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WORLDWIDE COMPONENT BASED AUTOMATION SYSTEMS ON PROFINET CBA NETWORK EXAMPLE

Summary. This article presents general concept of component based automation systems built with usage the Internet connection. The communication mechanism of PROFINET CBA network and example of worldwide component based automation system are presented. Authors are aware that because of non-deterministic character of the Internet network it cannot be consider as a control mechanism but their goal is to show that it is possible to provide visualization and other higher-level functions using PROFINET CBA network connected through the Internet.

Keywords: industrial networks, component based automation systems, PROFINET CBA, Internet

BAZUJĄCY NA KOMPONENTACH SILNIE ROZPROSZONY SYSTEM AUTOMATYKI PRZEMYSŁOWEJ OPARTY NA SIECI PROFINET CBA

Streszczenie. Niniejszy artykuł prezentuje koncepcję komponentowych systemów automatyki przemysłowej tworzonych z wykorzystaniem sieci Internet. Zaprezentowano mechanizmy komunikacyjne sieci PROFINET CBA oraz przedstawiono praktyczny przykład zastosowania tej sieci do stworzenia rozległego systemu automatyki bazującego na komponentach. Ze względu na niedeterministyczny charakter sieci Internet zastosowania sieci PROFINET rozpatrywano w kontekście systemów wizualizacji i innych funkcji wyższego poziomu występujących w systemach informatyki przemysłowej.

Słowa kluczowe: sieci przemysłowe, systemy automatyki bazujące na komponentach, PROFINET CBA, Internet

1. Component based automation systems

In the past, the structure of production systems was centrally orientated. This means, we had one control center and all field devices transferred their data through the communication systems.

With the development of microelectronic technology in the last years, prices of memory went down and computational power increased a great deal. This has enabled us to improve the field devices which have now a greater level of intelligence.

The device intelligence is now the controller or processor and memory. It is therefore self-sufficient to calculate the process data and implement extended functions, for instance, diagnosis. The field devices can process their own data so that the central control unit is no longer necessary and now there is a distributed control system instead. Thus, there are more and more functions in the field devices and, in addition, possibility of more complex ones, which brings us to the new problem, how to control the large variety of functionality when planning the new plants.

One way of solving this problem would be to use technological modules which would include all necessary hardware, software and electronics so that the field devices would work autonomously in a particular task in the factory.

In order to use this solution in designing the whole plant, we must define all necessary connections between components and data that would be transferred by them (fig. 1) [9]. The benefit is that the components can work autonomously and therefore be made and tested without the rest of the plant. What is needed for combining such components into a system is a specification of the interface between them and tools which support that design process.

The interface specification for those components was made by the Profibus International Organization which has more than a 1300 member companies around the world. According to this specification, called PROFINET CBA, every producer of a technological component, when building his component with whatever hardware, software and electronics, will be able to test the functionality before delivery but must describe his component in the form of a specified XML description. Some system providers, for instance Siemens, have already integrated a function for automatically generating such descriptions in their development tools.

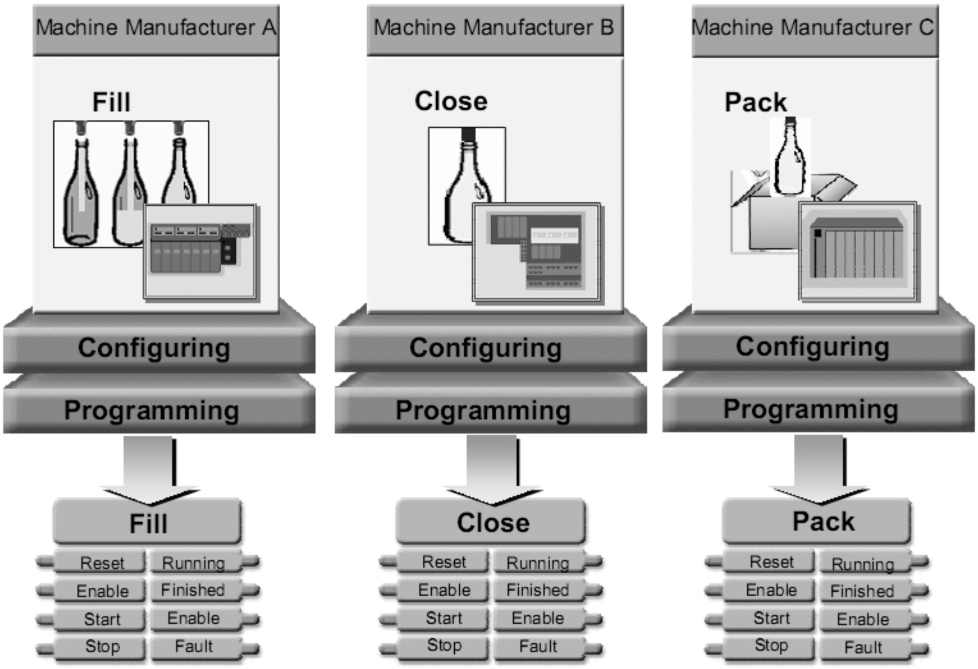

Fig. 1. Creating automation components for plant
Rys. 1. Tworzenie komponentowego systemu automatyki

Working with CBA consists of two phases. First we have to create the components with engineering tools from the provider of control systems or devices, for instance SIMATIC STEP 7, and then we can use the components to configure the whole plant. For this task we need a configuration tool, for instance SIMATIC iMap. In this step all descriptions of the components for the plant can be imported into the plant configuration tool and will be stored in the component's library. From there, the components are put on the graphical plant area where they will be configured. The described as XML file interface will be shown as graphical object and the outputs from this interface can be connected with inputs from other components.

After the system's configuration, the communications' relations will be downloaded onto the real components and then the system can start running. The configuration tool is not necessary during the runtime, but nevertheless, there is a possibility to leave the tool online to show the information about the running system. The defined communications' relations can be used to show graphically states of the connections and the components. It is possible to see in the component view the diagnostic information about the components and the connections and, in the network view, the information about the devices and networks.

2. The PROFINET CBA network

Automation system realized on PROFINET CBA base enables creation of large size component based automation systems made from parts delivered by different producers. Based on the DCOM model, the PROFINET CBA interface allows concealment of the internal structure of co-operating devices. The PROFINET CBA nodes exchange data and synchronization information using the input and output signals. The functional description of CBA component is delivered by its manufacturer, however detailed information describing the communication interface is delivered in the GSD file (GSD – German acronym roughly translated to Device Specification). The net of connections between distributed components of industrial automation systems based on the PROFINET CBA standard is created in the engineering phase of the project [6]. The particular CBA component model is presented on figure 2 [9].

Following objects come into this composition: Physical Device responsible for the access to the network transport, Logical Device responsible for outside automation component of interface presentation, RT-Auto responsible for the proper functionality of the component, and ACCO (Active Control Component Object) assuring the information exchange in the time of polling the devices. Co-operating with each other ACCO objects are responsible translation of logical connections into the real exchange of information among components.

Every ACCO object acts as the information producer and makes its own data accessible and acts as the information consumer as well. ACCO takes necessary input data from other components and delivers them its output data (figure 3) [9]. All data exchange parameters depend on the static structure of the automation system prepared while designing and configuring phase.

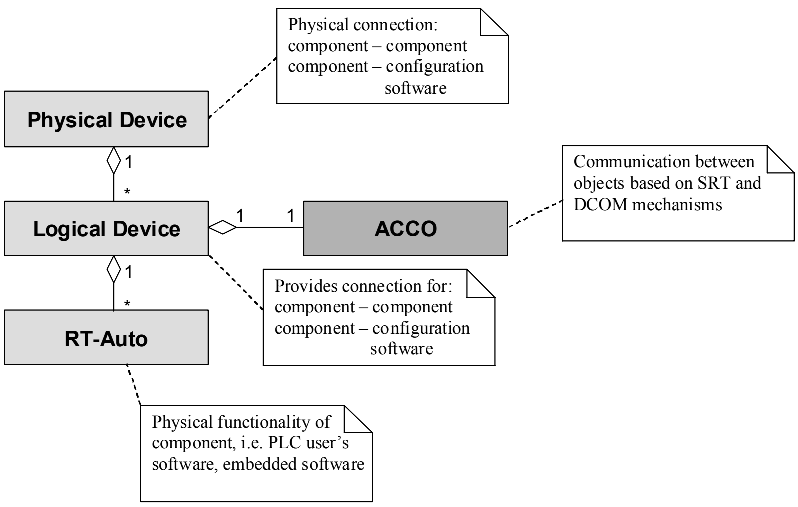

Fig. 2. Internal structure of automation component
Rys. 2. Wewnętrzna struktura komponentu

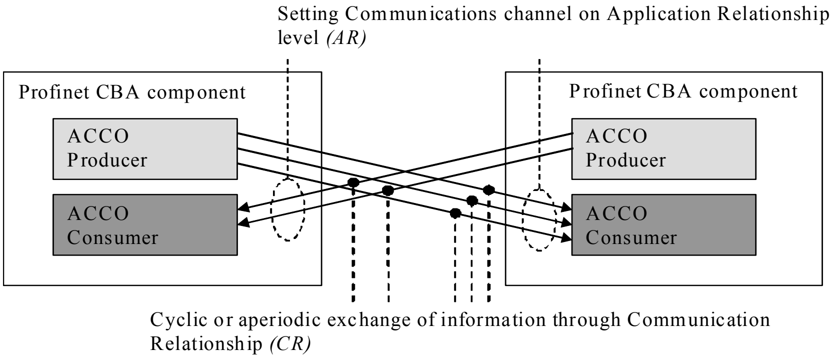

Fig. 3. PROFINET CBA communication model
Rys. 3. Model komunikacyjny w sieci PROFINET CBA

Connection between two automation components is defined as Application Relationship (AR). It consists of independent data exchanges produced and consumed by ACCO object. Particular exchange definition is called Communication Relationship (CR). Communication exchanges can be defined as aperiodic CR for example alarms and events with high priority, or as periodic CR for cyclic transmission among components. Both types of exchanges can be realized as non-deterministic transmissions based on TCP/IP protocol, as well as soft real-time transmissions based on specialized RT-Ethernet protocol.

From the point of view of treated problem second transmission mode is not analyzed in this paper. It requires specialized hardware with support for IEEE1588 precise time synchronization protocol and cannot be used in Internet. In the described experiment network automation system components are connected using DCOM standard, based on RPC connections and TCP protocol.

Communication procedure begins from logical communication channel AR setup. For decrease of occupied communication bandwidth, messages among components are exchanged in case of significant data change only. The deadband for each CR is fixed during system configuration phase. Such manner of communication procedure forces additional communication correctness control link. Additional control link is made possible by QoS service. Producer sends simple ping signals in the case of no actual data for a given period. Ping period depends on quality factor defined for each CR channel and is a factor of exchange period defined for given CR channel and QoS factor. Control of link correctness is optimized at the AR level of communication channel. It means that all CRs inside AR use common testing procedure. When needed pings were made between CRs to obtain results. Consumers know communication period for given CR and control the period of incoming information (actual data or ping signals) sent from information producer. In the case of communications delay longer that defined by QoS parameter, error information is produced [9].

This communication protocol assures data delivery with time limitations defined at the CR level. Data confirmation from the consumer level in case of new transmission is ping control signal, or error is generated in case of outreaching of time defined for QoS mechanism communication.

3. The practical example of worldwide component based automation system

Purpose of testing was to prove that there is a possibility to connect PROFINET CBA components through the Internet in easy and reliable way. There were 2 problems: Is it possible to have communication between CBA components through the Internet? How to evaluate connection quality?

It is possible to find many articles which describe PROFINET CBA as closed, local system, based on Microsoft services, unfit to use though the Internet [1, 2]. This is not the whole true.

Communication in PROFINET CBA consists of 2 parts: real-time inside component (deterministic field networks) and non real-time one for connecting to the outside components (based on RPC, DCOM and TCP). It is obvious that not-real-time systems cannot be used for control task but they can be used for collecting information for the next level of management – Manufacturing Execution System (MES). In our research 3 CBA components called nodes were used. They were placed at the Silesian University of Technology in Gliwice (Siemens S7-300), the Fachhochshule in Ingolstadt (Siemens S7-300) and the Høgskulen i Sogn og Fjordane in Førde (simulation software).

First objective was to find the best way to connect 3 'safely closed' CBA components. Normally PROFINET CBA uses RPC and DCOM/TCP network, but this kind of connection requires an external IP address for every component in CBA network, which cannot provide any kind of security for our network. The easiest way to connect safely nodes is to use dedicated network equipment for example Siemens Scalance S firewall. Those devices can create VPN secure connection through the Internet providing best connections parameters. However it requires one additional device in each node, which is too expensive in many cases and disturbs already fixed network with additional firewall just to secure one device.

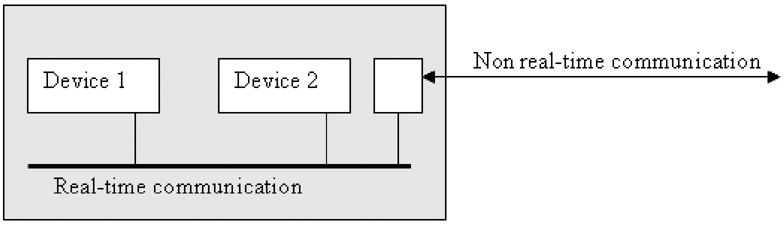

Fig. 4. Structure of PROFINET CBA component
Rys. 4. Struktura komponentu sieci PROFINET CBA

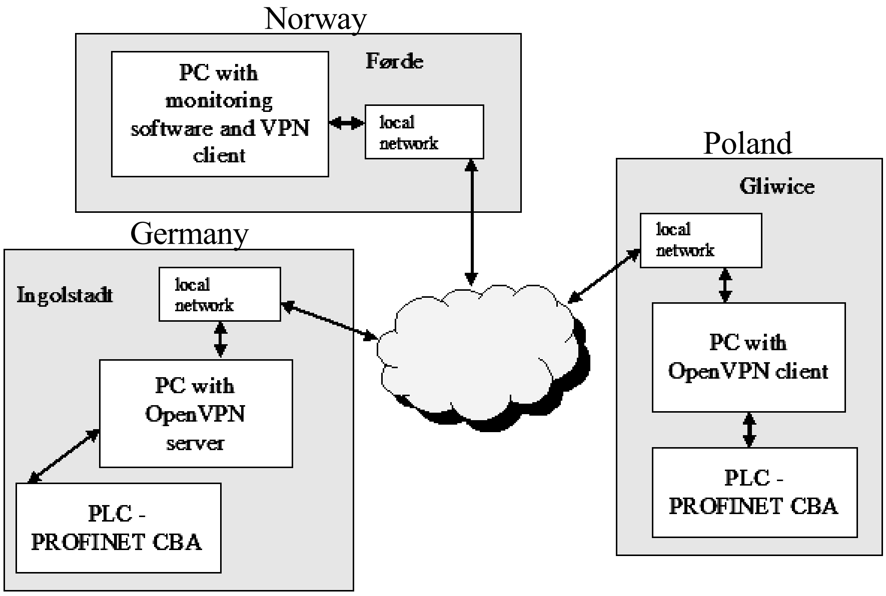

Fig. 5. Structure of PROFINET CBA test system
Rys. 5. Struktura testowanego systemu

Purpose of testing was to prove that there is a possibility to connect PROFINET CBA components through the Internet in easy and reliable way. There were 2 problems: Is it possible to have communication between CBA components through the Internet? How to evaluate connection quality?

Different approach uses software VPN tunneling which has the same advantages of hardware solutions like Siemens Scalance and has none of its flaws. Using this solution does not require additional external address for computer with this software but only one forwarded port (TCP or UDP) for tunneling DCOM protocol used by CBA network [3, 4]. We decided to use wide known and configurable OpenVPN software which allowed us to provide security using public key infrastructure (known as PKI).

Test system is presented on Fig. 5. First test relied on cyclically sending ‘presence’ bit. Each of PLC reads one bit, inverts and sends back. Aim of testing was to find how many frames were transmitted and received correctly and how long time it took this. Watchdog was set to 10s. If there is no frame in this period, it is consider as an error in the transmission. Accuracy of time measurement is 100ms.

Transmissions cycle was set to 500ms (minimum in iMAP configuration software if original SIEMENS equipment isn't used) and 1000ms. Results of 12 (2 times of 6 hour) hour test shows that during transmission of 84360 frames only 303 were lost. It gives 0.36% error. 3 times a long break in transmission occurred the longest of them took 40 second. When we switched from heavy-loaded low quality DSL connection on German side to high quality university connection all of the breaks in communication were gone.

It is noticeable that almost all of transmissions needed up to 500 ms for transfer. It is independent of daytime (night, day) and place (Poland, Germany, Norway).

Next thing to check was dependence between amount of transferred data and quality of transmission (delay). Both of PLCs have exchange cycle time set to 500 ms. During the tests 1 bit, 10 bits, 100 bits and 500 bits were sent between Poland and Germany.

Exchanged data in PROFINET CBA is sent with standard Ethernet frames without any fragmentation, therefore maximum amount of data to be exchanged in one cycle of this network is 1400 bits.

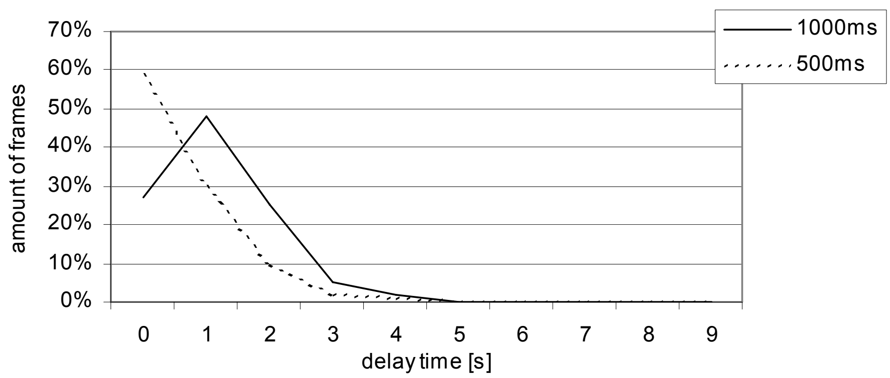

Fig. 6. Average time for transmission of frame
Rys. 6. Średni czas transmisji ramki

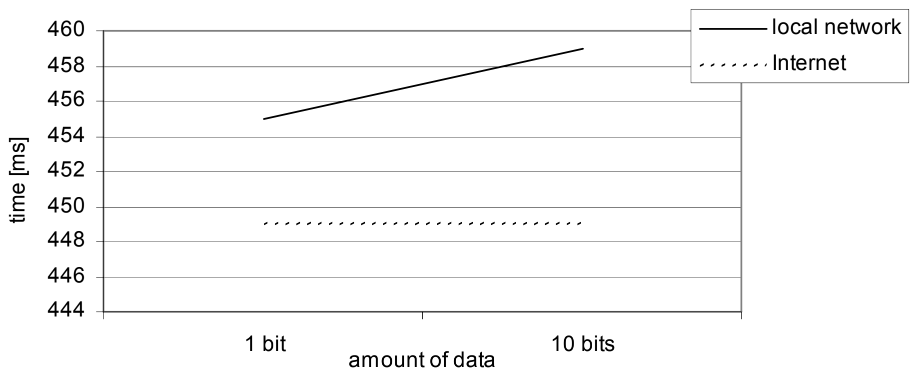

Fig. 7. Delay in transmission
Rys. 7. Opóźnienie transmisji

In next experiment we tried to research difference between local network and internet. It is interesting to compare not only average times but standard deviation

It looks like in local network larger difference in sending time exist. Sometimes it takes much more and sometimes much less time.

4. Conclusions

To establish connection we used tunneling of DCOM protocol. All of the operations that provide security, including encoding and decoding packets made the data transfer slower. Despite this fact, it was possible to evaluate utilization of PROFINET CBA in the Internet as entirely suitable.

All communications outside CBA component is nearly 1000 times slower than inside component. It is result of "structure" of PROFINET CBA network. Real-time exchange is necessary inside – to time critical processes. External communication was limitted to on critical transmission – set parameters or read status. Such approach can be used only to collect information for next level of management – MES systems. Our experiment has proven that it is possible to use connection of PROFINET CBA in the Internet. It is not the fastest communication but it fits this purpose.

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Omówienie

Bazujące na komponentach systemy automatyki przemysłowej umożliwiają dekompozycję funkcjonalną przemysłowego systemu sterowania i jego syntezę za pomocą komponentów składowych dostarczanych przez różnych dostawców (1). Model komunikacyjny stosowany w sieci PROFINET CBA (2, 3, 4) umożliwia tworzenie komponentowych systemów automatyki połączonych za pomocą otwartych rozwiązań komunikacyjnych, istnieje także możliwość wykorzystania jako medium komunikacyjnego sieci Internet. W artykule przedstawiono przykład bazującego na komponentach systemu automatyki, w którym wykorzystano sieć Internet (5). Ze względu na niedeterministyczny charakter tej sieci zastosowania skonstruowanego na bazie PROFINET CBA systemu połączeń pomiędzy komponentami rozpatrywano w kontekście systemów wizualizacji i innych funkcji wyższego poziomu, występujących w systemach informatyki przemysłowej. Dla zaproponowanego przykładu przeprowadzono eksperymentalny pomiar średniego czasu transmisji sygnałów sterujących (6) i pomiary opóźnienia (7). Wyniki eksperymentu wskazują z jednej strony, że zmierzone parametry sieci są znacznie gorsze od analogicznych wartości wykorzystywanych w lokalnych systemach sterowania bazujących na sieci PROFINET CBA. Z drugiej strony, wyniki badań doświadczalnych potwierdzają możliwość zastosowania sieci Internet w bazujących na komponentach, silnie rozproszonych systemach automatyki przemysłowej, ze szczególnym uwzględnieniem systemów wizualizacji i komunikacji z systemami nadrzędnymi.

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