CZECH TECHNICAL UNIVERSITY

BACHELOR THESIS

Integration of IEC 61499 with OPC UA

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in the

December 7, 2015

Declaration of Authorship

I, Slavomír K, declare that this thesis titled, "Integration of IEC 61499 with OPC UA" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Date:

"Thanks to my solid academic training, today I can write hundreds of words on virtually any topic without possessing a shred of information, which is how I got a good job in journalism."

Dave Barry

CZECH TECHNICAL UNIVERSITY

Abstract

Faculty of Electrical Engineering

Bachelor

Integration of IEC 61499 with OPC UA

by Slavomír K

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too…

Acknowledgements

The acknowledgments and the people to thank go here, don't forget to include your project advisor…

Contents

List of Figures

List of Tables

List of Abbreviations

LAH	**L**ist **A**bbreviations **H**ere
WSF	**W**hat (it) **S**tands **F**or

Physical Constants

Speed of Light $c_0 = 2.997\,924\,58 \times 10^8\,\mathrm{m\,s^{-1}}$ (exact)

List of Symbols

a	distance	m
P	power	W ($\mathrm{J\,s^{-1}}$)
ω	angular frequency	rad

For/Dedicated to/To my…

Chapter 1

Introduction

Automation, controlling and regulation are the most interesting topics for me. Always only in amateur and hobby level, because of rigidity and inflexibility of industrial tools and programming languages. While in the other sectors of IT terms like a object oriented access and code re-usability are matter of course, in industry theese are just topics of future.

When i came across this theme topic about industrial standards of close future it realized it can be very rewarding. This topic is about integration of two standards which goal is to delegate ideas of commerce IT sector to industry.

1.1 Industry 4.0

Nowadays we are standing in the time, when the fourth industrial revolutions starts.Every one of these revolutions were caused by technological improvements. First one was caused by change from labor work to mechanization. Second one was started by electrification, in this revolution electric machines were used instead of steam based motors. Third revolution was the last one, and was caused by digitization and invention of logical circuits. When we realize how much did the computers evolved it's logical that also industry has to pass another revolution. Upcoming revolution is caused by introducting Internet of Things into industry. Brettel et al., 2014

Term Industry 4.0 was first used at the Hanover Fair in 2011, and nowadays is currently prevalent in almost every industry-related fair, conference, or call for public-funded projects. Drath and Horch, 2014 This term describes project of German government aim of which is creating intelligent factories using interconnecting of manufacturing systems into Internet of Things.

1.2 Aim of thesis

Aim of this thesis is to integrate OPC UA communication protocol into system 4DIAC - controlling framework based on IEC 61499 standard.

Controll system created in 4DIAC framework is composed of function blocks, my task is implement communication stack inside of function blocks. Including client and also server.

OPC UA protocol allows user to create topologically ordered web of data. My task is also to create data topology on server based on a structure of control system based on a 4DIAC framework. By integration of these two technologies I create a system in which all elements of distributed control

system could load structure and status of every other element using OPC UA protocol.

1.3 Chapters overview

In following second chapter my aim is to introduce you a IEC 61499 standard and 4DIAC framework based on this standard. I am going to show basic principles of this framework as creating application, function blocks, deploying applications. Important part of using 4DIAC framework is compiling of your own version of 4DIAC runtime environment dedicated for your device. To this topic is dedicated whole section. Another section of this chapeter will be dedicated to compiling and runnig 4DIAC runtime on raspberry pi.

Third chapter is dedicated to communication protocol OPC UA, ways of using this protovol and its information model. I am going to mention stacks based on OPC UA protocol. I am focusing on OPEN 62541 stack, which i have choosen to use in this thesis.

In fourth chapter I am explaining my solution of problem explained in the previous sections of this chapter. Also I am describing example application to work with OPC UA in 4DIAC.

Chapter 2

4DIAC

2.1 IEC 61499

Standard IEC 61499 servers reference architecture for distributed, and modular control systems.

This standard specifies an architectural model for industrial distributed regulation systems. It extends its predecessor IEC 61131-3 with additional event handling mechanisms.Strasser et al., 2008

When comparing IEC 61131-3 and IEC 61499 the biggest difference is in the system of functions execution. While in IEC 61131-3 function was triggered by cyclic execution, the IEC 61499 came with the event driven execution.

Cyclic execution was problem that does not allow mass using of IEC 61131-3 in distributed systems. This type of execution is reliant to the system clock. This approach is not problematic in the scope of one device system. However in system with multiple devices there is a problem of sharing the system time. It is practically impossible to run this kind of system synchronously. In case of cyclic execution every 1ms and not precise synchronous system it can take up to 1ms to handle any kind of change. In some kind of applications this time delay can lead to the destruction of product, machine or even whole manufacturing system. This problem can be solved by decreasing time between two executions. However this solution of delay problem is causing need of huge bandwidth for data transfer. It leads to cost of data transport layer increase and also scale up data transfer error rate possibility.

In IEC 61499 standard this problem was solved by changing cyclic to event driven execution. Function Blocks are not executed cyclically, but are triggered by event. This solution prevents problem with central time and its sharing and caused also rapid decrease of needed bandwidth. In this approach the data are transferred only when event is triggered. For example function block handling the end switch of machine does not have to propagate its state every 1ms like in the previous example. It propagates its state only when change state event occurs.

There is no support in IEC 61499 for cyclic execution anymore, but for purposes of back compatibility there is a solution of implementing IEC 61131 function into IEC 61499 system. The situation of a program is simply depicted by triggering of cyclic execution by use of an E_CYCLE FB.Sunder et al., 2008

2.2 4DIAC

Current there exist only a few different implementations of the IEC 61499 reference model. Strasser et al., 2008

This could be also because of weak definition of execution model and event inside function blocks network scheduling.

The other reason for slow take up of the standard by industry is that the IEC 61499 standard is now mainly used in research work by various research and university institutes. Strasser et al., 2008 These research groups around the world apply to FBDK/FBRT Java implementation from HOLOBLOC Inc.

Aim of 4DIAC initiative is to create an open-source framework based on IEC 61499 standard which will provide reference implementation of execution model for IEC 61499. 4DIAC initiative is currently developing two projects IEC 61499 compliant :

- FORTE - runtime environment
- 4DIAC-IDE - engineering tool

To work with 4DIAC framework you have to use both of this parts.

2.2.1 Installation of 4DIAC-IDE

The installation of 4DIAC-IDE is independent from the used operating system. In order to run 4DIAC-IDE you require Java 1.7 SDK or later, whereas it is currently NOT recommended to use Java 8.

To install 4DIAC-IDE you simply download the latest version for your operating system from https://eclipse.org/4diac/. Unzip it to any desired folder and start the 4DIAC-IDE. It already contains a function block library, some sample applications and also pre-build versions of FORTE. If you only want to use available Function Blocks you are ready to go.

Building your own 4DIAC-IDE from source: Running 4DIAC-IDE from source has the great advantage that you can easily keep up with the developments performed in the Mercurial repository. In case you want to run 4DIAC-IDE from source follow the Installation steps at https://eclipse.org/4diac/documentation/hel

2.2.2 FORTE compilation

For conducting first experiments with 4DIAC you can use the pre-build version of FORTE which comes along in the runtimes directory of the 4DIAC-IDE package. However if you want to develop your own Function Blocks or you want to run FORTE on different control devices you have to download and build FORTE from source.

The compiling and debugging of FORTE consists of few steps:

Download source code You can download the latest Version of FORTE on http://www.eclipse.org/4diac/. Extract the file into your desired working directory. You can also use Mercurial Hg like TortoiseHG to get FORTE from http://hg.code.sf.net/p/fordiac/forte.

Prepare compilation and linking tools In case you want to create own function blocks, or edit existing one you are going to compile your own version of FORTE. According to your operating system, you have several

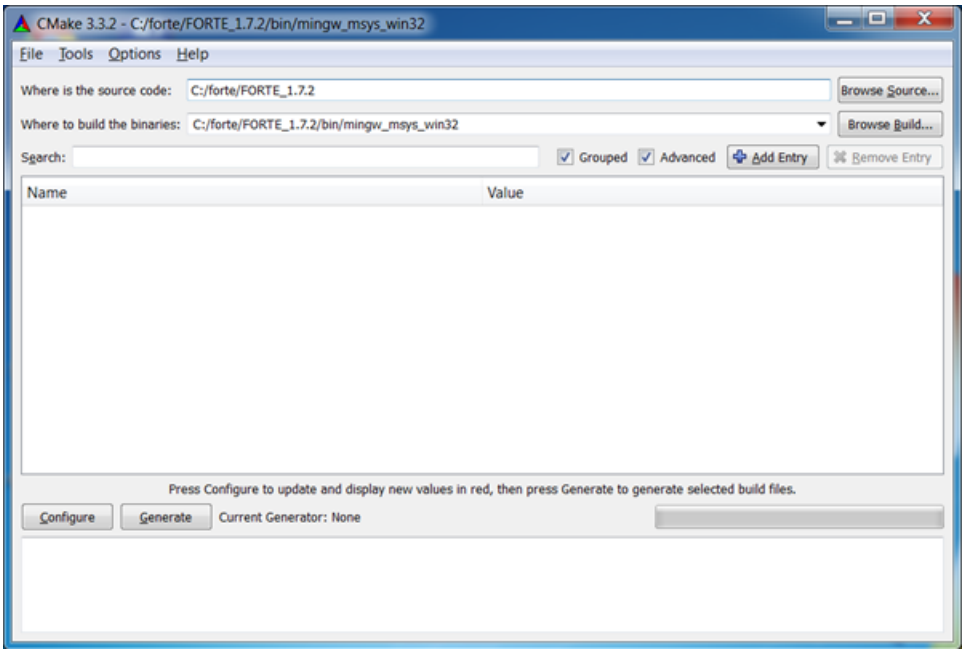

FIGURE 2.1: Selection of source data and output folder

options to choose. In Linux – like systems required packages to compile are:

- binutils
- gcc
- gdb
- make

In case you are Mac user you can compile FORTE in X-Code. Compiling on Windows is most complicated. There are few possibilities:

- Compiling and Debbugging FORTE with MS Visual Studio Express
- Compiling using Cygwin
- Compiling using MinGW – I have used this option. Whole subsection is dedicated to this option

CMake for generating the make file

CMake helps you to configure FORTE for compilation with your desired development environment or hardware device. For starters we recommend to use the GUI tool that comes with CMake.

When starting the CMake-GUI you have to select the source directory, which is the main FORTE directory and the bin directory (e.g.FORTE/bin/posix) which is the output directory. There CMake will put the build project files (e.g., the makefiles) as well as any configuration data.

After that you will need to press the configuration button. A window will pop up that lets you select the kind of project you like to build. In this step you have to have installed compillers. Select MSYS Makefiles as the generator for this project.

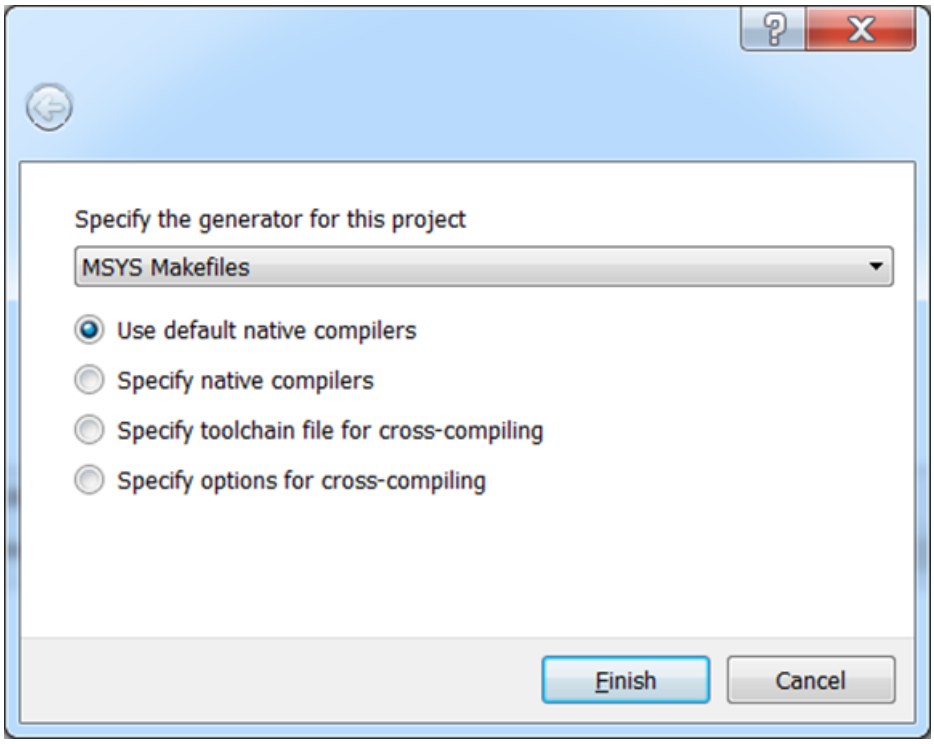

FIGURE 2.2: Specifing the generator

Windows	**POSIX**
FORTE_ARCHITECTURE_WIN32	FORTE_ARCHITECTURE_POSIX
FORTE_MODULE_CONVERT	FORTE_MODULE_CONVERT
FORTE_MODULE_IEC61131	FORTE_MODULE_IEC61131
FORTE_MODULE_OPC_UA	FORTE_MODULE_OPC_UA
FORTE_MODULE_Test	FORTE_MODULE_Test
FORTE_MODULE_UTILS	FORTE_MODULE_UTILS
FORTE_SUPPORT_MONITORING	FORTE_SUPPORT_MONITORING

For the correct Project Setting please have a look at the next step. In the CMake main window a list of red marked options will appear. These options allow you to configure your FORTE build. The minimal configuration you have to perform is to select the architecture you like to build for (e.g., FORTE_ARCHITECTURE to POSIX / WIN32) and the modules with the function block libraries you like to use. You should also keep FORTE_SUPPORT_MONITORING enabled for Debugging and FB-Testing.

Then you need to press again the configure button and depending on your selection in the previous step new options (marked in red) may appear. Press configure until no new options are appearing and then the generate button for generating the project files.

After that you can start the build process.

Configuration of CMake for different OS:

IDE to work with the FORTE code You can use different development Environments, whereas the C++ Compiler you can use to build FORTE not only depends on this environment but also on your operating system. For

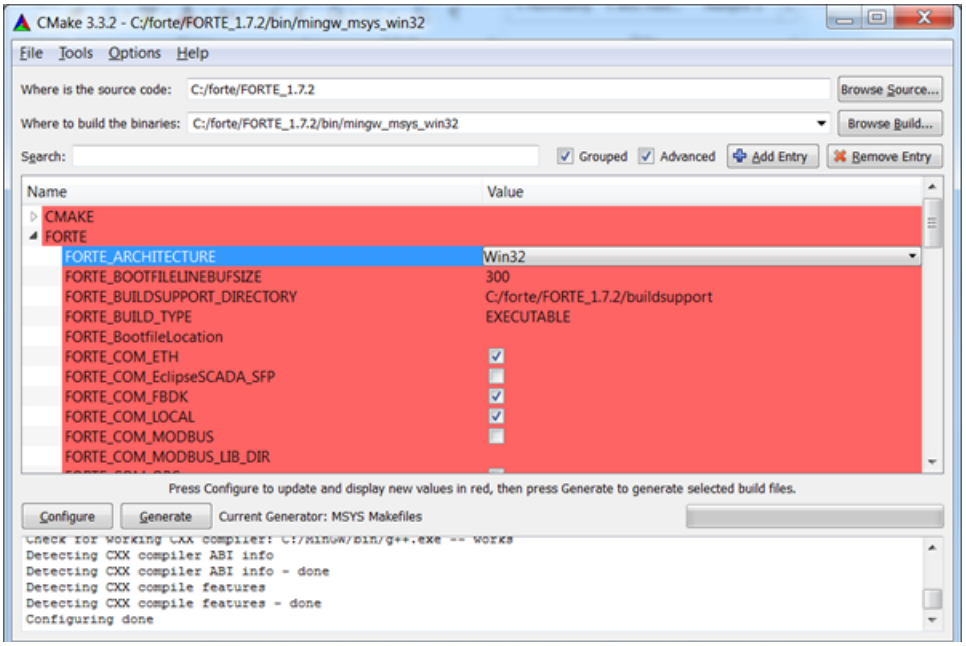

FIGURE 2.3: Configuring architecture of compilled FORTE

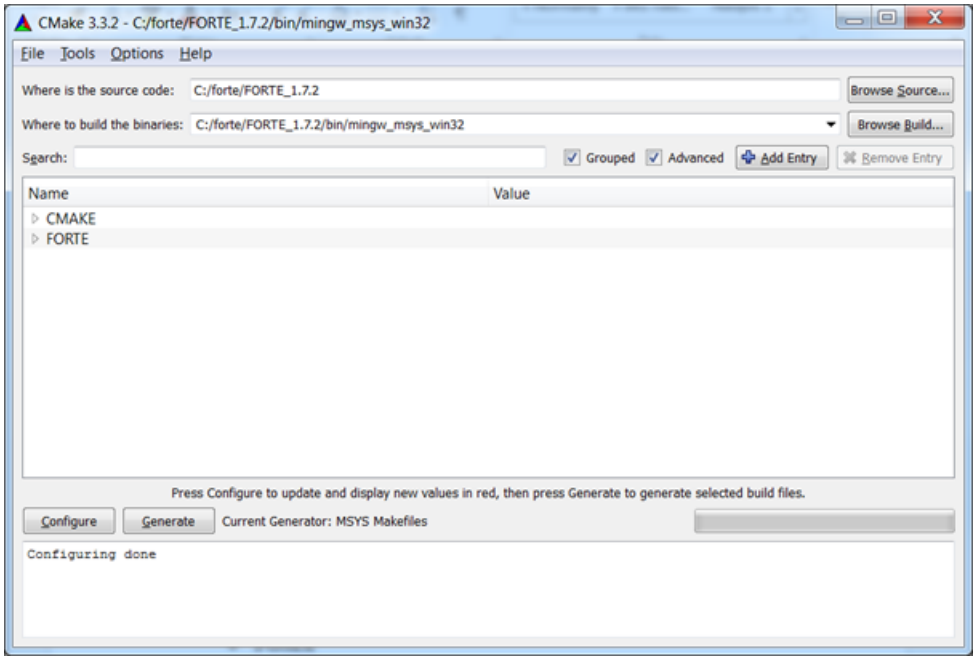

FIGURE 2.4: Configuration done.

compiling FORTE under Windows you can use either Visual Studio (Express or full edition) or Eclipse. When using Eclipse for development and debugging under Windows you will need to use a Posix emulation environment like cygwin or minGW.

- Compiling and Debugging FORTE with MS Visual Studio Express
- Compiling and Debugging FORTE with Eclipse
- Compiling and Debugging FORTE with CodeBlocks

For the development with FORTE the understanding of the general file structure is helpful. Therefore the essential parts as well as the Makefiles which are important for the configuration and compilation of FORTE are listed in the following:

- *src/modules* this folder contains the source code (cpp, h) of all Function Blocks available for FORTE
- *bin/<yourSystem>/src* contains the forte executable after compilation with Makefile all
- *bin/<yourSystem>/src_gen* contains the object files generated during compilation with Makefile all
- all this Makefile generates the object files for all FORTE core files and Function Block source code files
- clean this makefile removes all generated object files.

2.2.3 Installing and Settipg up MinGW for FORTE Development

Download and install MinGW from http://www.mingw.org/ Launch MinGW installer and install default setting and add following packages:

- Mingw32-gcc
- Mingw32-gcc-g++
- mingw32-make
- msys-make
- mingw32-libz (newer version of windows doesn't include libraries)
- mingw32-gmp (newer version of windows doesn't include libraries)

After install go to the Control Panel/System/Advanced/Environment Variables. Change PATH variable (click on it) add path where your MinGW binaries have been installed in e.g., C:
MinGW
bin
;. Add C:
MinGW
bin;C:
MinGW

msys
1.0
bin; in the Windows file PATH. **Test MinGW** Open command prompt window by pressing Windows button and entering cmd. Enter bash, if bash prompt appears it was successful.

2.3 Function blocks

Chapter 3

OPC UA

3.1 What is OPC UA

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3.2 Data structure

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3.3 OPEN 62541 stack

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3.3.1 compiling

3.3.2 first use

3.4 Other stacks

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Chapter 4

Chapter Title Here

4.1 Main Section 1

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4.1.1 Subsection 1

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4.1.2 Subsection 2

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4.2 Main Section 2

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Chapter 5

Results

5.1 Created function blocks

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5.2 Implementation of function blocks

5.2.1 server

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5.3 Example application

5.4 Main Section 2

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Appendix A

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