OPENING UP THE INFORMATION SETS OF MODERN FIELD DEVICES FOR VARIOUS ASSET MANAGEMENT APPLICATIONS

J. Müller, U. Epple
jochen.mueller@plt.rwth-aachen.de
Lehrstuhl für Prozessleittechnik
RWTH Aachen, Turmstr. 46
52064 Aachen
Germany

M. Wollschlaeger, Ch. Diedrich
christian.diedrich@ifak-md.de
ifak – Institut für Automation und Kommunikation, Steinfeldstr. 3
39179 Barleben
Germany

U. Enste
udo.enste@leikon.de
Leikon GmbH
Kaiserstr. 100
52134 Herzogenrath
Germany

Abstract – In modern process plants, with constantly changing equipment and setup, the efficiency of any asset management application is reduced up to date by closed and fixed system solutions. On one side the lack of a configuration-free access to innovative fieldbus devices still leads to high investments in engineering their information sets into various applications of process control engineering. Later on implemented asset management functionality causes additional engineering efforts. Additionally, engineering investments for the integration of synthesised asset information into informational bookkeeping of process control engineering reduce the efficiency of asset management tasks themselves.

The authors present an asset management system reducing investments in engineering and re-engineering of asset management tasks. It is based on an open information platform, which offers configuration-free analysis of fieldbus segments, an open access to all installed field devices and the automatically updated, structured and self-descriptive presentation of all device information in terms of device proxies. The paper describes results and experiences with various asset management applications, implemented at different level in process control engineering. The asset management applications do not need any investments in engineering or re-engineering while changing equipment and setup of a determined plant.

Index Terms — Asset management, asset management box, information worlds, device proxies, field device's information sets, field information server, universal fieldbus interface, ACPLT, automation of engineering.

I. INTRODUCTION

In the process industry, engineering functions for the administration and optimisation of devices are gaining importance in comparison with process control functions [1]–[3]. The term "asset optimisation" [4] is often used to describe techniques that exploit the full potential of plant assets. This applies in particular to field devices used in production processes.

Plant asset management are activities and measures undertaken to conserve or enhance the value of a plant. Online asset management focuses on assets whose current status can be accessed using the plant communication network, e.g. field devices and plant components. Based on the analysis of plant information and the presentation of the actual plant state, further applications access the available plant and device information.

In general, online asset management tasks involve the synthesis of plant information for the economic optimisation of technical plant support [3]: for example, the optimisation of planned maintenance (and, therefore, minimisation of breakdowns), improvement in process diagnosis and control, and an increase in production throughput by making better use of existing reserves. An efficient online asset management system is a prerequisite for optimised process control in process industry [5]. Validating process information and determining the functional reserve of production plants [6] also belongs to online asset management applications. Further tasks of online asset management are the online documentation of the field instrumentation and a central configuration of installed field devices. Furthermore, the replacement of field devices without any investments in reengineering, and device tracking are tasks of online asset management. To handle these applications, one precondition is the identification of different roles of field devices in process control engineering, e.g. the functional role of the field device in the plant or its behaviour in a device-specific view. In this context, a role is the behaviour of an entity (such as a field device) within a specific context [7].

Until now, enterprises are faced with high costs for engineering their asset management applications. One reason for this is the absence of a generic, manufacturer-independent and sufficiently complete model of field devices in process control engineering. This results in a diverse range of maintenance/optimisation tools for field devices. There is a number of dedicated asset management solutions existing in the market, specialised and optimised for fixed application scenarios. Any change of application parameters (e.g. plant setup, system topology) leads to huge efforts and high investments in adapting this specialised solutions. To extend additionally asset management functionality to already installed systems, enhanced investments in engineering are still necessary.

One of the most important unsolved problems of asset management solutions is the reduction of their engineering investments. Additionally the engineering of asset management applications has to be a integrated part of the general engineering concept of process control. Until now there is still a lack of seamless engineering concepts for heterogeneous automation environments. Especially for plants with frequently changing setup and a huge amount of assets the automation of engineering is of special interest [8].

II. ENGINEERING OF ONLINE ASSET MANAGEMENT APPLICATIONS

The efficiency of asset management tasks are determined by the investments for their integration into process control engineering. Caused engineering investments are on the one hand the integration of field device information sets into online asset management applications, on the other hand the engineering of asset information, served by the application, into the informational bookkeeping of process control engineering. In this context, informational bookkeeping of process control engineering consists of all information sets of various application areas and functional tasks in the process control level and the plant level. The efficiency depends on adaptation efforts of the asset management solution while changing the plant setup, and also by engineering investments for the integration of additional asset management functionality.

The development and establishment of microelectronics in field devices leads to a wide spread of innovative functionality and information, e.g. device diagnosis and maintenance information [9]. Thus, new generation field devices contain embedded information sets that are ever-increasing. These information sets consist of device information objects, parameters and attributes belonging to device functionality and configuration. Deploying these new generation field devices in process industry, especially the integration of their information sets in the informational bookkeeping of process control engineering is of special interest [10], [11]. For the potential of these devices to be completely exploited, they have to be fully integrated into various applications, without considerable investment in additional engineering efforts. In current industrial practice, the additional features provided by the new generation of field devices are often not fully exploited, since they can only be integrated into existing applications at considerable expense [12].

In industrial environment, various fieldbus technologies and systems are available, covering different application areas [13]. To allow interchangeability and interoperability of field devices, a number of standardisation activities have been performed [14]–[16], mostly initiated by the different fieldbus user organisations. For historical reasons, each of these standardisation activities has focused on a specific fieldbus. This results in different views and device models and in dissimilar definitions of similar functionalities. In order to overcome incompatibility between devices within a certain application area, such as drives, sensor devices, HMI devices and so on, device profiles have been developed by user organisations [17], [18]. A device profile defines functionality of field device types, the variables, parameters and their semantics, as well as methods for accessing this data. Besides the standards, device manufacturers are allowed to add proprietary device functionality.

The results of extensive tests deploying fieldbus technology [19] led to an increasing spread of fieldbus instrumentations in process industry. Since the increased information set in new generation field devices, fieldbus instrumentations deliver an extensive information supply in the field level of a plant (see fig.1). Hence, an important task of process control engineering is to make this information available in its informational bookkeeping. To handle information easily in complex and heterogeneous systems, the access to the information has to be open, independent of platforms and manufacturers and configuration-free.

Given the current industrial practice of installing multi-vendor instrumentation for process automation, a configuration-free and manufacturer-independent access to field device information and functionality is surely a precondition for efficient online asset management. From an application-oriented perspective, this open and uniform access must be extended to be independent of a particular fieldbus type.

Another cause of high investments in engineering are extended configuration requirements of the enhanced field devices. In general, the field device information set can be accessed using common technologies [20-22]. These technologies are based on the integration of device descriptions in additional tools. Besides the dependency on different versions of device descriptions and software tools, software maintenance and moderate availability of device descriptions are drawbacks.

The reduction of engineering investments for the integration of synthesised asset information into informational bookkeeping of process control engineering requires an open access to the information itself and to its semantical and syntactical description. In general, the availability of meta information especially at runtime (e.g. class information on an instantiated object) eases the analysis of unknown installed systems within the realm of the meta-model without prior knowledge: the information and its description (meta information) can be gathered completely from the installed system. Related to asset management applications the availability of meta information allows the interpretation of synthesised asset information, according to the used application model, which can be analysed at runtime.

Concerning the adaptation efforts while changing the plant equipment and setup, their automatic detection is required. This must lead to an automatic incorporation of the changed setup into the asset management applications. In modern process plants different kind of changes can be distinguished. Changes in system topology are caused by removing and inserting field devices or plant components. Changes in field device's internal structure can be caused by varying hard- and software versions or applications accessing the field device. Changes of parameter's information content, caused by engineering processes can also influence the field device's internal structure.

In modern process plants a wide extensibility and flexibility of asset management functionality is highly required. Because of changing asset management policies or new asset management methods and tasks a closed and fixed asset management solution reduces its efficiency. The efficiency is determined by the engineering investments while the implementing of additional functionality. In this context, a meta model based system solution is a prerequisite for the easily extension of functionality and thus a precondition for system's flexibility.

Discussing the efficiency of asset management applications, one has also to consider additionally needed system resources within the plant, e.g. bus load or memory requirements of installed applications [22]. General requirements to reduce engineering investments of asset management solutions are platform- and manufacturer-independence, as well as the use of standard technologies.

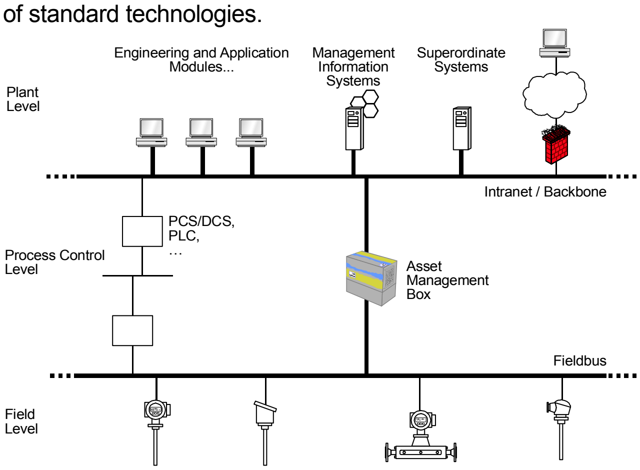


Fig. 1. System environment: the asset management box acts as an information server between plant and field level, serving an additional information channel in parallel to an existing process control system.

III. ASSET MANAGEMENT BOX

The asset management box (AMBox) is an information server, connected to both, plant and field level (see fig. 1). Usually implemented in the control room, the box, based on an industrial PC, is connected to the fieldbus network on one side, and to an Ethernet-based LAN (Intranet) on the other side. It provides an additional information channel to prevent an influence of implemented asset management functionality to the installed process control system [3].

The core functionality of the asset management box is the automatically-updated analysis of connected fieldbus segments, without prior knowledge about the installed field devices. The embedded information set of the actual installed field devices is represented in different views, achieving a clear information structure in process control engineering. The AMBox permits configuration-free browsing through the object-based representation of the field device information and the fieldbus structure. This representation is continuously monitored and kept consistent. Status information about the parameter values, like validation indices (good, questionable, bad, unknown) and the time stamp of latest update are available, as well as meta information about the device information, permitting easy access by any application.

The realisation of this basic functionality requires a generic model for field devices, considering their behaviour and interactions in different information worlds of process control engineering. The generic model enables the representation of field devices in the network view, plant view, process view, and device view (see fig. 2). Furthermore, the semantical and syntactical definitions of the field devices of the attached fieldbus, the device profile, are required.

The profile is accessible in the form of an XML (extensible Markup Language) file. Extending the file with new device types, additional manufacturer specific functionality is integrated. Using the developed generic field device model, the information defined in the device profile (data structures, block types and structures, parameters and attributes) is transformed into device block types at runtime. Thus, the complete information supply and the general specifications for the internal block structure of the field devices, the semantics of their parameters, and the structure of data types can be explored at runtime.

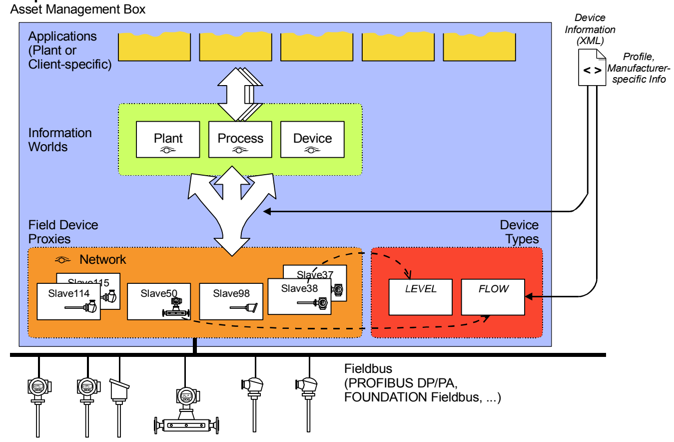


Fig. 2. Core functionality: automatically-updated analysis of attached fieldbus segments. Identification of the field devices and assignment to proxies representing the field device in different information worlds.

After the automatic exploration of connected fieldbus segments, the field devices found are identified according to the profile information mentioned above and then assigned to proxy objects [23]. Such a proxy object can be treated as a field device within a specific context in the informational bookkeeping of process control engineering. The proxy represents the field device's information set, functionality, behaviour or interaction in a specific view or information world of process control engineering.

The system architecture of the asset management box is shown in fig. 3. The object management system ACPLT/OV (Aachener Prozessleittechnik Objektverwaltungssystem) [24] is used as the object-oriented runtime system. It provides a metamodel-driven online database with open information access. Besides the instance data of objects, meta information (description of the class model) can be accessed at runtime.

The core functionality of the AMBox is implemented into its object management system by default. At runtime, further dynamically loadable modules can be added. These modules represent various asset management applications. Plant or application-specific applications access the information objects and their values within the device proxies. Results of this applications can be gathered by other applications, for example office software packages, manufacturing information systems, etc.

Fig. 3 shows the access of the field device information sets by different applications or users in the plant level. The object management system provides access to the objects in the database via the communication system ACPLT/KS (Aachener Prozessleittechnik Kommunikationssystem). ACPLT/KS is an open, platform- and application-independent communication system, a "Process Control Internet" [25]. In addition, a web server is implemented to allow browser-based access to the objects within the database. Thus, any web browser can act as a platform-independent display component and can be used to display reports on the installed field devices. Besides classical server-based web applications, browser-based applications can be realised, enabling complex user interfaces in a platform-independent way [26].

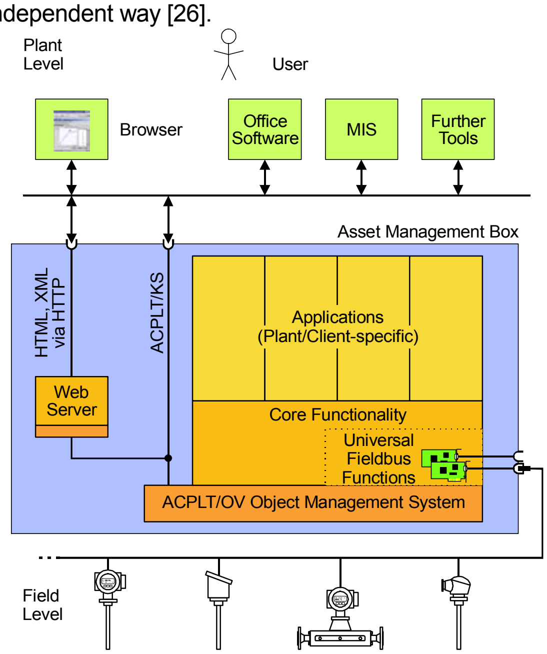


Fig. 3. System architecture of the asset management box: the core functionality is implemented by default, asset management modules or plant/client specific functionality can be added dynamically at runtime.

The main idea of the AMBox is to use a generic model of field devices, whose classes serve only generic functionality. This core model is not overloaded with the diverse specific features of different fieldbus systems, which would lead to too much specialisation and to enormous efforts in software maintenance.

The independence of the core functionality of the AMBox concerning fieldbus specific communication features is guaranteed by means of a generic fieldbus layer, which hides details and specifics of the fieldbus and used interface cards. Communication relies on universal functions, for example reading and writing parameters of a field device, or creation of a list of devices currently present in the fieldbus segment.

Using the so-called type-instance-design pattern, the independence of the core model from a specific fieldbus profile is guaranteed, and programming effort can be clearly reduced [25]. Instead of manually coding data types and block structures for a specific fieldbus profile, they are represented as type objects within the AMBox, dynamically created at runtime. For the users' perspectives, this ensures extensibility of the AMBox with respect to new profiles, without any programming effort ("description instead of programming").

IV. ONLINE ASSET MANAGEMENT APPLICATIONS

The asset management box permits the distribution of asset management functionality in various application layers. First, asset management functionality can be implemented within the automatically created device proxies in the information worlds of process control engineering. Examples for this intrinsic functionality described below are: the configuration-free, structured and object-based representation of the field device information and the fieldbus structure, the recording of device history (e.g. extremes to which the device has been exposed during operation), device replacement without re-engineering, etc. Another layer consists of locally implemented asset management modules, using several information of different device proxies, e.g. automatic online documentation, online device diagnosis. Furthermore, extrinsic applications implemented at the plant level outside the box can be developed using the open access to the field-devices via the asset management box (for example online documentation by office software, maintenance modules, ERP-modules, etc).

These universal, application-specific or client-specific applications can be loaded dynamically at runtime. Thus, a high degree of flexibility and extensibility can be achieved. The AMBox core separates the applications from the specific features of a particular fieldbus, like specific data types or specific communication services.

The application modules described below implement asset management functionality. The application modules access the information set of the device proxies, interpret and classify the data objects based on the semantics information, provided at runtime. Due to the availability of the semantic information an application can automatically detect appropriate input data. Thus, no engineering effort is necessary to adopt application modules to changes of the plant equipment or setup.

The corresponding output of the applications can be accessed by presentation clients or other application modules. Due to the availability of meta information any application model can be explored at runtime. In consequence the output data of the application can be interpreted at runtime. The model and concept of the asset management box are independent of the accessed fieldbus type. To improve the developed asset management concepts, a multi-vendor demonstration plant based on fieldbus technology has been installed. As an example PROFIBUS-DP/PA was chosen (see fig. 4).

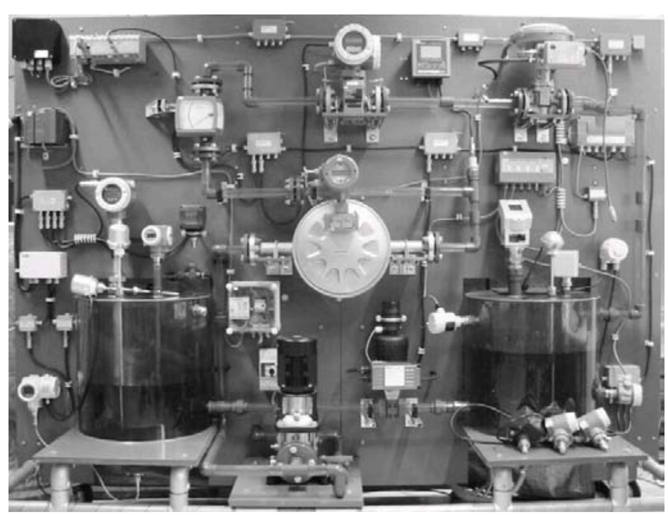


Fig. 4. Multi-vendor fieldbus instrumentation in PROFIBUS-DP/PA technology.

A. Online Documentation

A documentation module is preinstalled within the box. The module extracts information from the device proxies, representing the field device in different information worlds of process control engineering. Fig. 5 shows an example of the network device proxy. This view provides a general survey, e.g. implemented tags, detailed information about their tag-description, serial numbers of deployed field devices, the structure and types of the implemented function blocks up to a complete edition of the total field device information set, all values of parameters and attributes.

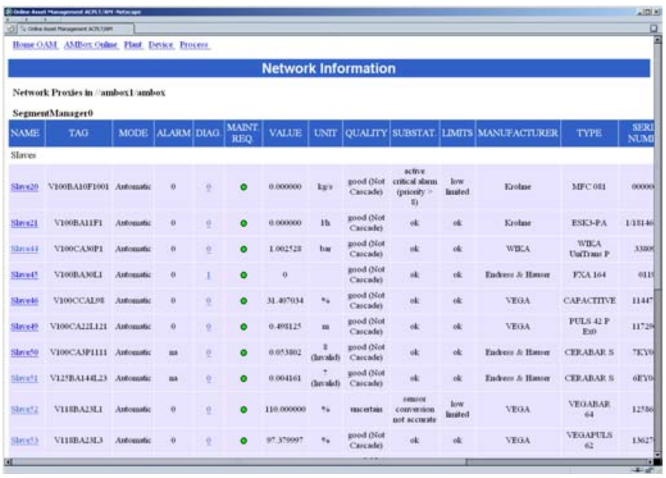


Fig. 5. Screen shot of a web based online documentation of the network field device proxy.

The actual state of the field devices can be analysed. Information on device diagnosis and a required maintenance is clearly arranged. Besides of actual diagnosis information of all installed field devices, a complete list of tags and device identification information (manufacturer, device type, serial number, etc.) is generated automatically. This includes information on the mapping of devices instances to its dedicated role, which can be identified by its tag.

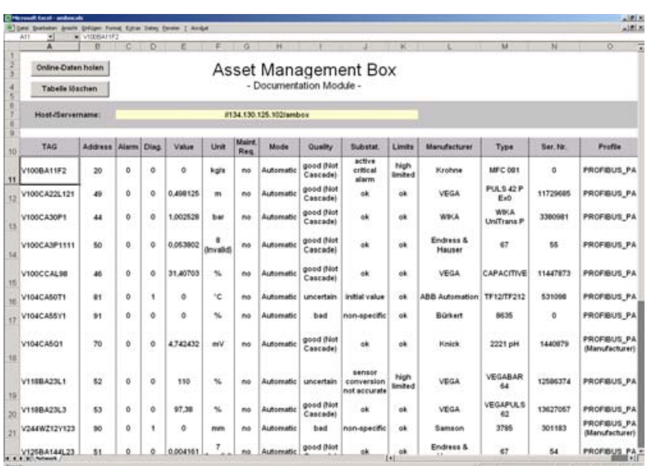


Fig. 6. Screen shot of an Excel-Documentation module.

The application module serves various output formats, including, for example, standard office formats (Excel sheet), XML-based exchange formats and OVS (Object Management Language). Fig. 6 illustrates the access of an office application to the information sets of the instantiated field device proxies. Using ACPLT/KS for communication, this access can be easily provided. The structure, defined by the documentation module, is filled automatically without any engineering.

B. Central Configuration of Field Devices

The AMBox supports the projecting of field device configuration. The blocks of a field device, their parameters and attributes can be determined by appropriate clients and transferred into the field device proxy. Following, the projected information is transmitted into the embedded information set of the assigned field device. In order to ensure a successful transmission of the projected information, the changed information is refreshed by reading back the affected parameters from the device.

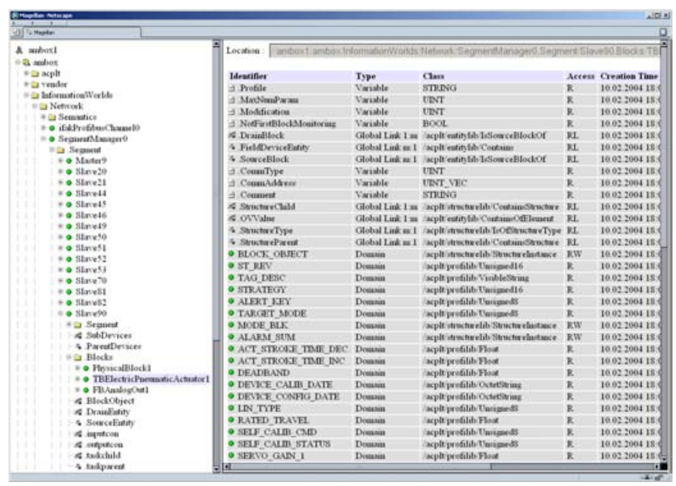


Fig. 7. Screen shot of a web based configuration client.

C. Online Diagnosis

The proxy of the field device in the process information world represents all information to figure out the actual state of the field device in the process. In addition to actual measurement values, the proxy contains alarms, diagnostic and status information.

An online device diagnosis application module supplies maintenance information from the underlying fieldbus system. This can be applied at different application levels. For example device related diagnosis modules access the diagnostic and parameter information of one particular device proxy, automatically for all existing device proxies. For a device type more specialised diagnosis functions can be available. They use the semantic information for automatically detection of appropriate target devices. Diagnosis information derived by combining information from different device proxies can also be implemented, as well as specific information for complex maintenance models.

The AMBox makes maintenance information such as “maintenance required” [27], configuration-free and directly available, to office applications or to maintenance modules on the plant level. This information is generated from the status, in the determined installation delivered together with the main value of a process value. The status information is mapped to definitions according to [27], enriched with tag and value. The colour assignment (red, yellow, green) allows an easy overview over the statuses of all installed field devices (fig. 8).

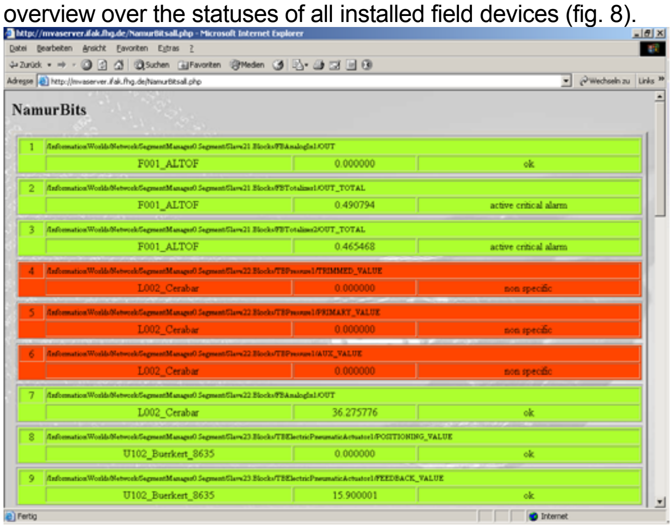
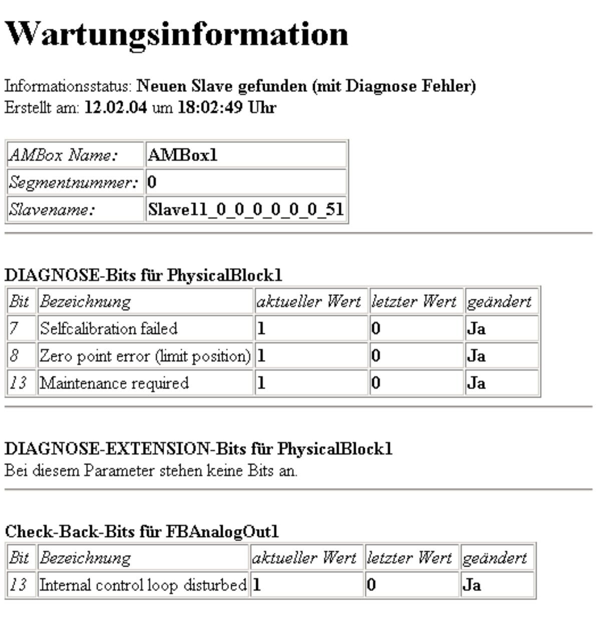


Fig. 8. Screen shot of an online device diagnosis module, serving the “NAMUR-bits” of field devices.

Based on the semantic information the application module within the asset management box searches a given structure, for data with required relations. Common web technologies access this information and opens the area of remote diagnosis. While changing the plant setup or equipment no configuration or engineering is necessary.



Wartungsinformation

Informationsstatus: **Neuen Slave gefunden (mit Diagnose Fehler)**
Erstellt am: **12.02.04** um **18:02:49 Uhr**

AMBox Name:	**AMBox1**
Segmentnummer:	**0**
Slavename:	**Slave11_0_0_0_0_0_0_51**

DIAGNOSE-Bits für PhysicalBlock1

Bit	*Bezeichnung*	*aktueller Wert*	*letzter Wert*	*geändert*
7	Selfcalibration failed	**1**	**0**	**Ja**
8	Zero point error (limit position)	**1**	**0**	**Ja**
13	Maintenance required	**1**	**0**	**Ja**

DIAGNOSE-EXTENSION-Bits für PhysicalBlock1
Bei diesem Parameter stehen keine Bits an.

Check-Back-Bits für FBAnalogOut1

Bit	*Bezeichnung*	*aktueller Wert*	*letzter Wert*	*geändert*
13	Internal control loop disturbed	**1**	**0**	**Ja**

Fig. 9. Screen shot of a report sent via Email

D. State Monitoring

An easy way to notify plant manager or process control engineers about failures of devices is to send warning reports via Email. Such a module is integrated inside the AMBox. The module scans the device proxies in a cyclic mode, identifies abnormal diagnostic states and generates standardised reports (see Fig. 9) which will be sent to a group of responsible persons.

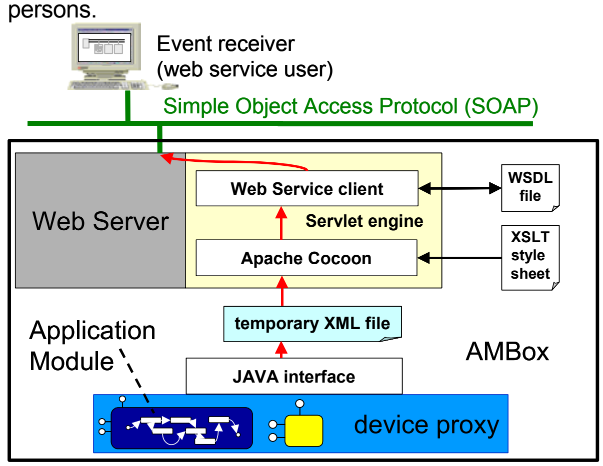


Fig. 10. Principle structure of an event notification application using web services.

Another application module for notification of diagnosis events was implemented using web service technology. The module monitors certain values for changes. It accesses the semantic information to enrich the data to be reported with additional information. For example, changes in the operation mode of devices will be detected, the new operation mode value is reported together with the associated tag. This allows the user to easily interpret the event.

The application module may be configured with the semantics of the data (type information) it shall monitor. It can search for appropriate targets to monitor – data which match the semantics. The module is capable of detecting changes in the system structure or setup.

An implementation example of the module is shown in fig. 10. If a relevant event has been detected, the module creates an XML structure, which is passed to an application through the JAVA interface of ACPLT. The application is hosted by a servlet engine of the web server inside the AMBox. The XML structure contains the monitored value and the additional information described above. It is passed to Cocoon as a transformation engine, which uses XSLT style sheets to generate the resulting web service message, according to the web service description in a WSDL file. The message is sent to the receiver via a SOAP (Simple Object Access Protocol) interface. The transformation can also be used to generate other output information by changing the style sheets.

E. Device Tracking

During its life cycle, every field device is supervised by its own proxy, which contains information relevant to device tracking. Proxy and field device are connected by the unambiguous combination of manufacturer identification and device serial number (e.g. “17_531098” in fig. 11).

The proxy represents the specific behaviour and functionality of the field device in the device information world. It contains an information set with a unique relation to the field device itself. This can be, for example, information necessary for identification of the device, but extremes of pressure and temperature to which a sensor has been exposed, the identification of devices installation place, the installation date, and any device diagnosis data generated before. The relevant information is synthesised automatically by the proxy. Device information about the initial and last installation (setup and installation date) is archived. The operation time of the field device can be easily calculated within the device proxy.

In case of a device failure or after decommissioning a field device from the fieldbus, the proxy concerning the network view is deleted, but the generated device-specific information within the proxy of the device information world is saved, so that the all device information remains available in the informational bookkeeping of process control engineering. The proxy contains a snapshot of characteristic device information just before a decommissioning or failure event, which is archived for every event. The availability of device-specific information even after device removal is very important to facilitate tasks like device repair or device maintenance.

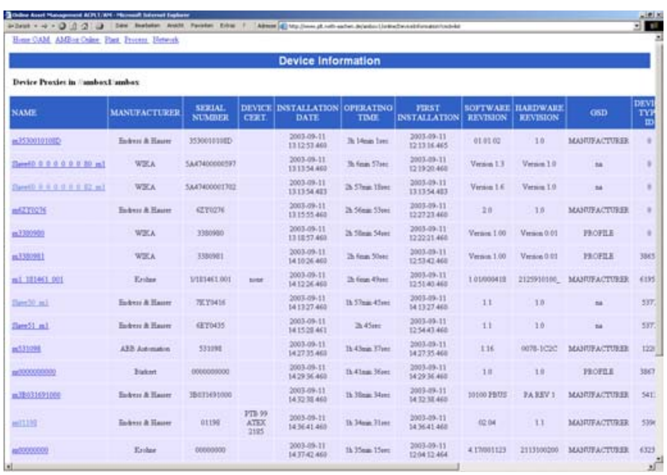


Fig. 11. Screen shot of a web based online documentation of the field device proxy in the device information world.

The proxy in the device world will be regenerated, if the field device is deployed for the first time (see fig. 12). In this case, the serial number of the field device is unknown. In case of a well known field device, identified by its serial number, a proxy object for the device-specific information is already available. This proxy will be actualised regularly, so that an automatic update of device-specific information during the actual deployment of the field device in the process is guaranteed.

F. Device Replacement without Reengineering

The plant proxies contain information relevant for the control system context. This kind of information is closely related to the functional role of a field device within the control system. The measuring of the process medium’s temperature is, for example, a functional role of a field device in the plant. The configured process parameters (e.g. values of a table for the linearisation of raw data, upper limit for a tank level) are represented by this proxy. In the plant information world the proxies are identified by the tag of the field devices in the plant. One aspect of the proxy’s behaviour is device replacement without reengineering (fig. 12 and 13).

As well as its proxy in the device information world, the field device proxy in the plant information world remains persistent within the system, even if the corresponding device is removed. This means that information about the functional role is still available in informational bookkeeping of process control engineering, even after device removal. This enables the opportunity for device replacement without reengineering: the configured information can be transferred into the new device after replacement.

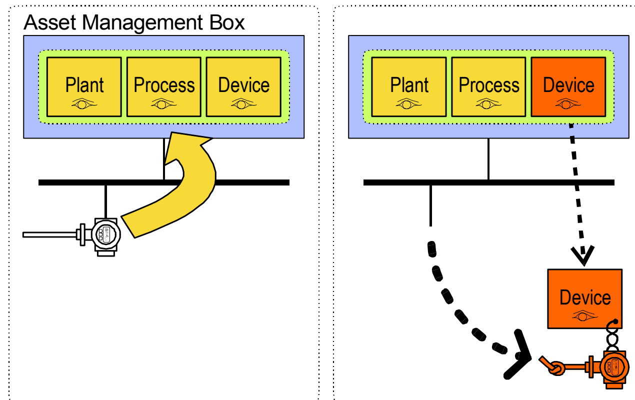


Fig. 12. Actualising or regenerating of field device’s proxies (l) and persistence (r).

The deployment of a new field device in the plant activates several procedures in the field device’s plant proxy. First, the tag structure of the new device is analysed. The tag structure represents the actual configured functionality, resources, blocks and parameters needed. Since a device can fulfil more than one functional role, the tag structure can be rather complex. For each functional role, a separate plant proxies is available.

If a tag, pre-configured in the device, is unknown in the system, the tag is added as a new detected role in the plant. Its current tag structure defines the minimum requirements to fulfil the specified functional role.

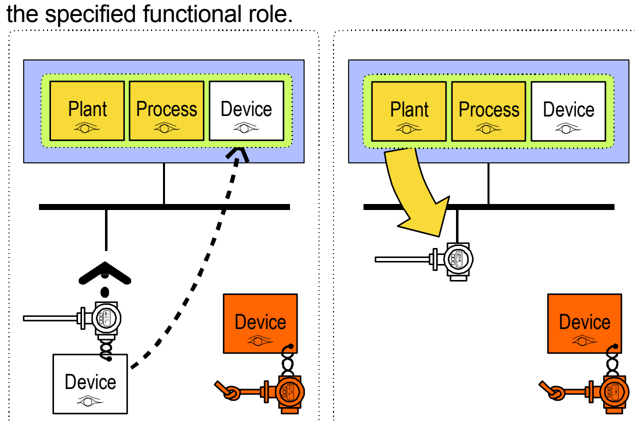


Fig. 13. Device Replacement: actualising of proxies (l) and assigning to field device (r).

For well known tags a decision has to be made whether to replace tag structure in the connected plant proxy, or to transfer the configuration stored in the plant proxy into the field device. The new device must therefore be checked with regard to the minimum requirements of the role to be taken over. By reading the capabilities of the device (number and type of blocks, specific parameters), this asset management module decides whether a device is able to fulfil a particular role in the control process. This requires the existence of certain information structures (e.g. blocks and parameters), which can be marked with different compatibility levels. Additionally the hardware and software versions must be checked.

The task of maintenance personnel is reduced to assign a unique bus address, and to inform the new field device of its role via its tag name (before or after installation).

V. CONCLUSIONS

To enhance the efficiency of asset management applications in process control engineering, the investments for their engineering has to be reduced. Especially in process plants, with constantly changing equipment and setup, closed and fixed system solutions causes high efforts for their engineering and adaptation. Modern field devices provide great opportunity for innovative asset management functionality, but requires a fully integration of their embedded information set. Until now, there is still a lack of a configuration-free access to the information set of fieldbus devices. Closed asset management solutions, without functionality to explore their structure at runtime, cause engineering efforts for the integration of asset information, served by the application, into the informational bookkeeping of process control engineering. Later on implemented asset management functionality causes adaptation efforts.

The asset management solution described above provides configuration-free and manufacturer-independent access to the information set of field devices, avoiding any engineering investments. In its function as an information server, the asset management box creates an additional information channel between field and plant level. Since field device information sets are represented structured and self-descriptive, the box opens up the full efficiency of asset management applications, whether such applications are located directly in the AMBox server or in other systems at the plant level.

The concept and implementation of the AMBox can be applied to asset management tasks of various complexity. Its system functionality provides an easily extensibility concerning supplementary functionalities of field devices. Furthermore, plant or client-specific applications, dynamically loadable at runtime, can easily be extended. To increase flexibility and extensibility features of an accessed fieldbus, like specific data types or specific communication services, are seperated implementing a universal fieldbus layer.

Because of the generic device model used for the core functionality, the application modules are protected against specific details of the underlying fieldbus system. The availability of semantic (type information) and meta information is a prerequisite for extensibility and flexibility of asset management functionality. The asset management applications do not need any investments in engineering or re-engineering while changing equipment and setup of a determined plant.

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VIII. VITAE

Jochen Müller graduated from University at Applied Sciences Cologne in 1991 with a diploma degree in electrical engineering. He has been a process control engineer in chemical industry until 1997. In 2000 he graduated from University of Cologne with a diploma in physics. Since 2000 he is working as a research assistant at the Department of Process Control Engineering, University of Technology Aachen.

Ulrich Epple is the head of the Department of Process Control Engineering, University of Technology Aachen. His main research areas are information oriented process control engineering, process control concepts, object-oriented block technology, process and plant supervision.

Udo Enste graduated from University of Technology Aachen 1995 with a diploma degree in electrical engineering. In 2000 he graduated a PhD degree in process control engineering. Since 2000 he is managing director of the LeiKon GmbH, Germany. He is a member of the German normative committee DKE931 "System aspects of process control systems".

Martin Wollschlaeger graduated from Otto-von-Guericke-University Magdeburg with a diploma degree and a PhD degree in electrical engineering. After spending ten years in academic research on fieldbus systems, in 2000 he joined ifak, Institute for Automation and Communication Magdeburg. His main research areas are the adoption of IT and web technologies in automation systems. He is involved in different national standardisation activities. In 2003, he was appointed as a professor for industrial communications, department of computer science, at Technical University Dresden.

Christian Diedrich graduated from Otto-von-Guericke-University Magdeburg with a diploma degree and a PhD degree in electrical engineering. Since 1992, he is the head of the automation systems' department at ifak. In 2000, he was appointed as a professor for integrated automation at Magdeburg University. His main research areas are fieldbus systems, device profiles and device integration, function blocks and engineering. He is involved in various standardisation activities, including PROFIBUS, DKE, ZVEI. He is convener of IEC SC65C WG7.