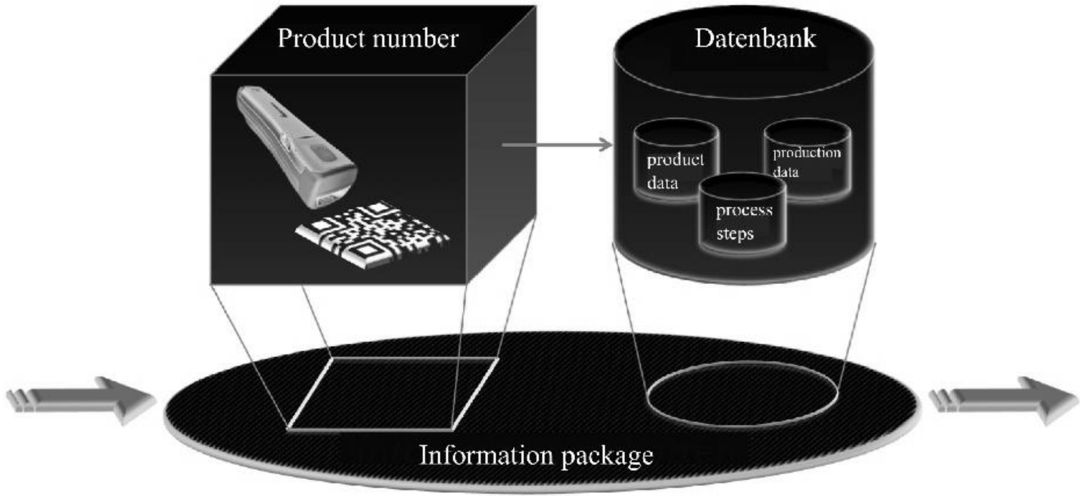


Figure 9: Generation of information packages

The intelligent networking of small-scale material flow elements can be based on a uniform description language realized in the CPPS. The presented description language for data communication was already transferred for first tests. In the future it will allow the decentralized control of CPPS based on information packages, which are transferred simultaneously to packets. Thereby, the presented description language increases the transparency insisted of a CPPS because the place and time data of each packet is always available.

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