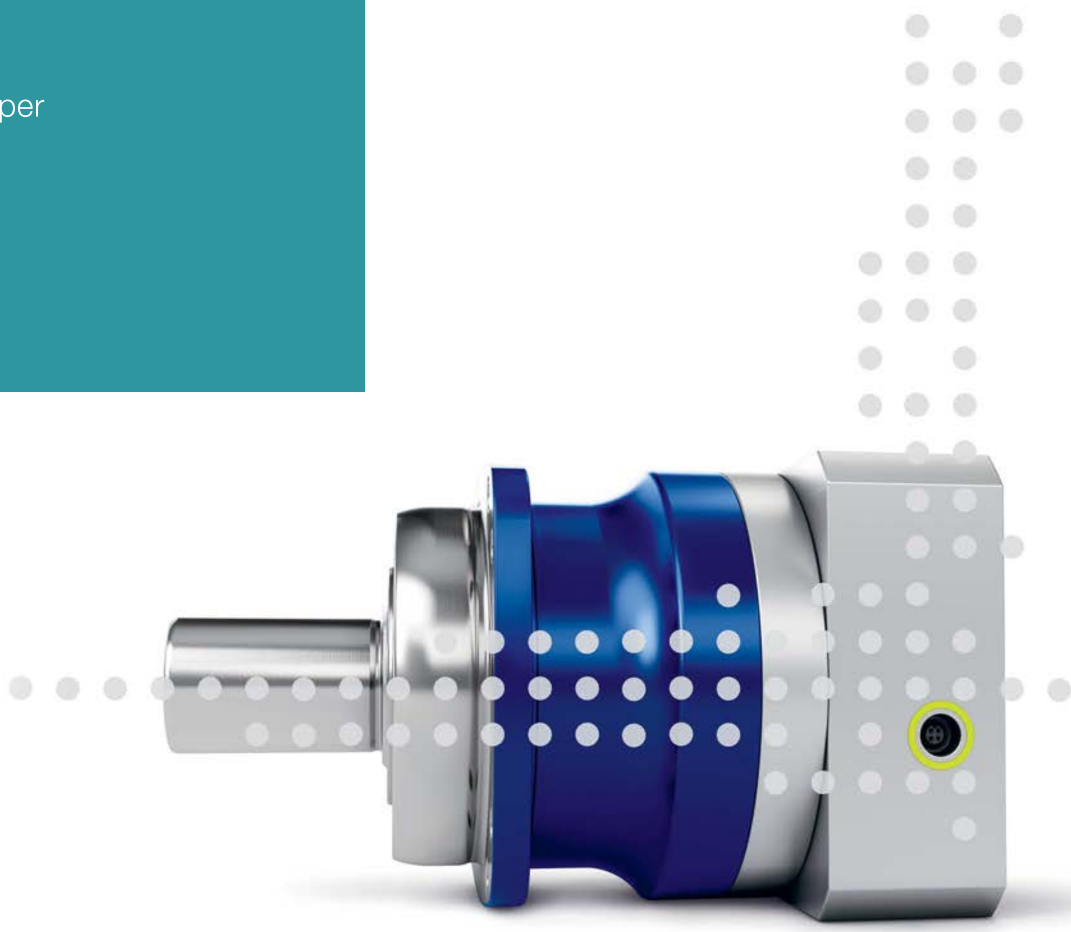
WITTENSTEIN

Whitepaper

Smart drive systems and digital services in the Industrial Internet of Things

Integration concepts for machine and plant engineering



Smart drive systems and digital services in the Industrial Internet of Things

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Motivation

The use of information and communication technology allows for ever-better connectivity between components and production systems – from suppliers to customers. This is accompanied by the development of data-driven services which increasingly bring complementary domain and expert knowledge to the products in the field. The machine and plant builder will not be able to acquire this specific knowledge and thereupon constructed services for all components and to further develop them over their entire service life by themselves. In order to expand their own service offerings, the increasing involvement of partners from the supply industry for key components is therefore necessary. This is also confirmed by a study by the Fraunhofer IPK (Patrick Müller et al., 2019). 71% of companies expect a rise in the number of collaboration partners owing to smart products. This is accompanied by an increase in the proportion of services in the product system, which is expected by 74%. Three quarters of the companies want to differentiate themselves from the competition through the use of smart products and almost a third expect an increase in turnover as a result.

However, this increasing connectivity in machine and plant engineering also results in a working environment which is becoming ever more complex – both in the development and the operation of machines and plants. In order to ensure the controllability and stability of the entire system despite this new complexity, existing integration concepts must be reconsidered and expanded.

This white paper is intended to provide new impulses and establish a common understanding of the integration of smart products and services, and is aimed at machine and plant constructors who want to digitize their own production systems through the use of smart products and services.

Industry 4.0 products and services

The definitions in the technical literature and the product labels created by the manufacturers for *cyber physical systems, smart products, industry 4.0 compatible components or digital services seem almost inflationary.* Especially manufacturers of machines and plants are challenged to take a closer look at this topic when they need to integrate various components.

The reference architecture model industry 4.0 (RAMI 4.0) created in collaboration with the associations Bitkom, VDMA and ZVEI in the Plattform Industrie 4.0 provides a framework for interdisciplinary and cross-vendor collaboration in the context of industry 4.0 (I4.0). The I4.0 component is the core concept of RAMI 4.0. The I4.0 component comprises an object which is clearly identified globally and its globally unique virtual representation – the asset administration shell. The asset administration shell can be considered to be a digital twin of the product and integrates the product into the I4.0 world. The asset administration shell offers access to all relevant information about and functions of a product throughout its service life and beyond.

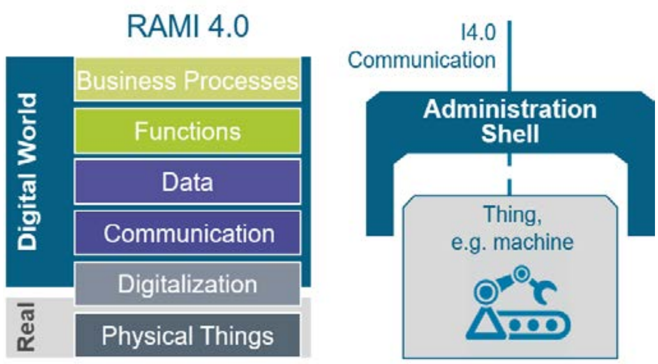


Figure 1: I4.0 component in RAMI 4.0
Source: Plattform Industrie 4.0

ZVEI provides cross-vendor and non-proprietary information regarding which concrete criteria industry 4.0 products should meet. A guideline which should provide a future-proof orientation for the selection and development of components based on the catalog of criteria and annually updated manufacturer and customer requirements was published for the first time in 2017. Component manufacturers in particular, as well as machine and plant builders, can use these non-proprietary requirements as a guide in order to allow for a minimum level of interoperability and cross-vendor connectivity.

Starting 2020, products in the field should therefore be identifiable by means of a unique global identifier in accordance with DIN SPEC 91406 (e.g. https://wgrp.biz/x3fpXu4) and allow for digital contact to service and information for product support incl. spare part information. In addition, other information relevant to customers, such as technical data or CAD files, should be accessible online. The information model from OPC UA should be used for industry 4.0 communication in the field and initial information such as status, error notifications, warnings, etc. should be output in accordance with an industry standard. Appropriate security capabilities for the components should be documented by means of a risk assessment. The complete list of the short, medium and long-term requirements can be found in the 2020 product criteria. (2020 product criteria – What criteria must 2020 industry 4.0 products meet?)

Integration concepts for machine and plant builders

Integrating smart products and services into production systems in machine and plant design is complex. The white paper therefore considers their technical integration in parts and divides it into the two components of communication infrastructure and information modeling. Here, integration into the **communication infrastructure** means the (global) networking of devices, sensors and actuators for data recording and processing. Building on this, integration into the **information world** is possible in order to achieve information transparency throughout the plant and its components.

Integration into the communication infrastructure

The control level of the automation pyramid with programmable logic controllers (PLCs) or industry PCs (IPCs) is far from obsolete in the integration of smart products and services. Dedicated IoT gateways which were specially developed for so-called edge computing supplement the existing components and provide integrated management and security functions. The PLC is typically a self-contained, embedded system which is used for the implementation of real-time capable control software. IPCs and IoT gateways, on the other hand, are accessible to the user and are particularly suitable for the integration of smart products and services. Container technologies are also recommended for the implementation of applications (smart services) since this makes a portable, high-availability system possible both “on edge” and in the cloud. A container collects individual applications together with their necessary resources such as software libraries or utilities in an executable unit. The container technology in particular offers the option of orchestrating applications from various manufacturers consistently, running them separately from one another and being able to transfer them to different machines.

Smart products are clearly positioned in the field within the production system. It is different for smart services. These can be implemented on the product, edge or cloud level. Ultimately, the resources required for data processing and storage and the proximity to the point of origin of the data are crucial, the latter owing to latency and data volume. Due to the data volume, vibrations in the several kHz frequency range are thus often pre-processed within the product, whereas aggregated data such as characteristic values derived from the vibration or events are transmitted to higher levels and analyzed there.

Figure 2 (page 4) shows the communication infrastructure for smart products (sensors, actuators) and the possible location of smart services (light bulb icon), which can run either in the field, on edge (PLC/IPC) or in the cloud.

It becomes clear in the communication infrastructure that smart products and services today are *additional* interfaces which by no means replace the fieldbuses and control level. It is expected that this separation will be solved through *convergent* networks (such as OPC UA over TSN) and the number of different bus systems and interfaces will be reduced. Conventional control and bus systems, analog input/output signals or IO-Link signals can already be integrated into many common IoT gateways. For IO-Link, IO-Link masters increasingly also offer a second so-called “IoT interface” which can communicate via HTTP, MQTT or AMQP.

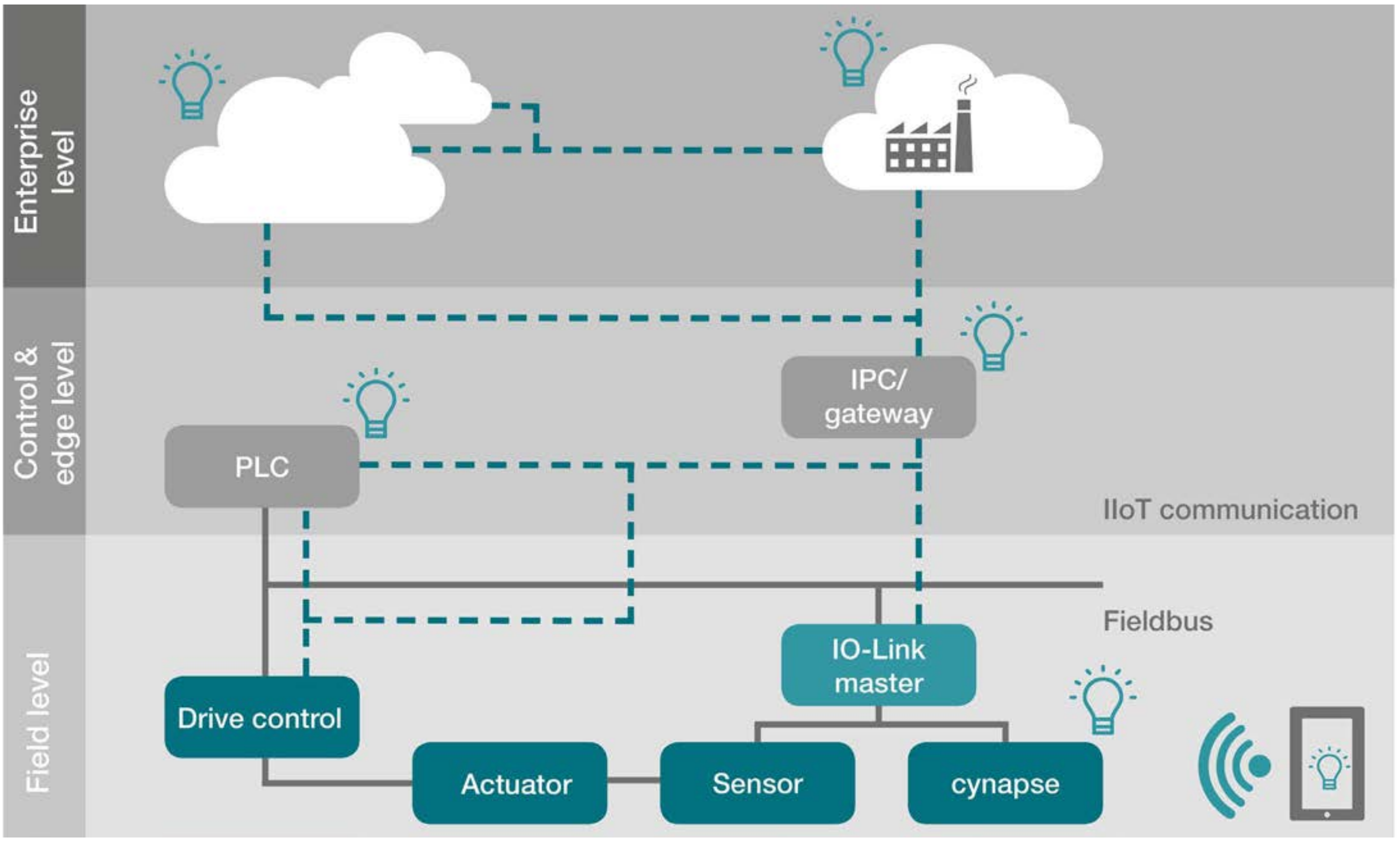


Figure 2: Overview of communication infrastructure

Wireless interfaces are particularly suitable for ad-hoc access to data in order to identify components, set parameters for commissioning or read the error log via a smartphone app in a service case, for example. This is very often done using RFID, NFC, WiFi or Bluetooth. Wireless connections for entire production systems or their flexible components are interesting in the context of the introduction of 5G technology, though it still remains to be seen to what extent this trend will impact the rigidly fixed components of a production system.

For machines and plants which constitute a self-contained production system, the approach of an IoT gateway per machine offers some advantages. For instance, such gateway can be used to establish superimposed access to the MES or cloud systems on the operator's shop floor. This procedure makes it possible to bring heterogeneous components and services together into a common interface in order to gain an overview of the system. In addition, higher security requirements and access figures can be achieved on gateways, which are often equipped with higher-performance hardware, then on embedded smart products, which is often only the case to a limited extent for microdevices.

Integration into the information world

Connected smart products and services provide only data – only integration into the information world turns the data into meaningful information and creates information transparency across the whole plant.

OPC Unified Architecture (UA) has certainly emerged as the standard here for cross-platform, interoperable and secure data exchange on the shop floor (OPCFoundation 2020). Numerous initiatives and joint working groups are involved in the content-related and functional development of the standard in order to establish transparent information exchange from the smallest sensors to the cloud with the common protocols and communication infrastructures. Abstraction to a common language creates interoperability since the underlying communication technologies can be replaced and bypassed as desired. Thus, for example, IO-Link or an existing fieldbus infrastructure can be integrated into a superordinate system using OPC UA. Well-known web technologies such as MQTT or AMQP are also OPC UA compatible.

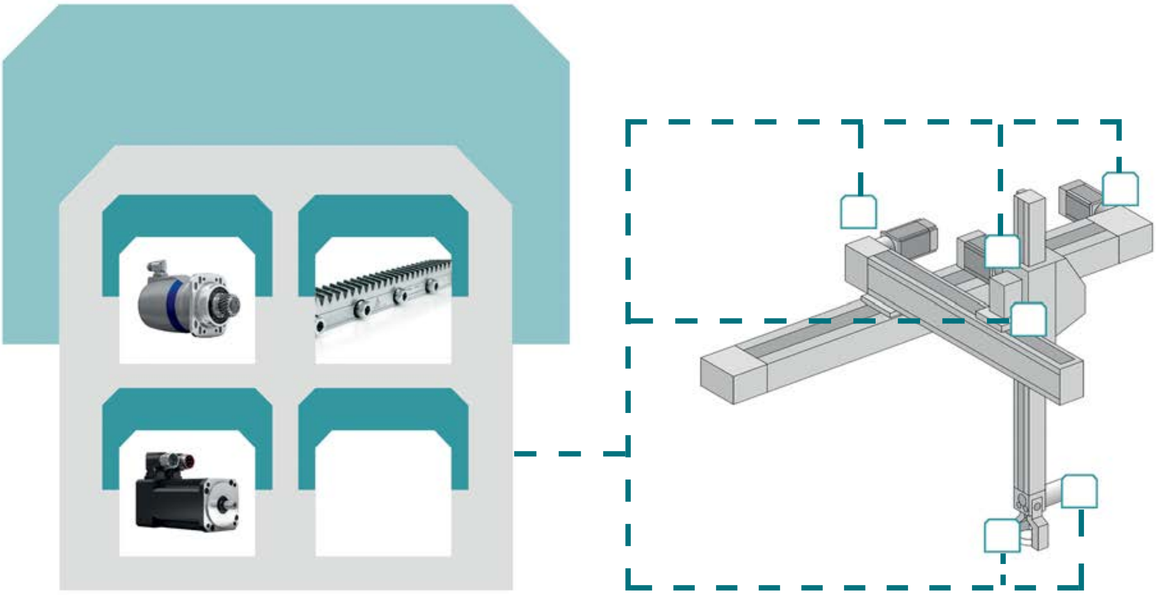


Figure 3: Information models can depict entire subsystems

OPC UA also helps to model the physical world in many ways in a “logical” virtual world using information models. Thus, for example, the information can put control of a sensor value into the context of an electrical axis which represents specific capabilities in the production process. At a higher level, this sensor value can, in combination with other machine data and its analysis, provide information about the quality of the workpiece, for example. The same sensor can also be depicted under the aspect of asset management in the information model in order to generate a digital machine handbook on the basis of the nameplate information.

Multiple objects can be meaningfully combined into a new I4.0 component with information models – these can depict subassemblies, machines, plants or even complete lines (cf. Figure 3).

Other data objects or CAD files can also be depicted in OPC UA in addition to the process data and method accesses in order to allow for direct access to all relevant content. These accesses can be managed easily and securely with the integrated user and role concept of OPC UA (such as read, write, browse).

The development of information models requires knowledge of the respective domain experts in order to combine simple sensor or process data with context information. The processing of the data at the point of origin in particular, for example with physical units or the importance in the appropriate context, is highly relevant for downstream assessment and analysis.

For machines and their components in machine and plant engineering, the VDMA offers a contact point when it comes to the development of cross-vendor information models. Robots or CNC machines thus already have cross-vendor models. The electric powertrain will soon follow. An overview of the currently active OPC UA work groups is provided at https://opcua.vdma.org.

Integration examples based on the smart gearbox

IIoT platforms, gateways, smart products and services have already been available on the market for several years. The maturity of the technology here varies greatly. Based on three case studies which build on one another, an overview of how smart products and services can be integrated into machines and superordinate platforms should therefore be provided below.

The cynapse smart gearbox from WITTENSTEIN has integrated sensor technology, an integrated storage unit and an integrated IO-Link interface. In addition, data-driven services can be implemented on the components or in superimposed systems.

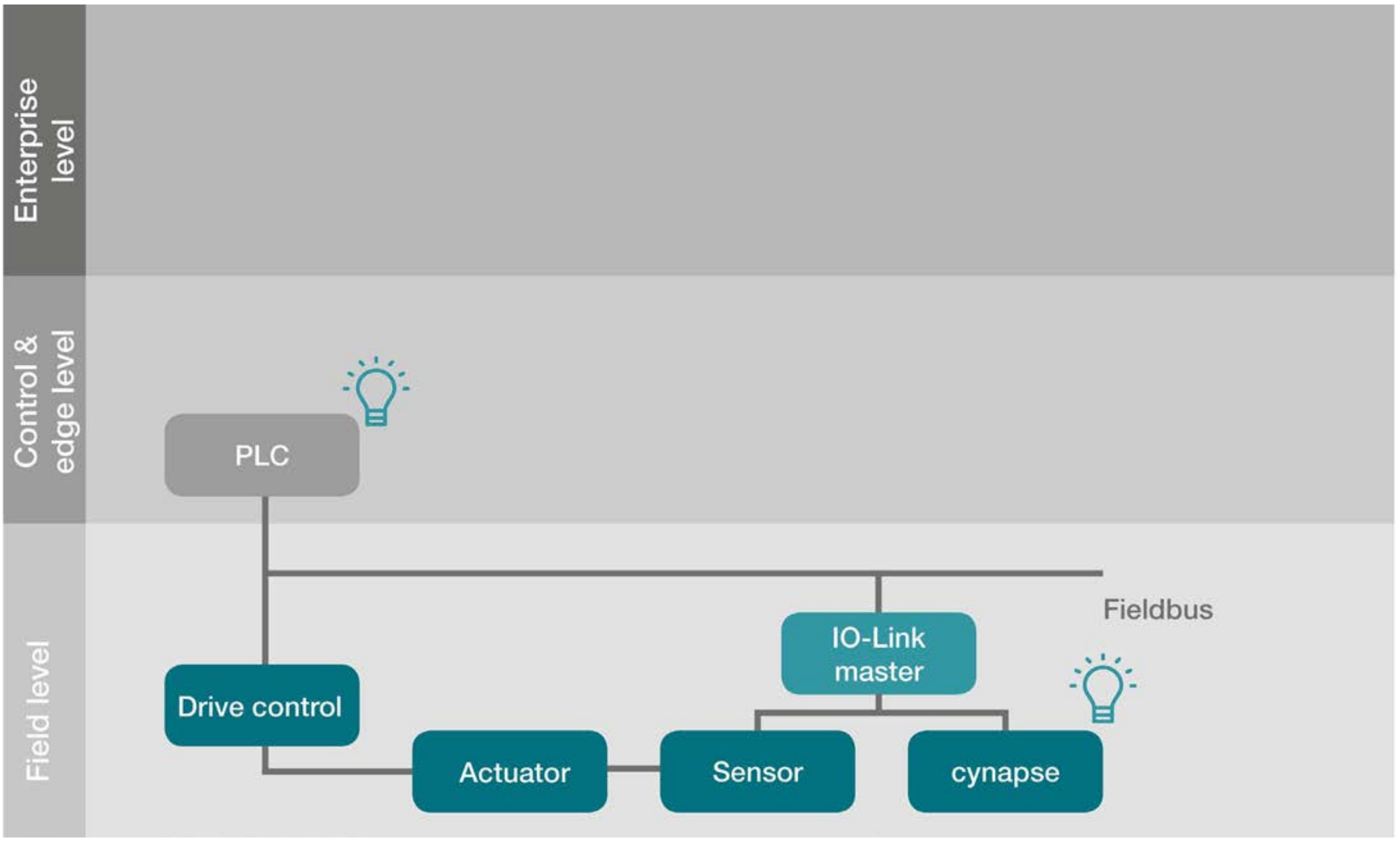


Figure 4: PLC integration of cynapse

Case study 1 – PLC integration

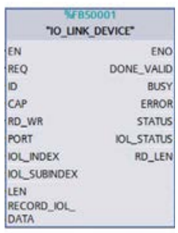
Through the standardized IO-Link protocol, the smart gearbox can be integrated into a machine using an IO-Link master which is connected to the control system using standard fieldbuses.

In addition to the sensor data which is cyclically transmitted, parameters and historic evaluations can be accessed through an acyclic query. Here, processing of the data is done solely on the drive itself and the PLC (cf. Figure 5).

The IO device description (IODD) file simplifies the integration of the IO-Link device into the development environment (such as TIA-Portal, TwinCat, Studio 5000, etc.) even "offline".

Although the IO-Link protocol is standardized, the IO-Link master of the relevant control system manufacturer is also recommended for seamless integration into the proprietary development environment. Once the IO-Link device is integrated, the cyclic and acyclic data for the smart gearbox can be accessed there in the PLC programming via components or directly in the code.

Standardized querying of BLOBS via IO-Link is less common. A BLOB is a binary data object which contains the raw data for the cynapse acceleration sensor available from WITTENSTEIN, in order to allow for in-depth vibration analysis, for example. A program for querying, reading and interpreting the content in the PLC programming is generally required for this.




```
"IO_LINK_DEVICE_DB"(
    EN := TRUE,
    REQ := #REQ,
    ID := #cyn_ID,
    CAP := #cyn_CAP,
    RD_WR := #Write,
    "PORT" := #cyn_Port,
    IOL_INDEX := #Index,
    IOL_SUBINDEX := #SubIndex,
    LEN := #len,
    DONE_VALID => #Done_Valid,
    BUSY => #Busy,
    STATUS => #cynapse_Error,

    IOL_STATUS => #IOL_Status,
    RD_LEN => #RD_Len,
    RECORD_IOL_DATA := #cynapse_DataExchange)
```

Figure 5: PLC component and code for reading cyclic and acyclic IO-Link data

The PLCs OPC UA server can serve as the central interface for the subordinate components for integration into superordinate IIoT systems. OPC UA mapping simplifies access to cyclic, acyclic and BLOB data by applications and gives the variables meaningful names (such as X axis temperature) in the context of the production system.

Case study 2 – Gateway integration and smart services

Many IO-Link masters have a dedicated IoT interface in addition to the fieldbus – some already have automated OPC UA mapping. These are recommended for consistent IIoT solutions and the greatest possible flexibility. The smart gearbox can thus be integrated independently from the PLC in the second case study and data can be read on a superordinate system in JSON format via HTTP or OPC UA, for example. In this scenario, further analysis of the data can be done through smart services on the gateway or in the cloud.

The "Data Gateway" service thus allows for collection of all values which cynapse provides and forwards these to any destination system. In this case study, the data is forwarded to the "cynapse Monitor" service which constitutes a status monitoring dashboard which can be accessed through an Internet browser. The smart service can be implemented with offline capability on the gateway or can be integrated into the ADAMOS IIoT platform. With IIoT platform integration, the dashboard can be accessed anywhere in the world – subject to authentication in ADAMOS and access to the service.

Third-party smart services can be integrated through gateway integration with little adjustment required and can be updated in operation. In contrast to PLC integration, higher-level programming languages and web technologies are used in this case study. Figure 7 shows the HTTP REST API for the "cynapse Storage" service by way of an example. Integrated version management makes it possible to use linked services, continue using the existing REST API and flexibly migrate to new APIs during the course of a functional expansion.

Figure 7: REST API documentation with Swagger for the cynapse Storage service

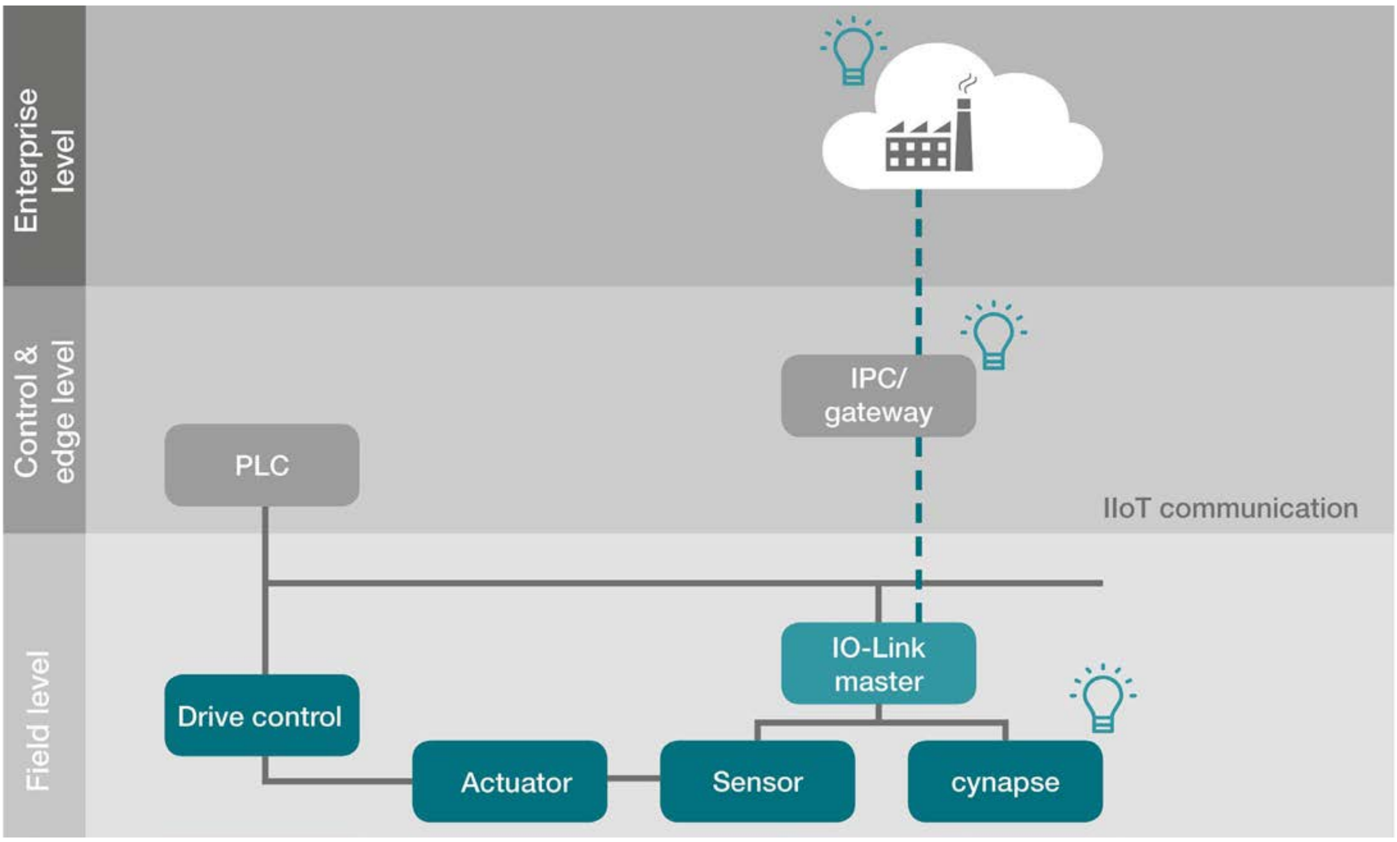


Figure 6: Integration of cynapse via gateway

Case study 3 – IIoT ecosystem integration with digital twin

In the third case study, integration into the production system and the asset administration shell as a digital twin of the smart gearbox is envisaged. Thanks to the high degree of networking, the service can obtain data from the components, the control system and the gearbox's asset administration shell. This allows for the efficient use of data which is already available, reduces the manual effort for data maintenance and prevents doubled collection of data with redundant sensors. The high degree of networking also makes it possible to create whole new services (such as digital machine files, optimized after-sales support, etc.).

In this example, the digital twin (asset administration shell) can be accessed via HTTP REST API online and provides the smart service with automated parameters for the product. The asset administration shell for the product is instantiated with its creation and can be populated with data using the other applications.

In Figure 9, the technical specifications for the component are provided by way of example in order to use them for commissioning or to be able to compare them with control data (current speed, etc.).
The digital twin can also record information from the field in order to keep the maintenance history file for the product up to date. Figure 10 shows a run history for the "cynapse Teach-In" services in the product's asset administration shell. cynapse Teach-In provides support for the determination of machine and process-dependent threshold values based of recorded sensor values over a defined period of time. Instead of the raw data, aggregated data on the duration of the teach-in and on the temperature threshold values is saved in order to share these generally in the value network with the necessary data economy.

Conclusion

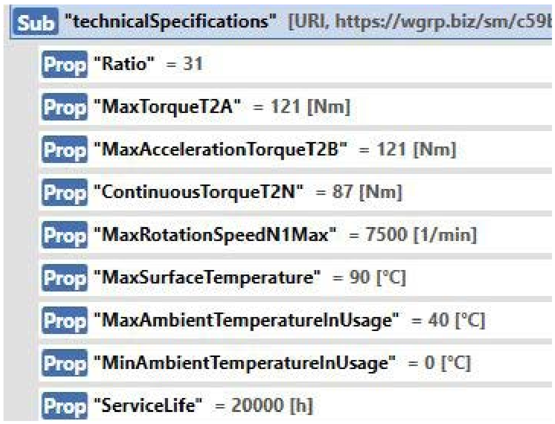


Figure 9: Technical data for a product in the asset administration shell

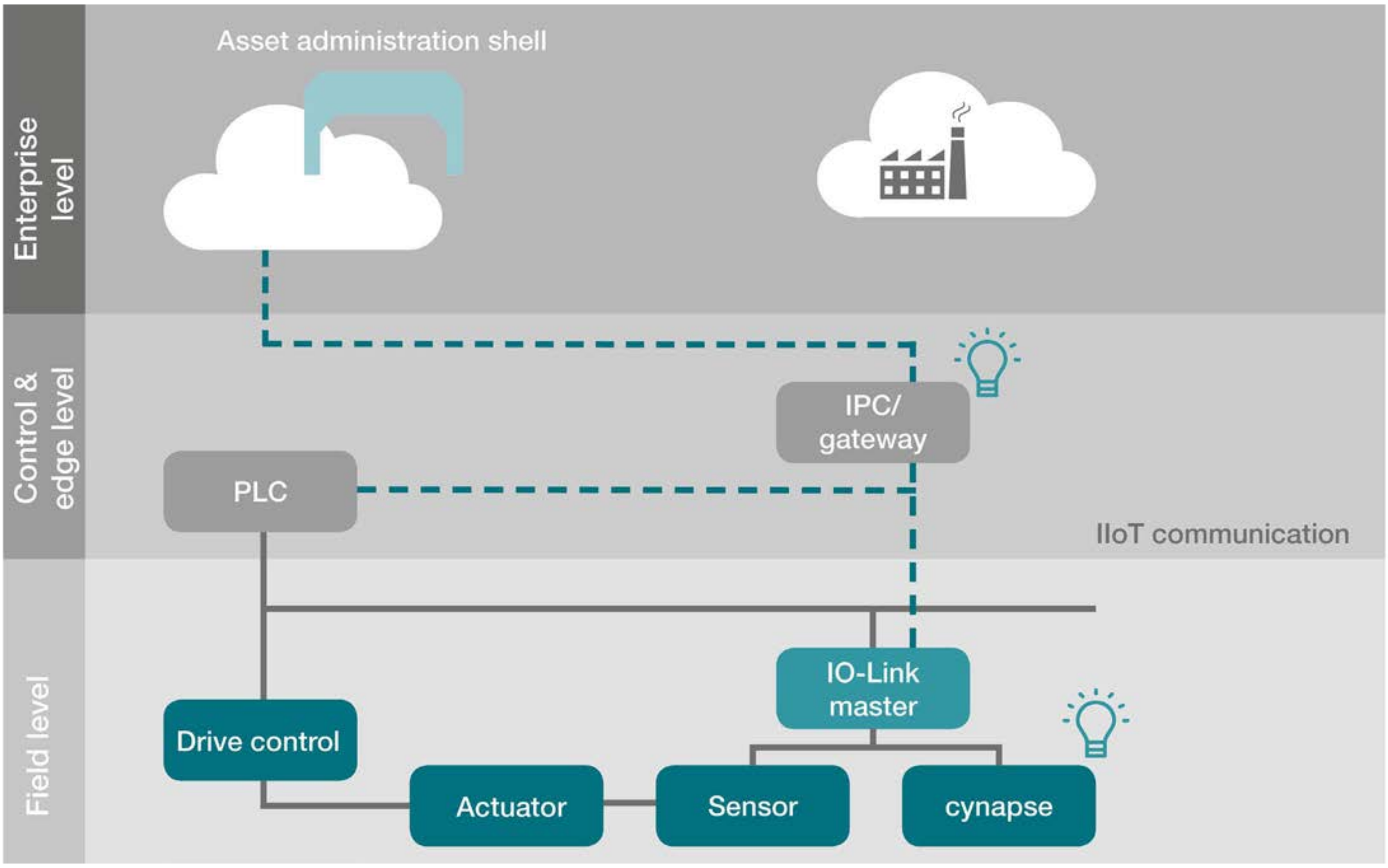


Figure 8: cynapse in digital ecosystems

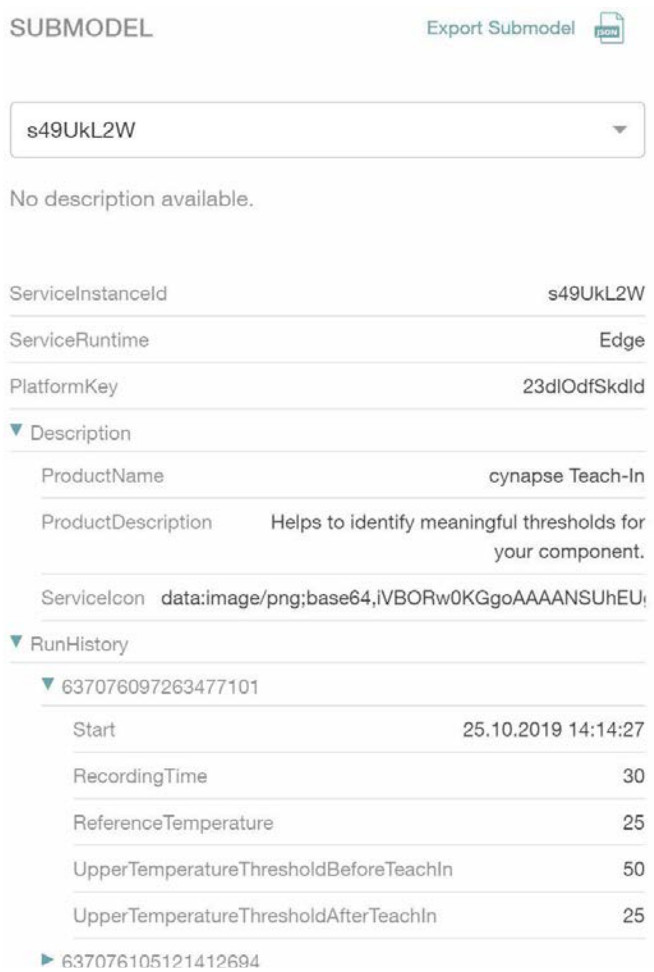


Figure 10: Aggregated data from the field is stored in the digital twin

In addition to the traditional control of technical processes for the production of goods and products, smart products offer several benefits. The technical integration requires an expandable integration concept which is tailored to the machine concept and the application. The case studies presented in this white paper demonstrate three possible integration concepts. Mere PLC integration is done with the familiar PLC programming tools and can be simplified with function blocks and code examples provided. Gateway integration makes it possible to use smart services flexibly and take advantage of existing offerings in the process. IIoT platforms and manufacturer-specific digital ecosystems makes horizontal integration possible in addition to vertical integration from the shop floor to the cloud. Horizontal integration between the value-adding partners results in entirely new integration options.

Validation of these new solutions should be done in protected environments such as test or prototype machines. With the right integration concepts, experience and data can already be collected from the field today in order to develop associated new offering and business models.

When choosing smart products and services, attention should also be paid to a minimum level of interoperability in order to be able to flexibly integrate and use other components, services or platforms along with the rapid technological progress.

References and literature

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PDF: Leitfaden Produktkriterien

Further links

Website: WITTENSTEIN alpha – cynapse

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