Cloud based CANopen system service approach

Heikki Saha, TK Engineering Oy, Pertti Vilenius, Cloudfield Operations Oy

Troubleshooting and configuration management in the assembly and service of distributed control systems has been understood a mission impossible, which partially explains why centralized systems have commonly been used instead. Traditionally used tools in service have been based on tools used in development, not primarily intended for easy and efficient execution of limited set of repetitive service tasks. It has also been challenging to get correct spare parts, configure them and get feedback from the problems in the field.

This paper presents a cloud based service approach, especially designed for the use in assembly line and field service of CANopen systems. Main focus has been in simplifying the tasks to be performed in the field. Effort has also been put on seamless integration of the framework into the standardized design process, in order to guarantee intrinsic availability of correct source information.

Main contribution is in coupling the information into target systems with standardized and widely adopted mechanisms for computer aided identification of the target positions. Each operation may be systematically targeted for correct position, without adding additional components and overloading the service persons. As a result, any service action may be achieved by up to single point and two clicks.

Introduction

Modern control systems are distributed by their nature, meaning that they consist of multiple devices communicating over field buses. There are typically several application programmable devices and the applications shall comply with numerous standards and regulations. Cost efficiency targets have lead into the use of as many instances as possible of as few types of devices as possible [6]. Thus, the adaptation of standard devices into specific locations is performed by assignment of different configurations. Configuration management is required in both design time [4] [6] [9] [10] and during assembly and service operations [11]. This paper focuses on the assembly and service operations.

Traditional way of working with sensors and actuators separately wired into I/O-devices does not fulfill the latest accuracy, dependability and safety requirements [8]. Especially missing standardized configuration mechanisms and device identification services introduce mismatch with the safety requirements. Thus, field bus frameworks, e.g. CANopen, are commonly used.

There is a significant difference in the way of working during assembly and service, between discrete I/O and field bus systems. Devices cannot be just installed or replaced. A proper configuration shall be stored instead. Due to the larger number of adjustable parameters and dependencies between the parameters, manual adjustments based on human readable documents cannot be applied for modern components [4]. Such approach is too prone to human mistakes, is too inefficient and requires too deep professional expertise.

In order to remain in the old technologies, a new, cloud-based system service approach is presented in this paper. The presented approach provides systematic operations in assembly and service and moves the technological ugly details into background in order to keep the operations simple. The approach is also seamlessly connectable to the standard design process, in order to avoid failures in manual operations during transforming design documentation into assembly and service [2].

The paper starts with description of the main service use cases – system analysis, spare part order and configuration download. Analysis and download also apply to the system assembly. Typical problems with current way of working are included. Then, the new approach is presented by starting with some global issues, followed by new implementations of the selected use cases. Finally results are summarized and conclusions set.

System analysis

System analysis is typically one of the first tasks in troubleshooting. Despite of the on-board diagnostics, analyses with off-board tools are required in many practical failure scenarios, when e.g. on-board system does not have full access to the system or when the failure occurs in a random interval. There may be smaller systems, where tight cost target prevents the implementation of comprehensive on-board diagnostics. Also typical users may not be capable of using the on-board diagnostics.

Traditional way of working has some major bottlenecks. The first problem is introduced by the use of discrete I/O – comprehensive diagnostics of discrete I/O needs a lot of additional instrumentation or the most error prone domain – I/O cabling – remains outside of the diagnostics [8]. This tradition has lead into too weak interest for providing off-board analysis tools.

Second problem is the use of proprietary protocols or poorly documented deviations from the standard protocols. Any implementation outside the standards introduces significant problems, because then special skills and knowledge are required but typically detailed enough information and education is not provided.

Third problem is, that standard design process is not followed. Such results additional workload and most often incomplete and continuously outdated analysis setups. As a result, there don‘t exist valid information for analysis, most often preventing the required results from the analyses.

Fourth problem is related to the earlier problems. Poor design tradition has lead into to availability of the human understandable communication description only. Thus service personnel typically have to translate such descriptions by themselves into the machine understandable format, supported by the commonly available tools.

Fifth problem is mainly caused by the fourth problem. Due to the weak interest on the standard protocols and documentation, it is typically not clear enough for service personnel, where to get the correct tools and information packages for analyses.

Sixth problem occurs with commonly available tools, even if the other problems are consistently solved. Typically field bus interface adapters are not harmonized globally. Each company, department or person may have different interface hardware. As a result, a person creating and maintaining the analysis packages may have different hardware setup than one or more analyzing person. Such leads currently into manual interface adjustments, requiring special expertize from actor. Inside a single company it may be possible to harmonize the interface hardware, but even though the selection may need to be changed randomly.

Spare part order

Spare part order is also very critical phase of the field service. Many components are provided from larger warehouses and typical delivery time may vary from couple of hours to one day. As a result, an order of an invalid spare part may easily increase the downtime by one day. Getting an invalid part also overloads the related persons by finding the ordered part invalid for the current location, returning it, finding the correct part number and making a new order.

Traditional way of working has weak points. The first weakness is, that spare part orders are commonly made by component ID-code of the existing part. However, the part existing in the system may be obsolete or even not officially supported, which is common case in the older systems. Thus, it may take many tries and errors to find a correct and valid type of part.

The second weakness appears in the case of invalid or obsolete spare part ID-code. Typically it takes from several days to several weeks to find out an absolutely correct replacement for such part. Typically finding is not enough, the system integrator needs to approve the correct operation by testing one or more part candidates. Successful testing needs a detailed information of the target system and location, which is not included into the ID-code.

The third weakness is the typical order process, which is based on human-to-human communication. It is often unclear, where to order and who are allowed to make orders. Furthermore, part ID-codes are often misspelled in the orders, introducing uncertainty and delay. Sometimes, organizational changes cause problems with changed contact information.

Fourth weakness is related with the delivery of the spare part. Order made as an ID-code does not contain information of possible 2nd sources. As a result, it may not be possible to optimize deliveries based on the availability of compatible components. There may not exist the ordered part in the primary warehouse capable of fastest delivery, but there may exist compatible parts in the other warehouses, from which the delivery may be slightly slower. However, delivery of an existing part is much faster than waiting arrival of the new lot of parts into the primary warehouse before the delivery.

Spare part configuration

Configuration download has traditionally been a significant problem in both assembly line and service. Recognized problems exist in both the parameter set contents [4], information transfer from R&D to assembly [2] and service and simple but reliable download procedure [11]. Many machinery companies are avoiding configuration downloads due to poor or missing process and tools for managing the configuration. Main reason for such seems to be in the history – there have not been standardized configuration interfaces in the old, discrete sensors and actuators.

Traditional way of working – which have been used with discrete sensors and actuators – has several problems. The first problem is, that typically there is no single location for consumers to obtain the data sets. It is mostly because configuration data sets cover all parameter, expecting cross-organizational co-operation [4]. Further consequence is, that due to the lack of single source, there will be various persons having their own parameter sets, each one having almost all problems solved. Moreover, the personal data sets are tuned after meeting a problem and thus always not up to date.

Second problem rises from the poor commitment to the standardized system integration interfaces. When there are devices with various kinds of interfaces, any single tool cannot cover the all components. Furthermore, proprietary interfaces typically cannot be covered by standardized data structures, most often files.

Third problem will be met, when 2nd sources need to be supported. The main requirement is, that each device and corresponding configuration data set shall have machine readable identity, in order to prevent downloads into invalid devices. In safety relevant systems this kind of identification provides a basis for maintaining systems consistent.

The cloud-based approach

Managed information storage, which is accessible everywhere, is the first issue to be solved. Cloud-based approach provides such by its nature. It also solves the responsibility problems – experts of each discipline have a single location for information storage. Also information consumers have a single source for all related information, regardless of the publishers‘ organizational structures, which is in line with availability of some global, open CANopen information [7].

Figure 1: Example sticker with machine understandable reference designator of the actuator position

A simple, reliable, well standardized mechanism – reference designators [12] [13] – is required in order to update certain information in the target systems machine understandable. The use of target position specific reference designators instead of component specific ID-codes enables more abstract addressing of the target positions. Reference designators are widely used in the industry and improving the position plates or stickers, as shown in Figure 1, with machine readability is the only mandatory change, when the proposed approach is compared with the traditional labeling approaches. After such improvement, misspelling and misunderstanding by human beings may be avoided.

Avoiding constraints

Based on the experience, commitment to the standards shall cover each part of the system. The size of the information used in the service may vary. Thus, the use of compressed packages not only simplify handling of multiple files, but also reduce the required network bandwidth. Widely used .ZIP format has been selected to maximize the supported operating systems and applications capable of reading and writing such files [14].

Compatibility is another key factor everywhere. In order to enable automated launch of various tools with corresponding information, target tool information has been included into standard packages. If a known tool indication does not exist, package can be handled just as a generic compressed data. The approach enables easy SW integration with the existing communication applications, e.g. web-browsers.

The use of generic compressed packages together with target tool information enables clear interface with the basic communication and 3rd party applications. Main advantage is, that the same approach may support as well other system integration frameworks than CANopen. The approach also enables flexible use of application or system specific diagnostics applications, when more generic analyzer does not apply for each use case.

In addition to the packet extraction only, compatibility of the tool setups may be improved on-the-fly. E.g. assignment of the physical network interfaces are different among larger number of people. Therefore, a dynamic re-assignment of CAN-channels has been developed for analysis and configuration download. Such feature provides improved interoperability of measurement and download set-ups among large number of users, without a need for special expertise. Constraints depend on the supported interfaces and possible license mechanisms of the tools.

Off-line operations

The most fundamental characteristic of the presented approach is, that all information is continuously up-to-date in the server. Thus, support for off-line actions provides very limited advantages or even null the advantages. Significant obsolescence risk occurs for local copies of distributed information. Synchronization of off-line information afterwards corrupts the timing and location, and weakens timeliness of the field operation status.

Improved analysis

Network analysis has been improved so, that there are predefined measurement set-ups available for the most common analysis tasks. With such arrangement the service person needs just to read the tag of the network and select required task from network specific menu, show in Figure 2. A menu click opens the measurement set-up and turns the measurement active, without additional actions from the user.

Figure 2: Example menu for a CANopen network

The set-ups contain analyzer software set-up, including visualization settings, corresponding communication databases and network interface hardware settings. Dedicated analyzer set-ups may have only the required view types and signals left visible in order to simplify monitoring, as shown in Figure 3.

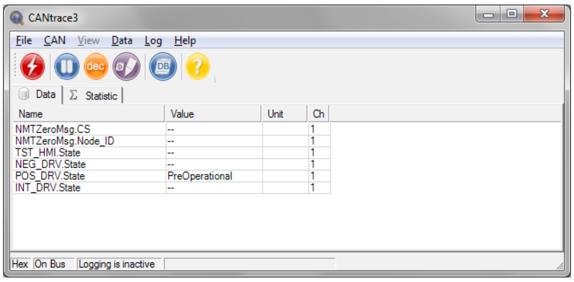

Figure 3: Example analysis setup

Simple views together with automatic activation of measurements enable service persons to focus only to the analysis and troubleshooting, instead of fighting with the tools and tool settings. In addition to the standard analyzer set-ups, system specific, customized monitoring applications [1] [3] may be used without constraints or differences in the way of working.

In the analysis example, interface hardware assignment is dynamically adjusted in the background. Thus, additional manual editing with potential failures due to the availability of different interfaces among the persons, may be avoided.

In the real work, failures still exist sometimes. Therefore, execution status feedback is sent back to the server, in order to provide concise and consistent status and indication, if there exists problems.

Such feedback enables fast repairs of the broken set-ups, without requiring any additional effort from the service persons.

Improved spare part order

As show in Figure 2 and 4, spare part orders are available for the target positions, too. The main idea is, that each spare part will be ordered based on a defined target position, not on the existing device type. Such update in the mindset solves majority of the practical problems with obsolete product codes and existing parts, which are not official spare parts. In the case of missing 2nd information, position information helps the system vendor to find correct parts based on the clear connection to the actual requirements.

Another advantage of using the target location instead of just one product code is, that it enables including information of 2nd sources into the orders. Furthermore, 2nd source information enables improved deliveries, because a single missing item in the warehouse do not necessarily delay the delivery.

Third advantage is, that the spare part identifications in the systems are always valid – only the information of successor devices will be updated in the server from time to time. As a result, regardless of the used components in field, official spare part supply chain will not face unexpected obsolescence problems.
Fourth advantage is, that all detailed spare part information is handled by tools, instead of persons. Thus, all human mistakes, such as misspelling, different languages and pronouncing, decreasing performance and reliability of the orders may be avoided.

Improved configuration download

Machine understandable position information provides several advantages for spare part configuration. The first advantage is, that integration interface used in each position is known and correct download tool may be detected in the server and correct configuration data packet returned. While the approach supports CANopen, support for another integration frameworks may be easily added.

In the case of CANopen, configuration packages are based on the DCF file dedicated for the current position. In addition, in order to provide easy-to-use user interface and streamlined download process, a device figure and a download control file are required. The more up-to-date CANopen implementation exists in the device, the more completed control file can be generated automatically during the design process [2]. DCF-files may be taken directly from the CANopen project.

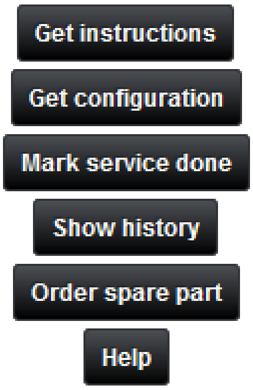

Figure 4: Example menu for an actuator position

There is an intrinsic management of 2nd source devices. The specified files for each alternative device may be just included into the same package and let the download tool to use the ones, which correspond with the device under configuration, presented in Figure 5. 2nd source devices may be systematically included as extensions of a CANopen project [5] providing a solid process from design to the assembly and service [2].
The download process and tools are outside the scope of this paper, but CANopen supports managed process with intrinsic support for verification of the downloaded parameters [11].

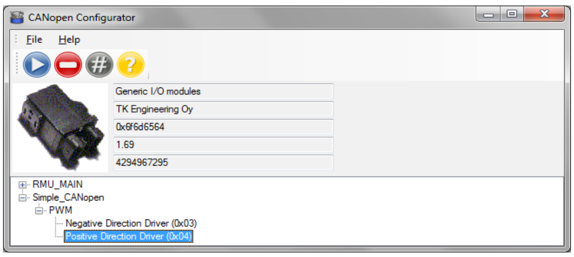

Figure 5: Example target position selection view with only the locations allowed for the device under configuration

Configuration download is a task, where various kinds of failures may exist. Therefore, execution feedback supported by the presented approach is essential. Any problem in the download process may be communicated back to the server, in order to enable fast and reliable repairs of the broken configuration packet, update tool license, provide a correct type of interface hardware, send more detailed instruction for the user, etc.

20.08.2015, 11:34:06
System: **DemoSyst**
Position: **Y1000A**

Date	Time	Lat	Long	User	Action
20.08.2015	10:12:21	60.162903°N	24.942100°E	TestUser	'Download completed'
20.08.2015	10:10:37	60.162903°N	24.942100°E	TestUser	'Download started'
20.08.2015	10:10:32	60.162903°N	24.942100°E	TestUser	'Get configuration'
20.08.2015	10:10:08	60.162903°N	24.942100°E	TestUser	

Figure 6: Successful operation in a history of an example actuator position

20.08.2015, 11:54:18
System: **DemoSyst**
Position: **Y1000A**

Date	Time	Lat	Long	User	Action
20.08.2015	10:24:48	60.162903°N	24.942100°E	TestUser	'Download failed'
20.08.2015	10:21:03	60.162903°N	24.942100°E	TestUser	'Download started'
20.08.2015	10:20:51	60.162903°N	24.942100°E	TestUser	'Get configuration'
20.08.2015	10:20:38	60.162903°N	24.942100°E	TestUser	

Figure 7: Failed operation in a history of an example actuator position

An example position history view is presented in Figure 6, where dedicated entries exist for start of the configuration packet download – ‚Get configuration', completed download and start of a download tool – ‚Download started' and successfully completed download transaction – ‚Download completed'. Figure 7 includes an example of a failure, where the root cause can be easily detected, based on the phase of the workflow, where the failure occurs.

Main advantage is, that the status is automatically updated into server and service persons don't need to care and put effort on reporting. Based on such accurate history of the action performed by authorized organization, it is trivial to review, whether the system safety integrity level is maintained or not. For such review, some features not related with CANopen are required, but such are not within the scope of this paper.

Discussion

The core of the presented approach is an intrinsic support for simple, point a tag and click a menu based operation principle. Such user interface is easy to use with any kind of terminal device and by any kind of person. Main advantage of target location information tagging to the system itself is, that users do not need to enter manually such information and take care of correct format of abstract identifiers. Further advantage is, that a separate login is not required after registration of the user. Such mechanisms enable the use of the approach as an integral part of the process, instead as just another software tool.

In the best case the status information indicates successful progress and completion of operations. Failed actions before successful action may indicate missing training of the service persons.

Furthermore, detailed information of the customers, persons, systems, positions and locations will reveal many interesting bottlenecks in the service process and background information regarding spare part consumption.

While improved analysis, spare part order and configuration of CANopen systems and components have been presented, the approach provides an intrinsic support for any other, field bus based, system integration framework. Analysis may also cover electrics, if e.g. USB oscilloscope with corresponding application is available. Spare part order does not have any constraints, it has an intrinsic support for any kind of components, down to nuts and bolts.

Conclusions

A cloud based service approach was presented by using CANopen systems as example environment. Cloud based operation principle ensures, that both service information and feedback are continuously up-to-date. While CANopen was used as an example target technology, the approach does not limit the network technology. Any kind of network technology may be supported as long as corresponding tools are available.

Majority of the problems caused by traditional way of working, based on manual operations and human understandable documents, have been solved. The presented approach is based on machine understandable tags holding easy-to-use location information and automated information distribution and 3rd party tool management, enabling service persons may concentrate on the primary service actions, instead of fighting with the tools, tool set-ups and documents.

However, there exist a pre-requisite for consistent information from the design departments. If the information is not consistent, the presented approach provides help for improving the information consistency by extensive feedback information. Main advantage regarding the feedback information is, that it is continuously collected by the tools, without a need for writing manual reports etc.

The first pilots with CANopen – which is comprehensively standardized system integration framework including management process, device-, tool- and service ecosystem – has proved, that complexity in the service information management may be significantly reduced by commitment to the standardized technologies. It was also recognized, that service oriented tool may also improve the installation and troubleshooting activities in assembly lines.

Further development in the near future will concentrate on the improvement of information logistics from design into assembly line and field service. Configuration packets are already automatically generated from corresponding CANopen design projects, but measurement set-up creation from the projects shall be implemented. There are also demand for other network technologies, supplementary for CANopen.

Dr. Heikki Saha
TK Engineering Oy
Yrittäjänkatu 17
FI-65380 Vaasa
Tel. +358 50 588 6894
heikki.saha@tke.fi
www.tke.fi

Pertti Vilenius
Cloudfield Operations Oy Ab
Yrittäjänkatu 17
FI-65380 Vaasa
Tel. +358 45 801 7424
pertti.vilenius@cloudfield.fi
www.cloudfield.fi

References

[1] Helminen M., Salonen J., Saha H., Nykänen O., Koskinen K.T., Ranta P., Pohjolainen S., A new method and format for describing CANopen system topologies, Proceedings of the 13th iCC, CiA, 2012
[2] Saha H., Accelerated transfer of CANopen projects into assembly and service, CAN-Newsletter 4/2012, CiA, 2012, pp. 16-20
[3] Saha H., Exception management in CANopen systems, CAN-Newsletter 2/3013, CiA, 2013, pp. 12-17
[4] Saha H., CANopen device configuration editors, CAN-Newsletter 4/2013, CiA, 2013, pp. 30-33
[5] Saha H., Optional structures in CANopen projects, CAN-Newsletter 1/2014, CiA, 2014, pp. 32-35
[6] Saha H., Systematic re-use of information, CAN-Newsletter 2/2014, CiA, 2014, pp. 20-25
[7] Saha H., CANopen in the frontline of open data, CAN-Newsletter 3/2014, CiA, 2014, pp. 42-45
[8] Hietikko M., Malm T., Saha H., Comparing performance level estimation of safety functions in three distributed structures, Journal of Reliability Engineering and System Safety, issue 134, Elsevier, 2015, pp. 218-229
[9] Saha H., Model-based design of distributed mechatronic systems, CAN-Newsletter 4/2014, CiA, 2014, pp. 38-45
[10] Saha H., Improved management of CANopen-based distributed control systems, Proceedings of the 2nd MMC, CiA, 2015, pp.
[11] Saha H., CANopen in series production, CAN-Newsletter 3/2015, CiA, 2015, pp. 8 -11
[12] Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules, IEC 81346-1, IEC, 85p.
[13] Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 2: Classification of objects and codes for classes, IEC 81346-2, IEC, 45 p.
[14] ZIP (file format), https://en.wikipedia.org/wiki/Zip_%28file_format%29, Referenced at 24.08.2015