Open Source OPC UA PubSub over TSN: Current Status and Implementation Plans

The global crowdfunded initiative:
Building an Open Source
OPC UA/TSN Ecosystem
Project Phase #2:
“Security & Certification”

Letter of Intent, 2nd edition (V6, January 31, 2019)
Today, the biggest challenge companies face when exploring new business opportunities is interoperability and solving this challenge will unlock the potential of Industry 4.0.

There is major international momentum around OPC UA and TSN as everyone sees that this technology combination has the potential to solve the interoperability challenge.

The new initiative by the OPC Foundation – OPC UA FLC promises vendor independent and end-to-end connectivity from sensor to cloud.
The OPC UA PubSub Extension

- Extends OPC UA by Publish/Subscribe one-to-many Communication
  - First Draft in 2015
  - Final Release in February 2018
- PubSub is an extension and does not replace client/server protocol
  - PubSub Configuration is part of the information model
- PubSub is not a single network protocol
  - Multiple transport possibilities
  - Based on existing standards
OPC UA PubSub
Global momentum shift around OPC UA for Vendor independent end-to-end interoperability from sensor to cloud
Initial supporting Automation Industry Players

- ABB
- BECKHOFF
- rexroth
- CISCO
- Hirschmann
- HUAWEI
- intel
- kalycito
- KUKA
- MITSUBISHI
- molex
- OMRON
- PHOENIX CONTACT
- PILZ
- Rockwell Automation
- Schneider Electric
- SIEMENS
- TTTech
- WAGO
- YOKOGAWA
Community Project History
Community Project

Why Open Source?

• The community project by OSADL, Fraunhofer & Kalycito builds on top of this major global initiative – OPC UA FLC.

• We believe that community driven open source software can alone offer true interoperability.

• Such an eco-system also helps reduce R&D costs for organizations significantly.

• Organizations can now focus on their core differentiators instead of spending on base technologies like OS, communication and security which are no longer a key differentiating factor in their product or service offering. Thus the cost of development for these shall be community driven.

• As you can see Open Source should be part of your core business strategy and should not be a distant second option for consideration or seen as an alternative to proprietary technologies. You may still need proprietary components to differentiate your product or service.
History of the Community Project
About the partners

• In 2005, OSADL (Open Source Automation Development Lab) was founded to provide support for industry when using Open Source software in products. OSADL provides services. These services comprise software development, hardware and software quality assessment as well as legal support, project management and consulting.

• In 2013, Julius Pfrommer of Fraunhofer IOSB along with several other German Institutes began the open source project to implement IEC62541 OPC UA in the name of open62541. Fraunhofer IOSB (Institute of Optronics, System Technologies and Image Exploitation) is based in Karlsruhe, Germany, and its department of Information Management and Production Control has a long history of successfully developing and researching solutions for the design, operation and maintenance of information, control and test systems. Fraunhofer IOSB is member of the OPC Foundation.

• In 2017, Kalycito identified the potential behind the open62541 stack, PubSub and TSN as candidates to become a universal communication standard from field level to the cloud. Kalycito triggered the initial move by building OPC UA TSN prototypes and funded Fraunhofer IOSB to develop the PubSub parts under an Open Source license suitable for industry and to build an ecosystem around it. Kalycito is member of the OPC Foundation and of the newly constituted Field Level Communication (FLC) Steering Committee of the OPC Foundation.
History of the Community Project

Relationship between the partners

• Since early 2018, Fraunhofer IOSB, Kalycito Infotech and OSADL are jointly working towards building an open source ecosystem for OPC UA and TSN. OSADL acts as the nodal entity for managing the relationship with community contributors and funding partners.

• Fraunhofer IOSB, Kalycito Infotech and OSADL wholeheartedly agree and adhere to the principles of a community funded Open Source software development:
  • Release early, release often, manage everything as transparently as possible.
  • Do not retain any community funded material for proprietary purposes

• As a desirable objective,
  • Building an open source eco-system for OPC UA & TSN that promises longevity, maturity and commercial support options from multiple vendors
  • The project endeavours to have the implementation of the open62541 project certified by the OPC Foundation for client server today and Pub/Sub+TSN as the compliance specification becomes available
  • The project endeavors to leverage work done by other eco-system partners like AccessTSN and avoid re-inventing of the wheel or duplication of work
History of the Community Project

License Choice

• Every software component that is intended to be copied and distributed to customers is and will be licensed under the Mozilla 2.0 (MPL-2.0) license.

• This license is an internationally accepted Open Source license with a so-called weak copyleft.

• Software that merely links to such MPL-2.0 licensed software can be licensed under the license of choice of the owner.
History of the Community Project

Architecture

Operating System
Linux with PREEMPT-RT

Layers 5, 6, 7

Security Layer

Layer 4

Layer 3

Silicon Specific Layer 2

Open Source Software

Yang Data Model

- Real-time Application
- Edge Application
- Diagnostics

- OPC UA Configuration Application
- TSN Configuration Application

- OPC UA Server
- NETCONF Agent

- Brokered OPC UA Pub/Sub
- OPC UA Pub/Sub

- Brokerless OPC UA Pub/Sub

- OPC UA

- Time Sync
- PTP Stack

- RAW/UDP
- TCP + Realtime Sockets

- IP

- TSN Driver

- MAC with TSN

- MAC with TSN

- NETCONF Agent

- PREEMPT-RT

- Linux
Community Project – Phase 1
Project Phase #1

Kalycito triggered the initial move and funded Fraunhofer IOSB to develop the PubSub parts under an Open Source license suitable for industry and to build an ecosystem around it.

Phase #1 developed the world’s first Open Source

- Brokerless OPC UA PubSub via IP multicast and binary message encoding format according to the draft of part 14 of the OPC UA specification
- Integration of the publisher in a regular OPC UA server with additional real-time interrupting
- Implementation of the subscribers as standalone software
- A first step towards secure client/server communication

The above phase #1 was completed successfully and the software can be accessed via Github at the URL https://github.com/open62541/open62541/
Output GIT SHA
From Project Phase #1

• Fraunhofer IOSB developed PubSub and released it in github
• Kalycito integrated
  • the open62541 open source PubSub implementation
  • with the Time Based Scheduler (TBS) patch based I1210 network driver
  • in a x86 Linux environment that was configured for real-time performance
• A related quick start guide has been created by Kalycito to enable interested developers to access the source code and setup the open source PubSub application integrated with I210 TBS driver
• The quick start guide and related performance measurements whitepaper can be accessed here (https://www.kalycito.com/guides/)
Community Project – Phase 2
Project Phase #2 - Aim

Make the OPC UA PubSub

• Feature complete, stable and certifiable
• Enable use of OPC UA PubSub over TSN in real products
• Release to the industry and automation market

Software components

• Configuration of TSN endpoints
• Generic interface to TSN
• Improvement of the Real-time Capabilities of OPC UA
• Certification Assistance and Related Code Corrections of OPC UA and PubSub
• Adding a Security Layer

Building an Open Source OPC UA/TSN Ecosystem

Project phase #2: “Security & Certification”

Letter of Intent, 2nd edition

(V6, January 31, 2019)

This Letter of Intent is signed between

hereafter Open Source OPC UA/TSN Ecosystem participant or simply as participant

and the

Open Source Automation Development Lab (OSADL) eG, 69120 Heidelberg, Germany

hereafter OSADL

Introduction

A rapidly growing number of companies and organizations is fostering the development of a standardized method for real-time network communication based on OPC UA as platform protocol and TSN as link layer. This broad interest has led to the open62541 project (https://open62541.org/), it was founded to provide an OPC UA
## Project Phase #2
### Contribution Levels

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<th>Logo display and listed as contributor</th>
<th>Certification assistance</th>
<th>Number of votes when deciding on the development priority of components</th>
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*The Diamond contribution level can be taken only once.*
Project Phase #2

Budget

- Overall budget estimate
  - 180,000 euros

- Minimum threshold to launch
  - 60,000 euros
    (Reached on 26-Feb-2019)
  - At this budget, some of the software components will only have a partial or even rudimentary implementation

- Depending on the budget available,
  - The more budget will be available, the more software components will be developed and reach production quality
Project Phase #2

Schedule

• Latest start date: February 26, 2019
• Duration: As long as project funds are available
• It is possible that project participants can join in after the start of the project which will be possible during its entire duration
Project Phase #2
Software Components Planned to be Developed

• Configuration of TSN Endpoints
• Generic Interface to TSN
• Improvement of the Real-time Capabilities of OPC UA
• Certification Assistance and Related Code Corrections of OPC UA and PubSub
• Adding a Security Layer
Configuration of TSN Endpoints

Generic Interface to TSN

PubSub should be represented in the information model of the related OPC UA server.
- The PubSub configuration may be modified interactively using this information model
- The TSN working group of the OPC Foundation currently is designing a similar mechanism to represent the TSN configuration in the OPC UA information model.
- In parallel to this standardization process, the proposed project will continuously implement the standardization drafts
  - using representative network hardware
  - and submit the practical experience when doing so as feedback to the standardization working group.

The tests that were conducted so far as part of the phase #1 of the OSADL OPC UA/TSN project as well as evaluations at the OSADL QA Farm
- were primarily based on the Intel I210 network adapter
- and on the Linux network driver that was provided by the manufacturer.
- In order to facilitate the use of future TSN network adapters and on-chip network hardware by other manufacturers, a suitable framework is needed.
- This framework also should provide a uniform configuration interface.
- To provide such a framework is the goal of the “AccessTSN” project the results of which are planned to be continuously integrated into the proposed project.
In comparison to conventional field bus protocols, OPC UA PubSub does not provide any general definitions of the size of the payload.
• The user may define it in so-called data sets.
• The implementation of OPC UA PubSub for open62541 makes it possible – as requested by the standard – to dynamically adapt the data sets at runtime.
• In addition, the source of the values of the PubSub messages is an OPC UA information model.
• Therefore, the OPC UA read service must be used to obtain these values which usually requires
  • more overhead that merely resolving a previously known storage address
  • and may lead to a longer latency in a real-time setup.

In phase #1 of the project, a number of technical workarounds were used to obtain the required real-time capabilities without jeopardizing the flexibility of the setup as requested by the standard.
• A number of accesses to the OPC UA information model and plausibility checks of initially unknown message lengths remained inevitable.
• The code, therefore, still needs to be slimmed down in order to be usable in endpoint devices with very limited resources.
• In addition, a separate PubSub “fast path” will be provided
  • where the configuration of the data sets will be done at compile time
  • and the related source code that already contains the network payload will be generated
  • to be able to execute with a minimum of processor cycles.
• We shall also complete the subscriber implementation in the open62541 stack
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Certification Assistance
Adding a Security Layer

Certification Assistance and Related Code Corrections of OPC UA and PubSub

- Many customers and projects require that the software products are certified to ensure interoperability.
- Participants of this phase #2 of the OSADL OPC UA/TSN project will receive support to certify their products for OPC UA client server implementations.
- This certification will be conducted at the test laboratories of the OPC Foundation.

Adding a Security Layer

- Deploying OPC UA/TSN for sensitive communication may require end-to-end encryption of the communication.
- Different from the OPC UA client/server protocol encryption, OPC UA PubSub for many-to-many communication
  - relies on symmetric encryption and a so-called Security Key Service
  - to distribute encryption keys for PubSub via the client/server protocol.
- This mechanism will be provided for this purpose that enables all involved peers to verify the integrity and to trust the source of the data.
The tests that were conducted so far as part of the Phase #1 of the OSADL OPC UA/TSN project were primarily based on

• the Intel I210 network adapter
• on the Linux network driver that was provided by the manufacturer.

In order to facilitate the use of future TSN network adapters and on-chip network hardware by other manufacturers, a suitable framework is needed that should also provide a uniform configuration interface.

To provide such a framework is the goal of the German publicly funded “AccessTSN” project

• the result of “AccessTSN” project is planned to be continuously integrated into this OSADL project.
Project Funding

Project Management

• Type of project
  • OSADL mixed-funded project, i.e. a subgroup of OSADL members and non-members is formed who contribute to the project

• Project management, software development and testing
  • Provided by OSADL
  • Partly funded by the project
  • Partly provided from the regular annual OSADL budget while employing existing office and laboratory infrastructure
Confidentiality
And IP Issues

• Any contribution or communication will be kept confidential on request of the Open Source OPC UA/TSN ecosystem participants
• The only exception is that the developed software will be made publicly available under Open Source licenses as outlined previously
Community Project – Phase 2 Status
PLC APPLICATION
Round Trip Time Measurement @100us

UDP + Strict Prio + PTP Sw
Missed counters: 42
Repeated counters: 38

UDP + 802.1 AS + Qbv
Missed counters: 14
Repeated counters: 2

UDP + Strict Prio + PTP Hw (802.1 AS)
Missed counters: 55
Repeated counters: 44

UDP + Strict Priorities
Missed counters: 292
Repeated counters: 287
Impact of M2C (via Container) on M2M

- Missed counters: 1505
- Repeated counters: 302
Certifiability of open62541 Stack

- Compliance
- Interoperability
- Robustness and reliability
- Usability
- Efficiency

- Pass: 88%
- Fail: 1%
- Warnings: 6%
- Skipped: 1%
open62541 is small and fast

- Server runs on embedded devices starting at 100kB RAM/ROM

- LoC of `/include`, `/src` and `/src/server`:

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- Not counted:
  - `/src/client`, `/src/pubsub`, `/arch`, `/plugins`, `/deps` (e.g. mbedTLS, ...)
  - Auto-generated code from XML and CSV definitions that are part of the standard
  - Tools, unit tests, examples

- 16,000 req/sec measured on a single core
  - 1,000,000 req/sec on a single core for request decoding / processing / response encoding (without network overhead)
Interoperable Communication

+ Information Modelling (Semantics)

+ Security

+ Realtime (TSN)

Integration with Established IoT Technology (AMQP / MQTT)
OPC UA PubSub over TSN,
2nd edition of the Letter of Intent of Phase #2 released

• The start of this Phase #2 project was announced at a press conference at Embedded World 2019 (26-Feb-2019)
• For time being, only the minimum funding threshold is reached. The more participants join-in, the more funding will be available and the better software will be produced.
• Please use this URL to circulate this Letter of Intent
  • http://www.osadl.org/OSADL-OPC_UA-TSN-LoI2
• Contact: enterprise.services@kalycito.com or office@osadl.org for more information.