Open Source OPC UA over TSN Ecosystem

Project phase #3: “Scalability & Tool chain”

Fraunhofer IOSB
kalycito creating a difference
OSADL Open Source Automation Development Lab eG

Why OPC UA?

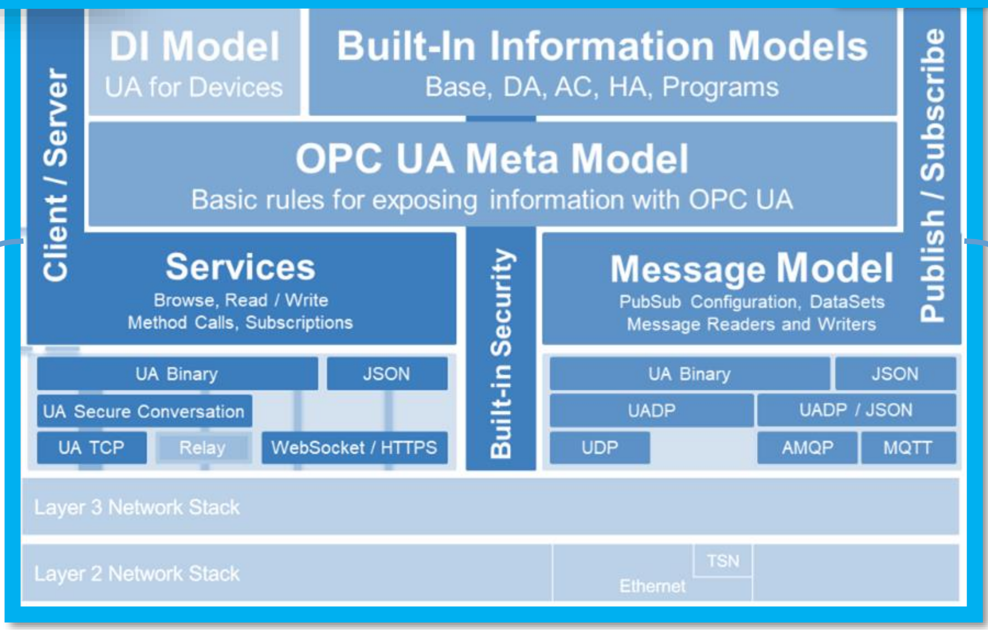
OPC UA has travelled some distance in the endeavor of

- being the “English” language of the equipment world
- through its industry widespread adoption, cooperation and collaboration and
- enabling digitization and Industry 4.0 use-cases by offering an
  Open Platform for Communications & an Unified Architecture

Unlike MQTT, OPC UA is a complete package

Domain Specific Information Models

Oil and gas
Plastics and rubber machinery
CNC machine tools
Packaging machinery
etc.



Client/Server

- Browse information model for device capabilities
- Read and write current and historical data
- Execute actions through method calls
- Data change and event notifications

Pub/Sub

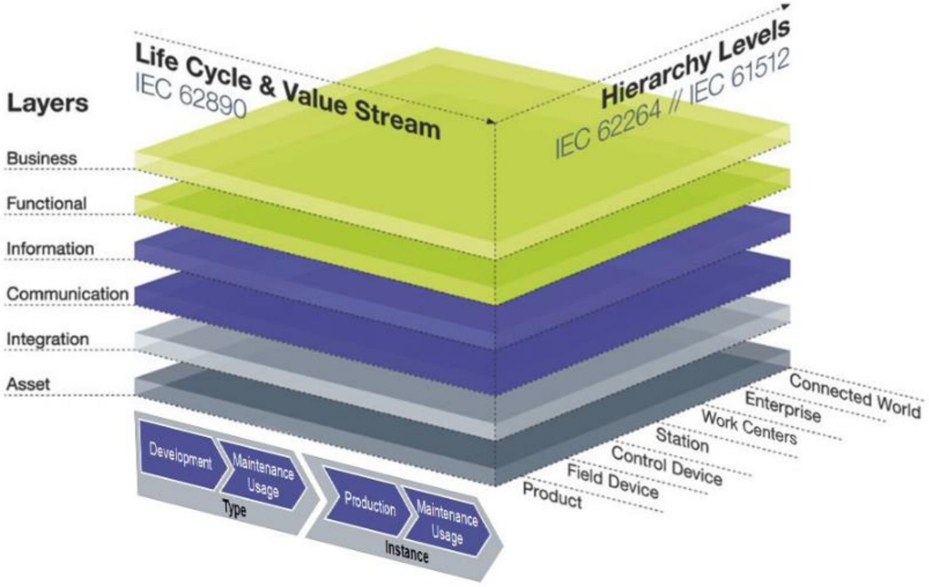
- One-to-one and one-to-many communications
- High frequency data and event notifications
- Power and latency constrained devices
- One-to-many communications

How does OPC UA fit into Industry 4.0?

OPC UA has been recommended as an important technology in the implementation strategy of the Industry 4.0 platform.
-Platform Industrie 4.0
https://www.plattform-i40.de/PI40/Redaktion/EN/Downloads/Publikation/secure-implementation-of-opc.pdf?__blob=publicationFile&v=5

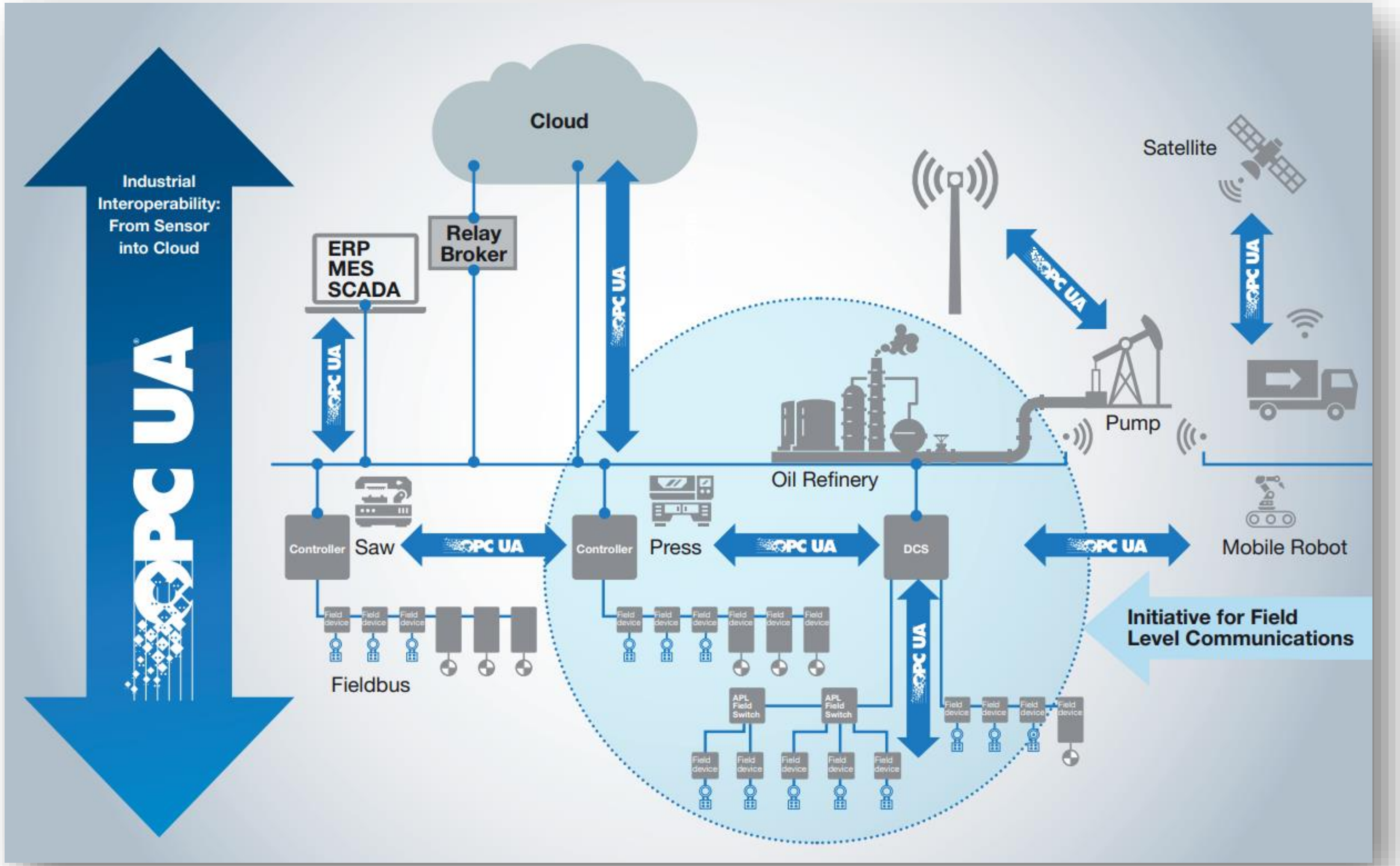
OPC-UA IS THE COMMUNICATION TECHNOLOGY IN RAMI4.0
-OPC Foundation
https://opcfoundation.org/wp-content/uploads/2016/05/OPC-UA-Interoperability-For-Industrie4-and-IoT-EN-v5.pdf

RAMI 4.0



OPC UA Field Level Communications

Why OPC UA Field Level Communications?



Security

by design

Interoperability

by design

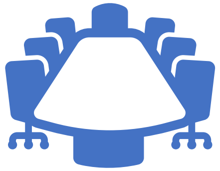
Enable all Industrial use-cases (IEEE 60802)

Realtime pub/sub and scaling down to embedded devices

FLC steering committee

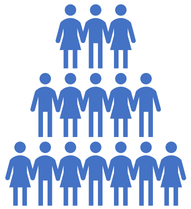
OPC Foundation

Organization & Members Companies



Board of Directors

Mitsubishi Electric, Ascolab, ABB, Siemens AG, BECKHOFF, Schneider Electric, Honeywell Process Solutions, Microsoft, Yokogawa, SAP AG, Rockwell Automation, Emerson



Members companies

Over 750 typically from small system integrators to the world's largest automation and industrial suppliers.

FLC steering committee

ABB, BECKHOFF, rexroth A Bosch Company, B&R, CISCO, EMERSON, FESTO, hilscher competence in communication, HIRSCHMANN A BELDEN BRAND, HUAWEI, intel, kalycito, KUKA, Lenze, MITSUBISHI ELECTRIC, molex, MOXA, MURR ELEKTRONIK stay connected, OMRON, PILZ, PHOENIX CONTACT, Rockwell Automation, Schneider Electric, SIEMENS Ingenuity for life, TTTech industrial, WAGO, YOKOGAWA

Nearly all major automation suppliers are part of this group

Recently Google Cloud and Amazon AWS became members of OPC Foundation

Open Source Ecosystem for OPC UA

Why Open Source

Going forward

You will see open source becoming a critical part of your commercial solutions

Standard Hardware

- Intel x86, ARM, FPGA
- IEEE 802.1 AS
- IEEE 802.1 Qbv, etc

Standard interfaces for Industry 4.0

will result in common software components to be delivered via collaborative effort

Standard Software

- Linux Kernel 5.4+
- Realtime Linux (PREMPT_RT is now a mainline)
- Linuxptp 3.0+
- Iproute 2+
- Open62541 1.0+

Landscape is complex

Open-source projects enable sharing of costs and lets you invest more on your core differentiators

Why this community project?

- Lean, Scalable, Standards-based, Secure, Open-Source path for customers to achieve:
  - real-time machine to machine applications, as well as
  - simplified cloud integration
- Top Goals of Phase 3
  - Upgrade certification for Embedded profile (Current: Micro Embedded + Security)
  - Load configuration during runtime for use in production environments
  - First implementation of Pub/Sub security

OPC UA and TSN
Frequently Asked Questions

Why should I spend money on an open-source project?

- OPC UA is a standard - it is not your core differentiator
- You can
  - Share cost of development
  - Avoid duplication of work
  - Reduce standard compliance and certification effort
  - Reduce after sales support cost – interoperability surprises from the field
- By investing money in open source, you can have a say in prioritizing features that you need and also influence the long-term roadmap of the project

If its already a successful project, then why should I fund now?

- Phase 1 added PubSub
- Phase 2 certified the stack for micro-embedded & optimized for CPU cycles
- Phase 3 will focus on
  - Pub/Sub security (Work has commenced with joining of a diamond contributor)
  - Upgrade certification for Embedded profile (Current: Micro Embedded + Security)
  - Load configuration during runtime for use in production environments

Standard Ethernet Vs TSN

- With TSN, extensions for standard Ethernet in accordance with IEEE 802.1 that break free of past limitations have successfully been developed.
- Thus, there’s now a standardized layer 2 in the ISO 7-layer model with upward compatibility to the previous Ethernet and hard real-time capability.
- With 802.1AS-rev, TSN also defines an interoperable, uniform method for synchronizing distributed clocks in the network.

Other Industrial Ethernet Protocols Vs TSN?

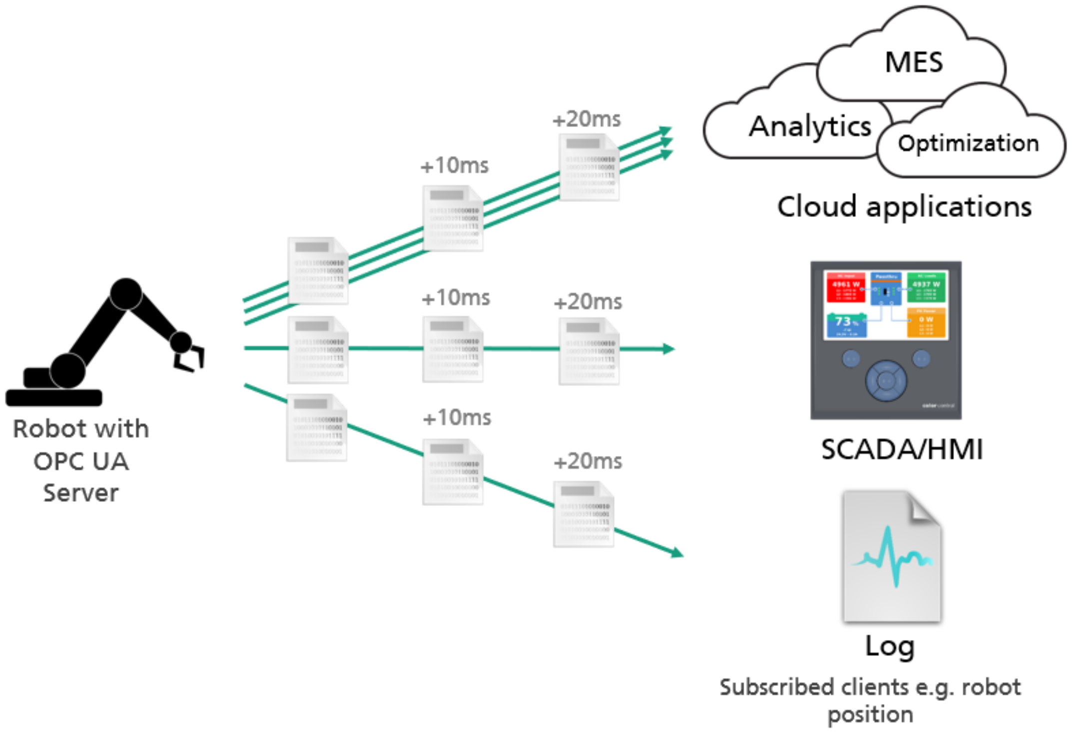
- TSN is not an extension to Ethernet – it is the new Ethernet
  - Economy of scale
  - Elimination of custom hardware
  - Possibility for open-source software eco-systems

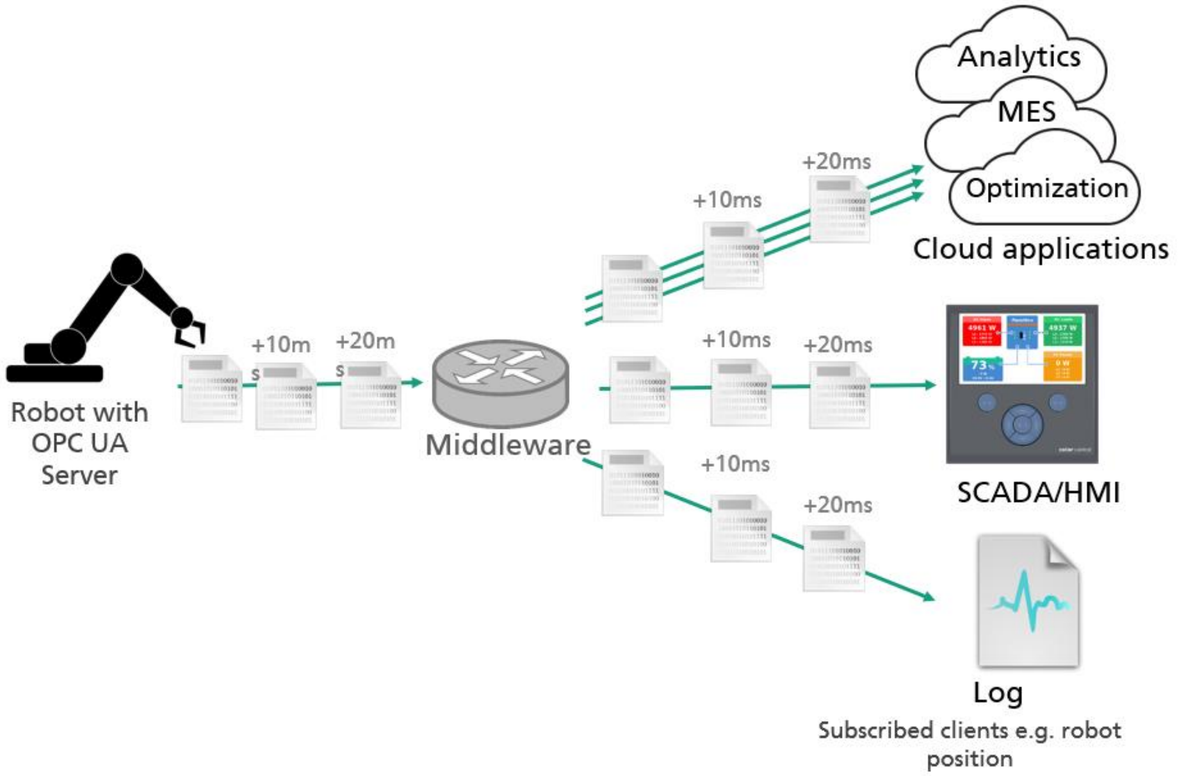
Why open62541?

open62541

- Open Source OPC UA SDK (Stack / Server / Client)
- Licensed under the MPLv2 (weak copyleft)
- Professional Development Processes and Continues Integration
  - 80%+ test coverage
  - Static Code Analyzers
  - Runtime Sanitizers
  - Build on several Platforms and Setups
- Used in commercial products
- Extended Plugin concept for ease integration and customization
- +70k Downloads

Why PubSub?





OPC UA **without** PubSub

OPC UA Server Load : e.g. 5 Clients @ 10ms

msg per sec * devices = 100 * 5 = 500 msg/sec

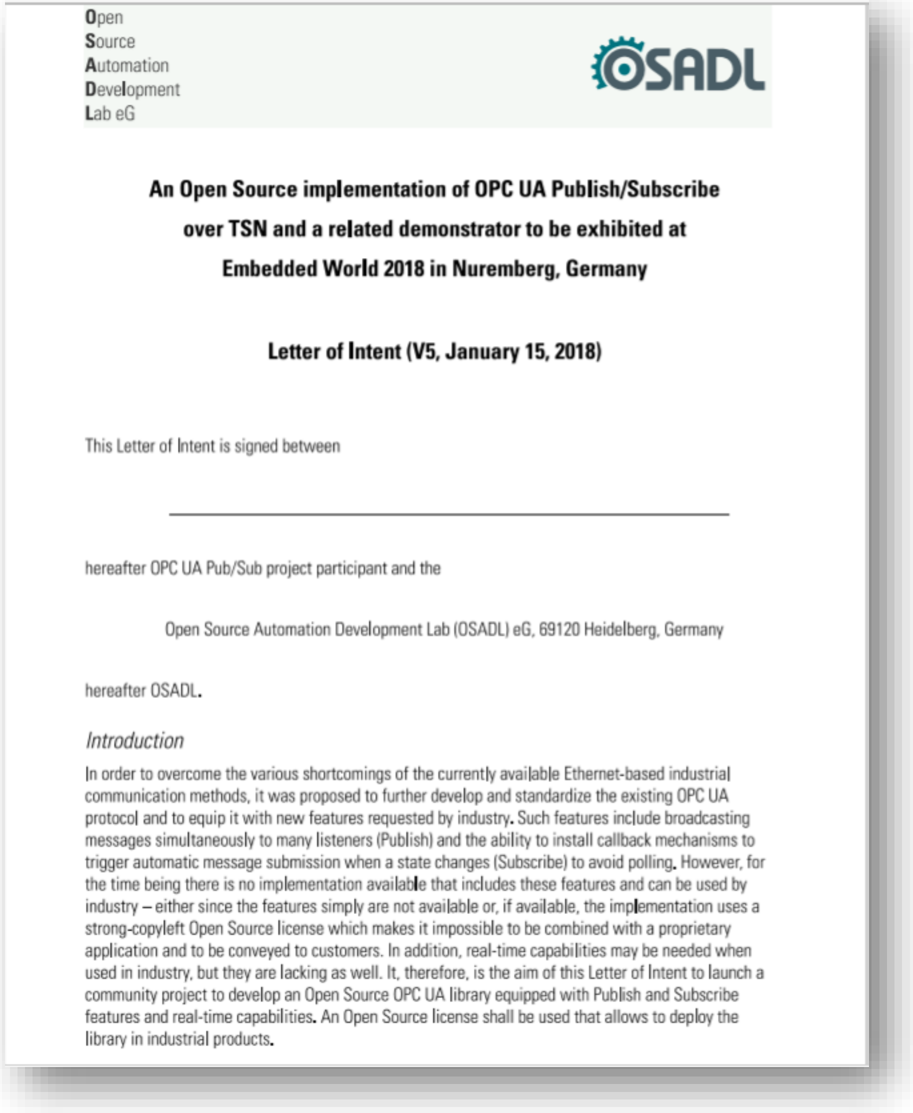
OPC UA **with** PubSub

OPC UA Server Load : e.g. 5 Clients @ 10ms

msg per sec = 100 msg/sec (const)

Deliverables
LoI Phase #1

- Deliverables
  - Brokerless OPC UA PubSub with binary message encoding via IP multicast
  - Integration of the publisher in a regular OPC UA server with additional real time interrupting
  - Standalone subscriber
  - Integration of TBS in OPC UA Publisher to publish the packets at hard real time (nano second jitter)
  - First step of secure Client/Server communication
- The above deliverables were gradually merged in existing open62541 repository in April 2018



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OSADL

An Open Source implementation of OPC UA Publish/Subscribe over TSN and a related demonstrator to be exhibited at Embedded World 2018 in Nuremberg, Germany

Letter of Intent (V5, January 15, 2018)

This Letter of Intent is signed between

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hereafter OPC UA Pub/Sub project participant and the

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

hereafter OSADL.

Introduction

In order to overcome the various shortcomings of the currently available Ethernet-based industrial communication methods, it was proposed to further develop and standardize the existing OPC UA protocol and to equip it with new features requested by industry. Such features include broadcasting messages simultaneously to many listeners (Publish) and the ability to install callback mechanisms to trigger automatic message submission when a state changes (Subscribe) to avoid polling. However, for the time being there is no implementation available that includes these features and can be used by industry – either since the features simply are not available or, if available, the implementation uses a strong-copyleft Open Source license which makes it impossible to be combined with a proprietary application and to be conveyed to customers. In addition, real-time capabilities may be needed when used in industry, but they are lacking as well. It, therefore, is the aim of this Letter of Intent to launch a community project to develop an Open Source OPC UA library equipped with Publish and Subscribe features and real-time capabilities. An Open Source license shall be used that allows to deploy the library in industrial products.

Deliverables
LoI Phase #2

- Deliverables
  - Integration of TSN functionalities with user defined time triggered send (ETF) in OPC UA Brokerless PubSub Ethernet communication
  - Improvement in the real-time (RT) capabilities of PubSub
    - Faster encoding and decoding – Encode and decode only the modifiable values (datasets, timestamps, sequence number, …)
    - Introduction of external Datasource variable for the faster access of value nodes in the Information model
  - Certified SDK - The open62541 v1.0 (server_ctt sample) is certified by the OPC Foundation regarding the 'Micro Embedded Device Server' profile
  - Alpha release of OPC UA PubSub Security Layer (SKS) & MQTT

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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.

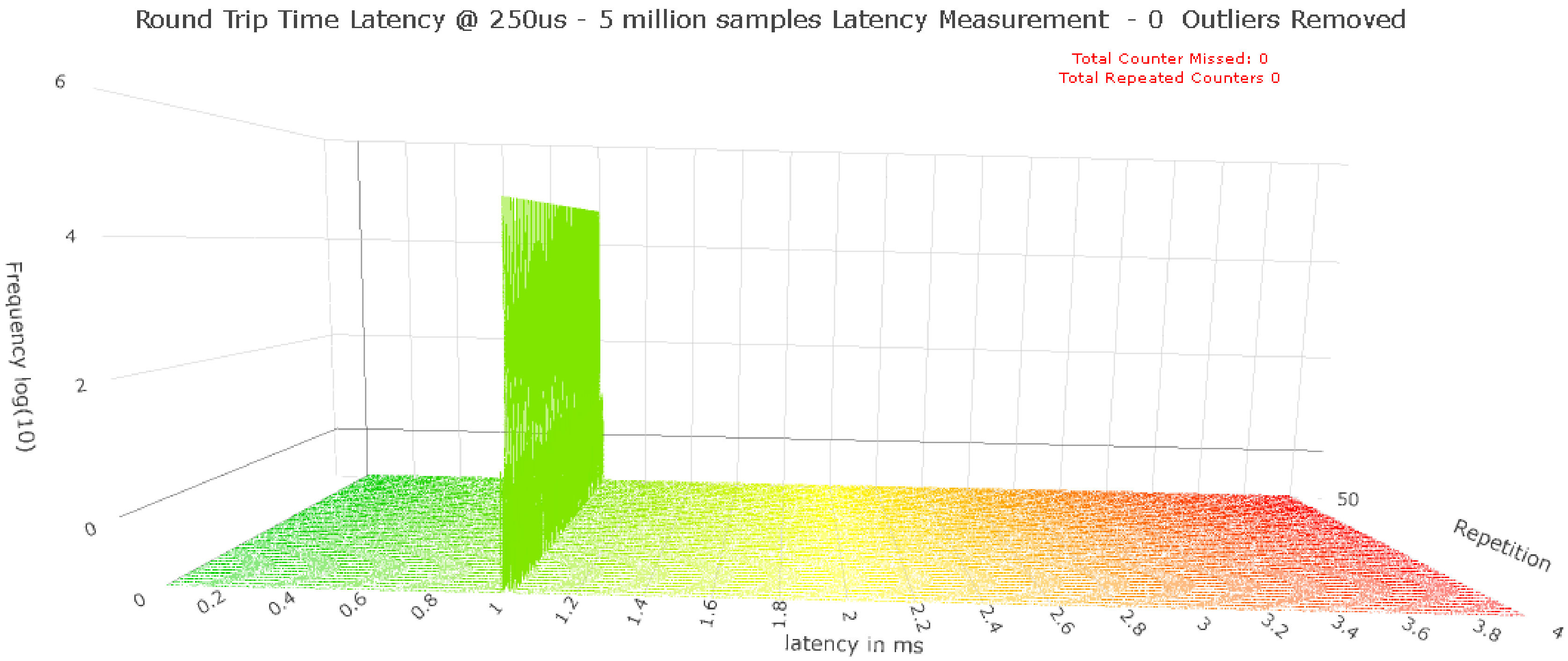
Introduction

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 implementation that can be freely copied and distributed under the Mozilla 2.0 Open Source license.

The next important evolution of OPC UA after having implemented the base technology were the Publish/Subscribe (PubSub) components to allow for a connection-less and, thus, resource saving communication suitable for the low-power devices that are expected to be used throughout the future Internet of Things. For this purpose, Fraunhofer IOSB in Karlsruhe, Germany, the India based system integrator Kalycito In-

OPC UA PubSub Application

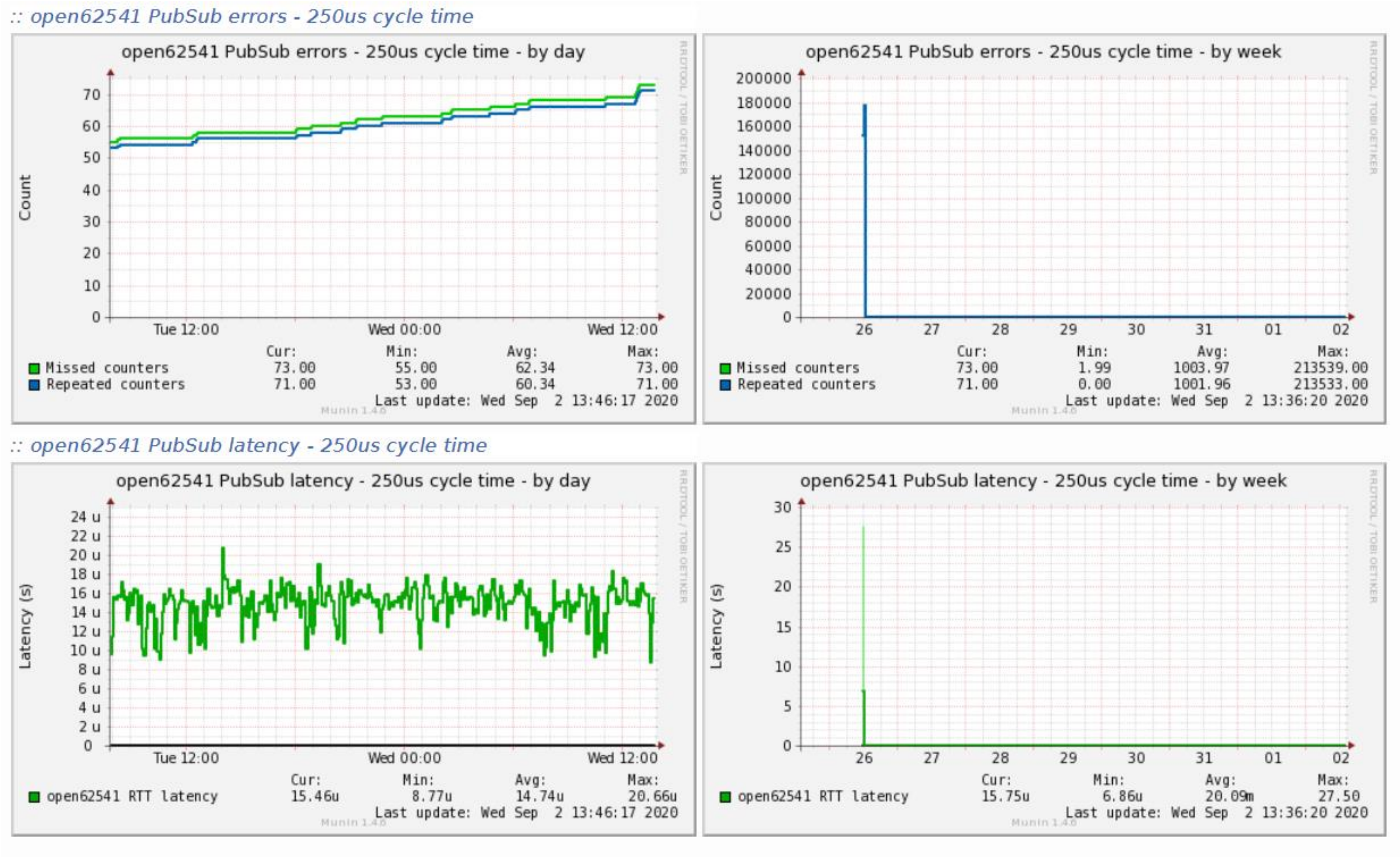
Round Trip Time @ 250us cycle time – 5 million samples



This shows the performance graph with Round Trip Time (RTT) of PubSub TSN Application running in peer to peer connected nodes with 250 microseconds cycle time for 5 million samples. It shows RTT is always 4*cycle time as expected i.e. 1ms when configured at 250us

OPC UA PubSub Application

Round Trip Time @ 250us cycle time – 24x7 results @ http://munin.osadl.org



Shows the two remaining bugs that we are working on as on 02-Sep-2020:

- Crash seen on 26th Aug
- Missed/repeated counters

Next steps:

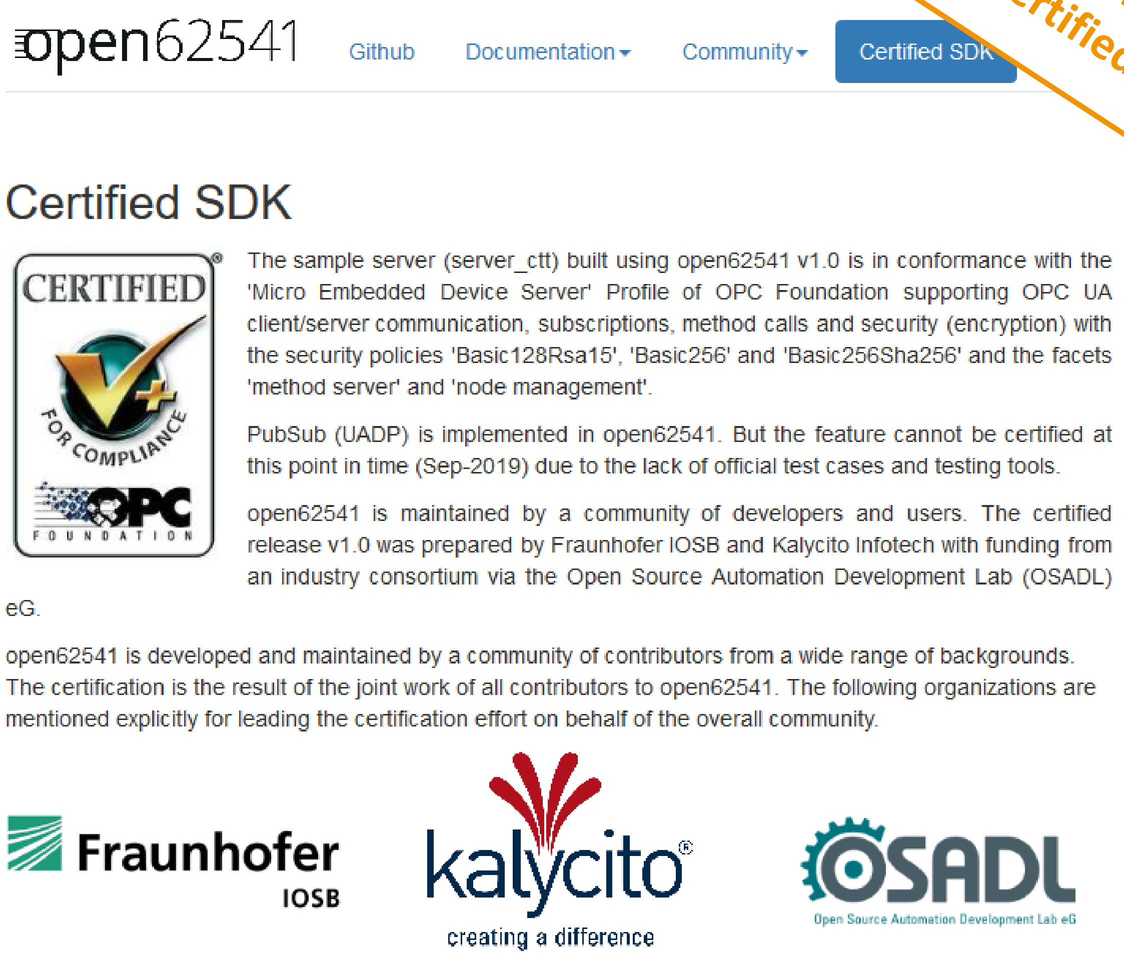
- Latest hardware and kernel
- Lower cycle times – 125, 62.5, 31.25
- More nodes in the network
- Simultaneous m2m and m2c
- Mixed traffic scenarios

Results of the LoI#2 Project

open62541 certification

https://open62541.org/certified-sdk

- The open62541 v1.0 (server_ctt sample) is certified by the OPC Foundation regarding the 'Micro Embedded Device Server' profile
- Support for the security policies 'Basic128Rsa15', 'Basic256' and 'Basic256Sha256' was added
- Based on our certified code base, the certification process for your products should be simplified
- The PubSub implementation can't be certified due to lack of official test cases



Results of the LoI#2 Project

Alpha Releases

- Initial release of early version implementations
  1. Publish/Subscribe Security (SKS)
  2. Publish/Subscribe over MQTT
  3. MQTT Security
  4. Multiple traffic classes/types
  5. Memory optimization using binary encoded node store

Customer feedback after phases 1 and 2

Many major companies are now using open62541 for their products and many more are using it in their proof-of-concept activities. This can be inferred from the increased downloads, increased activity in the forums and use for joint prototyping activities in different standardization bodies. The following are the feedback from these companies, and this serves as the input for the next phase.

- Use case 1: When there is a new information model, today we have to recompile the binary. Most customers do want to recompile and want to reload the new information model along with the same binary.
- Use case 2: Customers would like to have multiple client/server event loops in the same application.
- Use case 3: Customer would like to have support for multithreading without breaking deterministic use cases.
- Use case 4: We are already certified for micro embedded device server profile and security. Customers want us to implement the full embedded profile and undergo certification for the same.
- Use case 5: More optimal solutions for bare metal and FreeRTOS targets.
- Use case 6: Tool concept and ecosystem of an OPC UA modeler.
- Use case 7: Tool concept and ecosystem of a Pub/Sub TSN configurator.

Phase 3: Overview

Why LOI3?

- After the successful completion of the project phases #1 and #2, there is now an Open Source licensed OPC UA SDK available to be used by industry to create a state-of-the-art OPC UA server that can be certified by OPC Foundation to adhere to the “micro embedded device server” profile.
- In addition, a PubSub implementation is available that allows using Virtual Local Area Network (IEEE 802.1Q) along with components of Time-Sensitive Networking (TSN) such as high-precision time synchronization (802.1AS) and time-aware traffic shaping (IEEE 802.1Qbv) to establish real-time communication via Ethernet.
- To further enhance the existing Open Source ecosystem software pool with the goal to make open62541 the single fully fledged state-of-the-art hard real-time successor of the wide variety of former real-time Ethernet communications systems, more features of the software itself and additional software components around the SDK are needed.
- It, therefore, was decided to launch phase #3 of the community project. Since it continues to primarily take care of base technologies, it addresses the various target groups (e.g. controller vendors, field device vendors, machine builders, end users) in the same way.

The Letter of Intent Phase 3

Subproject and priorities

- The project activities are divided into two different subprojects
  - Project #1: OPC UA specific developments
  - Project #2: Realtime Linux + TSN + OPC UA + PubSub + Support for new hardware + Technology demonstrator + Tools ecosystem

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Building an Open Source OPC UA over TSN Ecosystem
Project phase #3: "Scalability & Tool chain"
Letter of Intent (V11, January 25, 2021)

This Letter of Intent is signed between

____

hereafter Open Source OPC UA over TSN Ecosystem participant or simply participant

and the

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

hereafter OSADL.

Introduction and overview about previous project phases

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 Time Sensitive Networking (TSN) as link layer. This broad interest has led to the open62541 project (https://open62541.org/). It was founded to provide an OPC UA implementation that can be freely copied and distributed under the Mozilla 2.0 Open Source license.

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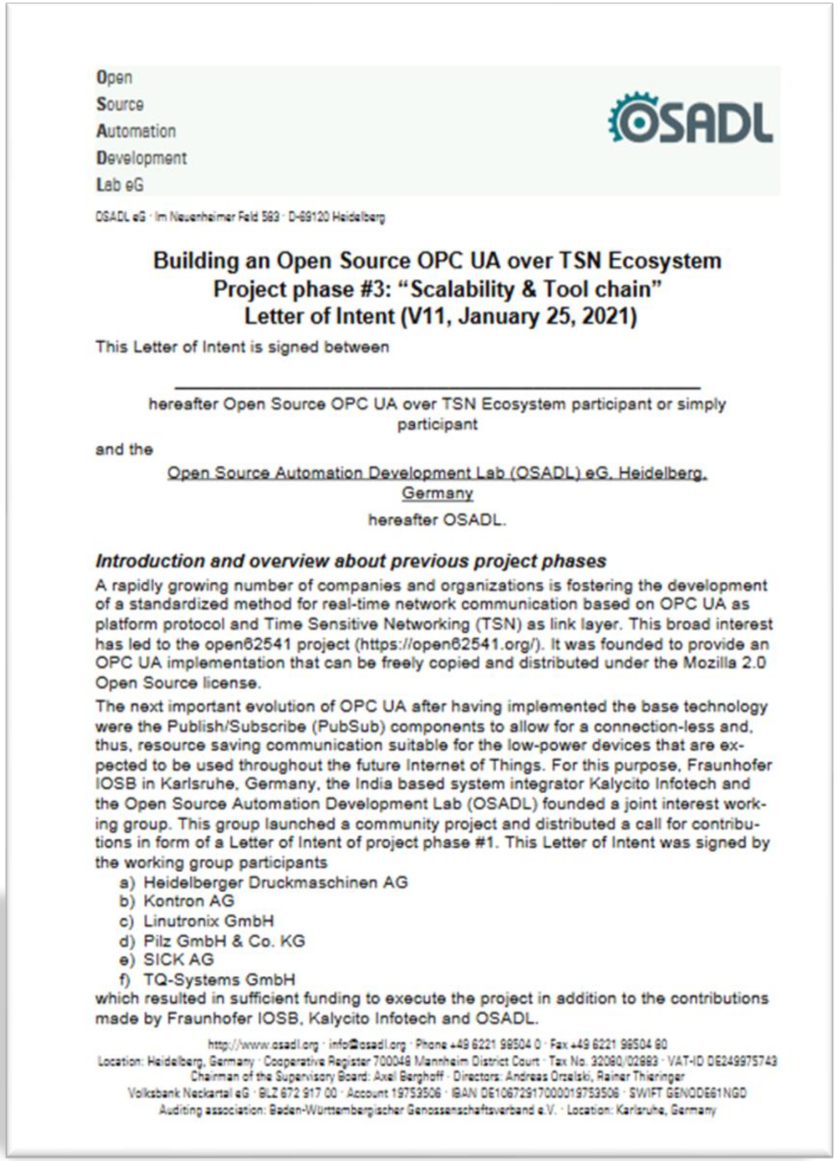
a) Heidelberger Druckmaschinen AG
b) Kontron AG
c) Linutronix GmbH
d) Pilz GmbH & Co. KG
e) SICK AG
f) TQ-Systems GmbH

which resulted in sufficient funding to execute the project in addition to the contributions made by Fraunhofer IOSB, Kalycito Infotech and OSADL.

The Letter of Intent Phase 3

Project #1: OPC UA specification development

- Parse server/client configuration from a text file
- Common event loop for multiple clients/servers
- Client multi-threading
- Implement the entire feature set of the "Full Embedded Profile" certification category as defined by OPC Foundation
- Undergo the regular OPC Foundation procedure to obtain certification for the "Full Embedded Profile"
- RAM/ROM optimizations for constrained devices (e.g., binary file node store) and tooling
- Custom memory manager (static memory allocation)



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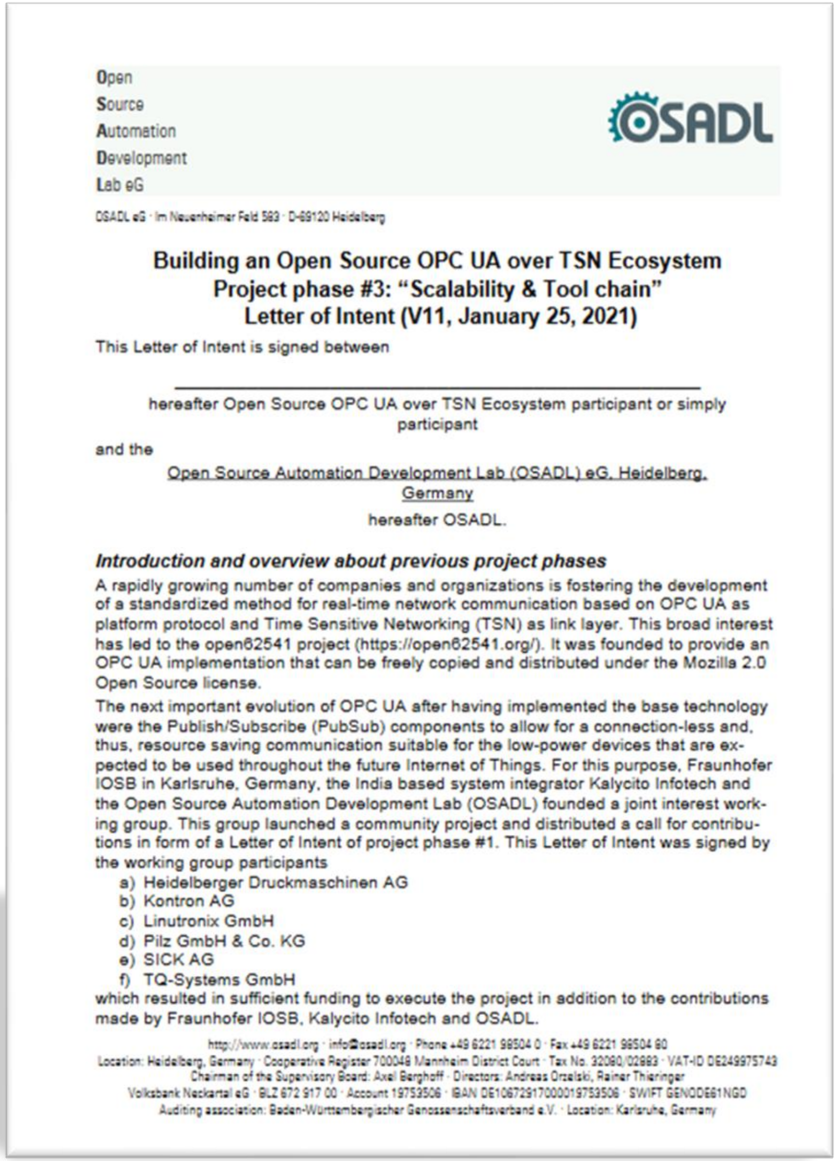
Auditing association: Baden-Württembergischer Genossenschaftsverband e.V. · Location: Karlsruhe, Germany

The Letter of Intent Phase 3
Project #2: OPC UA Pub Sub + TSN ecosystem

- Security support for the PubSub UADP protocol
- Creating a new technology demonstrator using 11th Gen Intel Core processors with TSN capability based on the most recent Linux 5.x-rt
- Creating a new Quick Start Guide for OPC UA PubSub over TSN-capable realtime Linux that works out of the box
- Incorporating all software components that are needed to successfully follow the new Quick Start Guide boards using 11th Gen Intel Core processors with TSN capability in an image for virtualization and automatically executing a script with the Quick Start Guide commands when the image is booted



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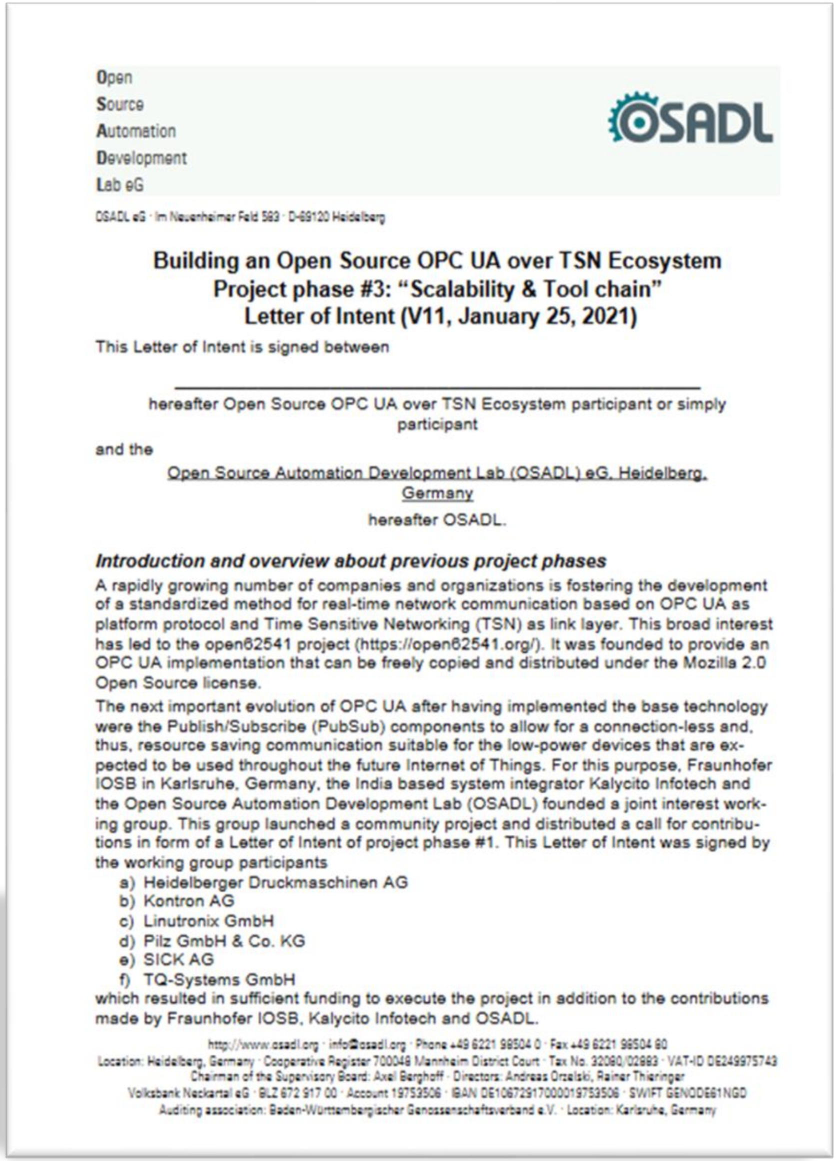
The Letter of Intent Phase 3

Project #2: OPC UA Pub Sub + TSN ecosystem

- Testing and optimizing multicast real-time PubSub in a larger network with up to 16 nodes
- Architecture concepts/application design for PubSub time offsets and RT interrupting based on publishing offset, thread synchronization and wakeup latency of threads
- Generic interface to TSN
- Open Source tool concept and ecosystem of an OPC UA modeler
- Open Source tool concept and ecosystem of a Pub/Sub TSN configurator
- Represent PubSub over TSN configuration in the OPC UA information model as per the latest FLC specification



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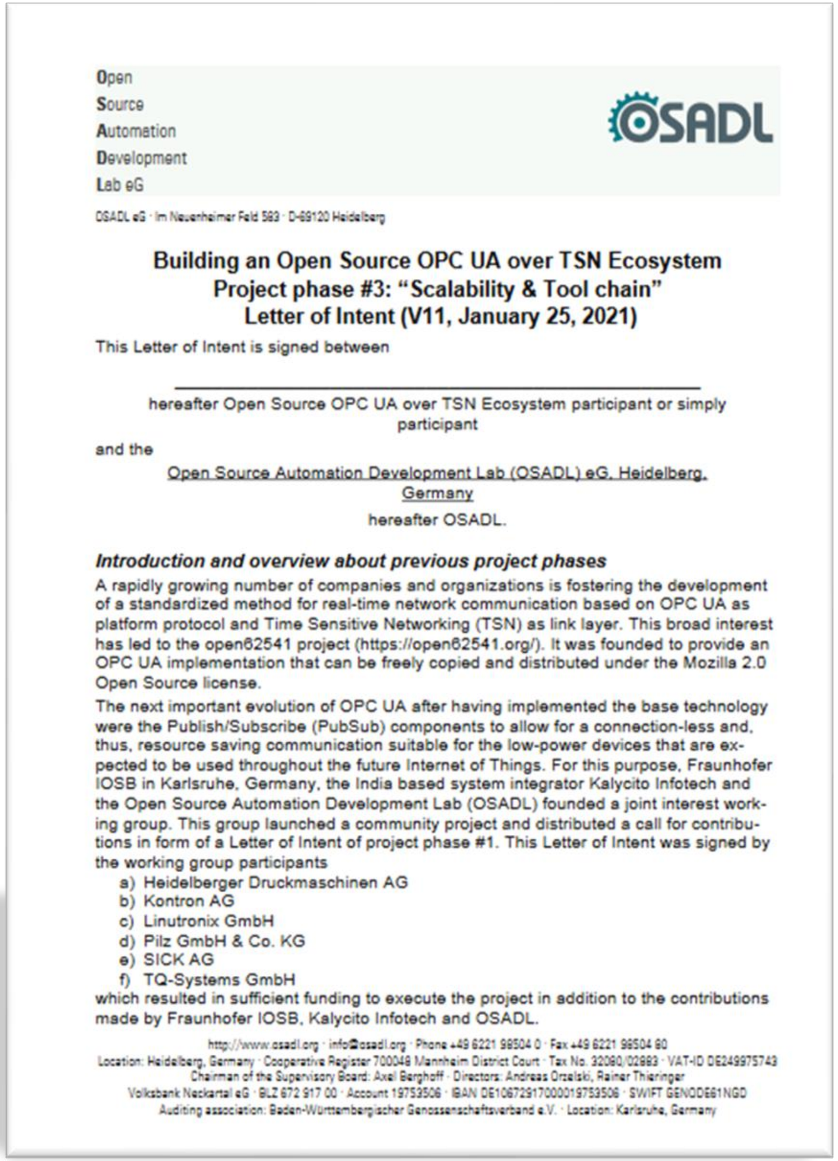
The Letter of Intent Phase 3
Project funding and management

- The project will be managed in form of a so-called 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 is partly funded by the project and partly provided from the regular annual OSADL budget while employing existing office and laboratory infrastructure.



Open
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Development
Lab eG

OSADL eG · Im Neuenheimer Feld 583 · D-69120 Heidelberg

Building an Open Source OPC UA over TSN Ecosystem
Project phase #3: "Scalability & Tool chain"
Letter of Intent (V11, January 25, 2021)

This Letter of Intent is signed between

____

hereafter Open Source OPC UA over TSN Ecosystem participant or simply participant

and the

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

hereafter OSADL.

Introduction and overview about previous project phases

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 Time Sensitive Networking (TSN) as link layer. This broad interest has led to the open62541 project (https://open62541.org/). It was founded to provide an OPC UA implementation that can be freely copied and distributed under the Mozilla 2.0 Open Source license.

The next important evolution of OPC UA after having implemented the base technology were the Publish/Subscribe (PubSub) components to allow for a connection-less and, thus, resource saving communication suitable for the low-power devices that are expected to be used throughout the future Internet of Things. For this purpose, Fraunhofer IOSB in Karlsruhe, Germany, the India based system integrator Kalycito Infotech and the Open Source Automation Development Lab (OSADL) founded a joint interest working group. This group launched a community project and distributed a call for contributions in form of a Letter of Intent of project phase #1. This Letter of Intent was signed by the working group participants

a) Heidelberger Druckmaschinen AG
b) Kontron AG
c) Linutronix GmbH
d) Pilz GmbH & Co. KG
e) SICK AG
f) TQ-Systems GmbH

which resulted in sufficient funding to execute the project in addition to the contributions made by Fraunhofer IOSB, Kalycito Infotech and OSADL.

http://www.osadl.org · info@osadl.org · Phone +49 6221 98504 0 · Fax +49 6221 98504 80
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Chairman of the Supervisory Board: Axel Berghoff · Directors: Andreas Orzelski, Rainer Thieringer
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The Letter of Intent Phase 3

Contribution levels

Contribution Level	OSADL Member (EUR)	Non-Members (EUR)
Silver	5,000	7,500
Gold	10,000	15,000
Platinum	20,000	30,000
Diamond	30,000	45,000

Project assignment and participative project management

Selection (please tick)	Project #1: OPC UA specific developments	Project #2: Realtime Linux + TSN + OPC UA + PubSub + Support for new hardware + Technology demonstrator + Tools ecosystem
☐	100 %	0 %
☐	75 %	25 %
☐	50 %	50 %
☐	25 %	75 %
☐	0 %	100 %

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The Letter of Intent Phase 3

Benefit of various contribution levels

Contribution level	Logo display and listed as contributor	Certification assistance	Number of votes when deciding on the development priority of components
Silver	yes	no	1
Gold	yes	no	2
Platinum	yes	yes	4
Diamond	yes	yes	6

The Diamond contribution provides the privilege on adding the company’s hardware or software components as part of the technology demonstrator that is built.

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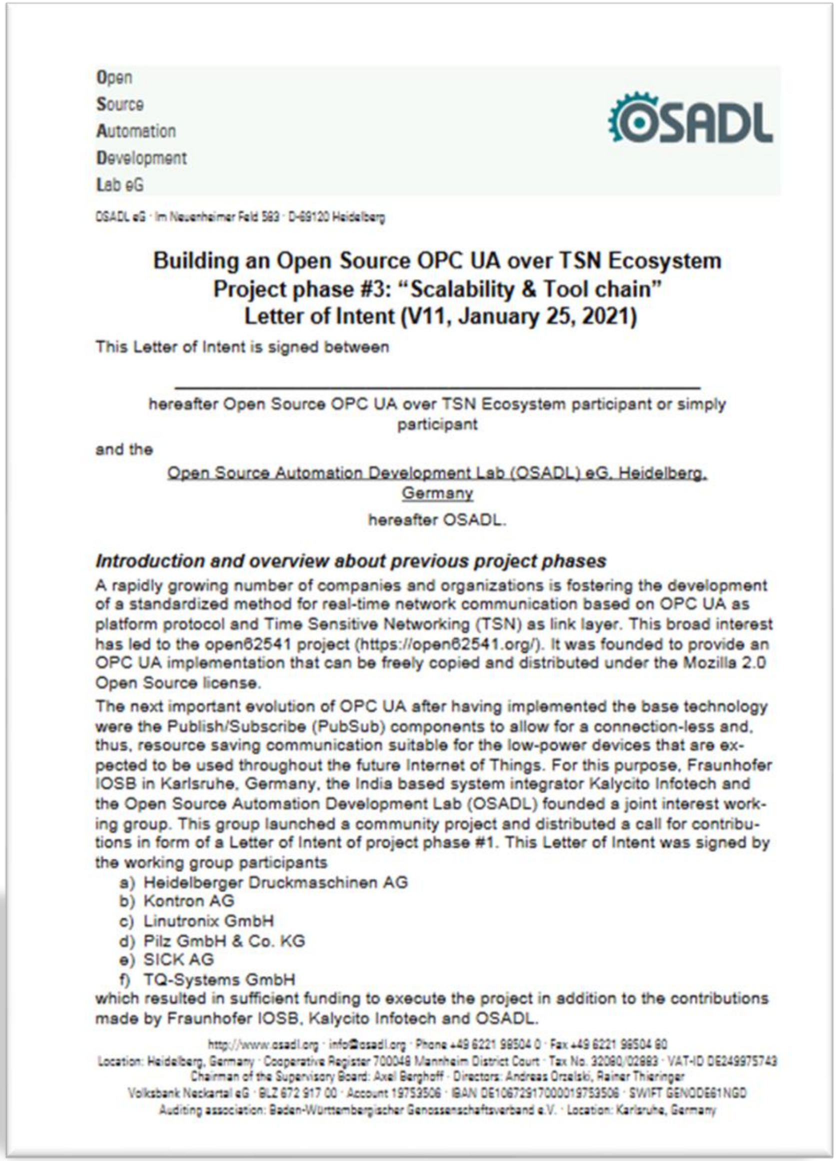
The Letter of Intent Phase 3

Overall budget and schedule

- The overall budget to provide the below given software components is estimated to amount to about 120,000 euros.
- However, the project will already be launched when and if a minimum funding threshold of 30,000 euros will have been reached.
- If this also is the final budget, the low-priority and some of the other below given software components will only have a partial or even rudimentary or no implementation at all.
- The more budget will be available, the more software components will be developed and reach production quality. It, therefore, is expected that project participants will also join in after the start of the project which will be possible during its entire duration.



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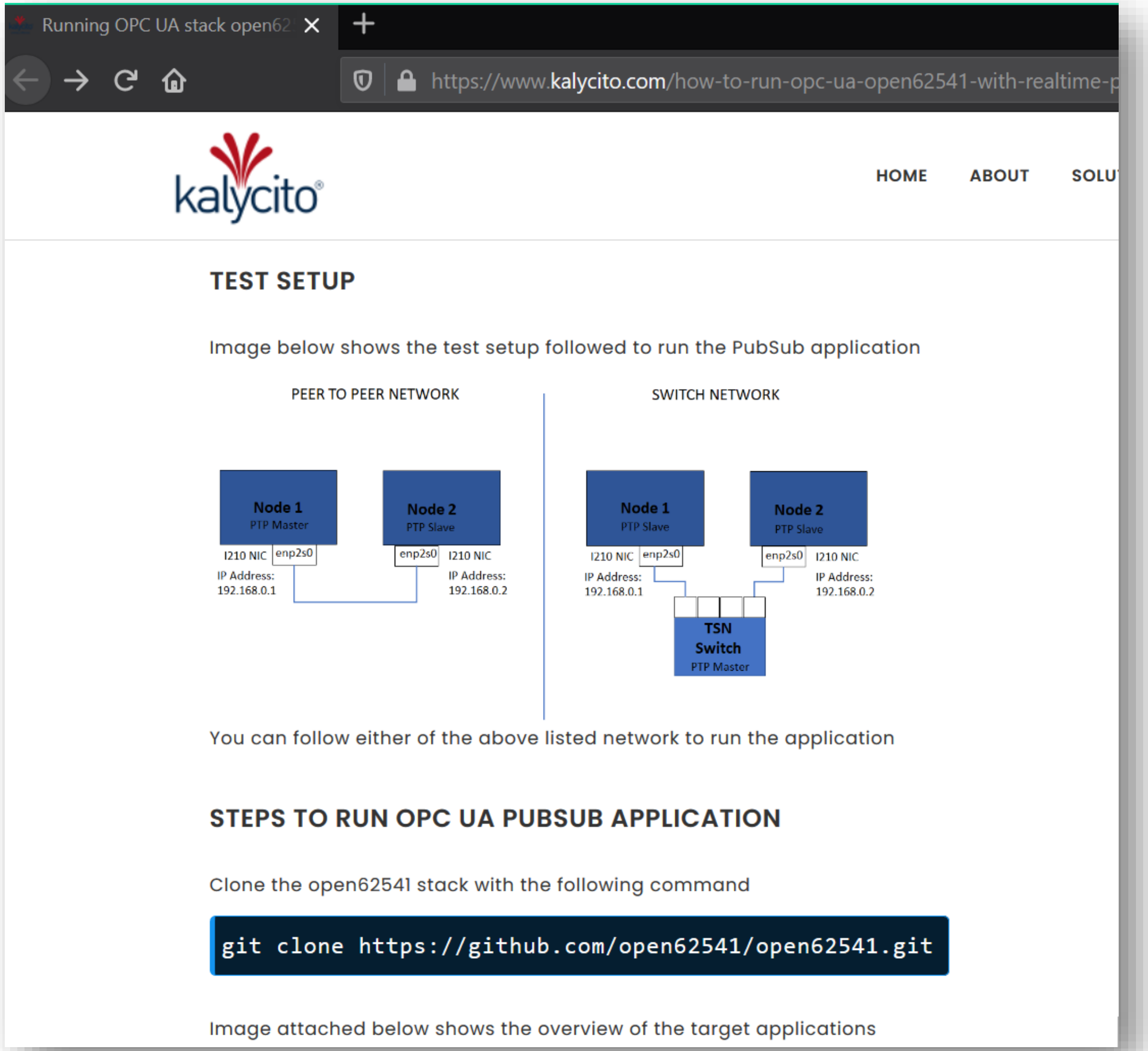
Phase 3: For more Information

Visit: https://www.osadl.org/OPCUA-Project

Open Source Resources

Quick Start Guide



How to run OPC UA stack open62541 with Realtime PubSub on Realtime Linux and TSN using Intel i210 ethernet card

This quick start guide serves as a starting point for a user in learning/evaluating OPC UA including TSN technology for their products/projects.

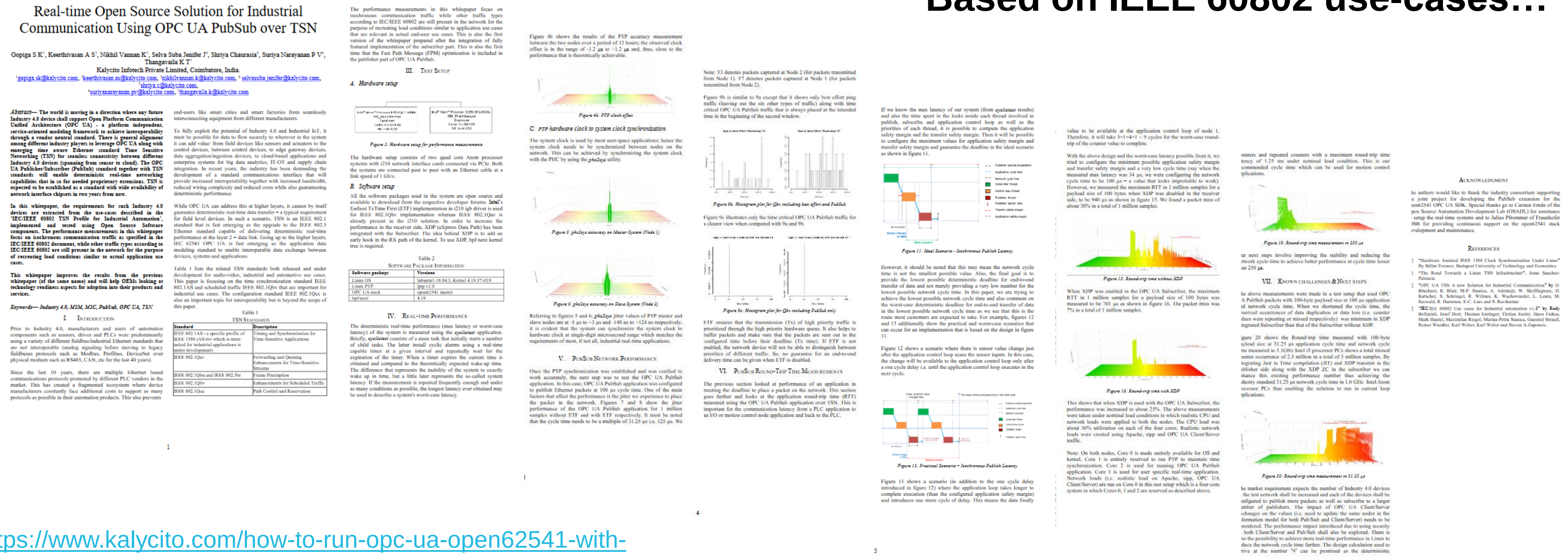
This quick start guide uses “Open Source OPC UA stack open62541 with Pub/Sub feature” and leverages the TSN features available on “standard Linux kernel + PREMPT_RT patches” on an X86 PC hardware with intel i210 Ethernet Card.

The initial release of the quick start guide may not have worked on all platforms, but the most recent version repeatedly and successfully underwent test runs of more than 24 hours duration.

https://www.kalycito.com/how-to-run-opc-ua-open62541-with-realtime-pubsub-on-realtime-linux-and-tsn-from-source/

Whitepaper

Based on IEEE 60802 use-cases…



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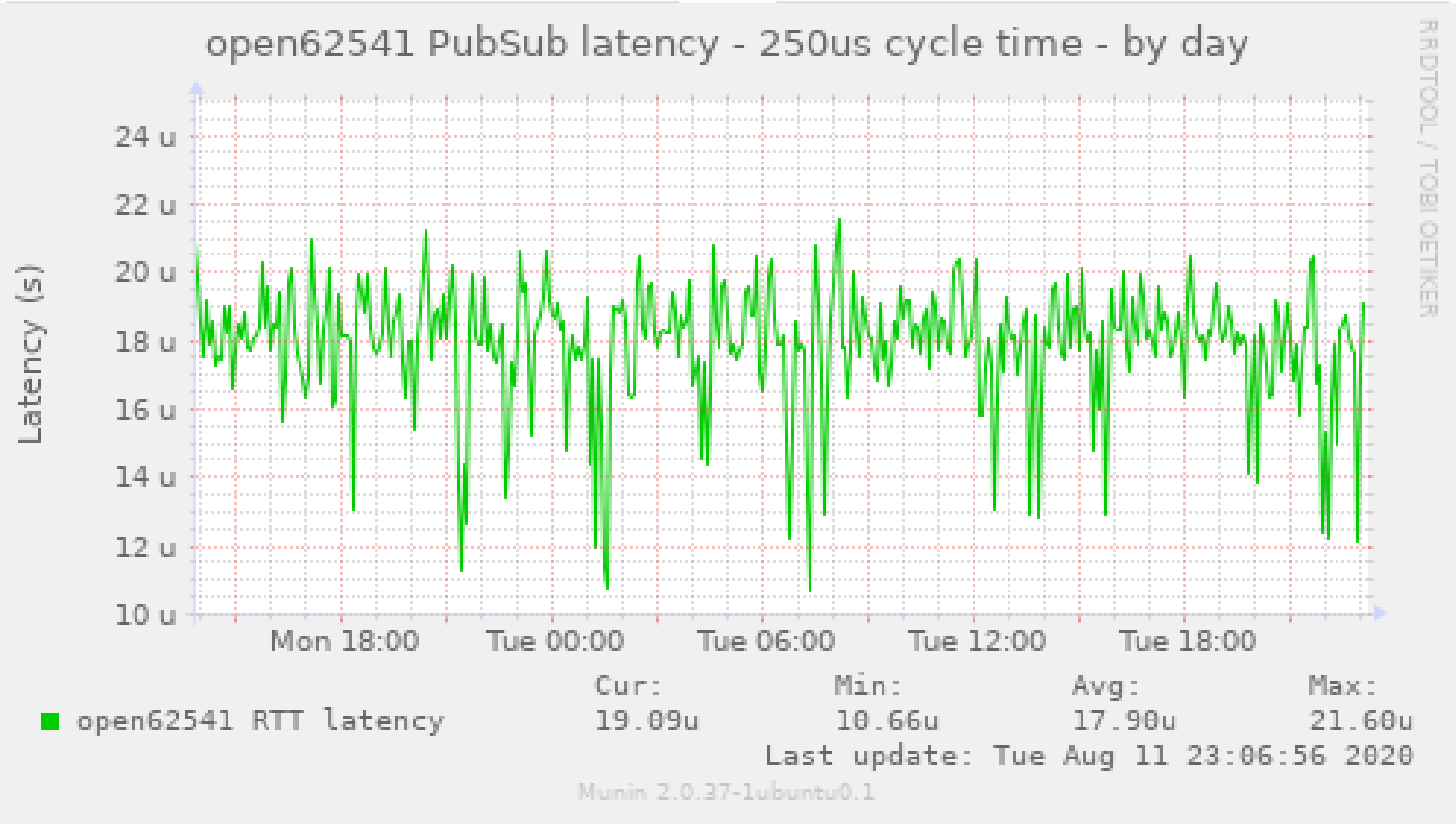
Download Whitepaper

24x7 Demonstrator @ OSADL

- OSADL primarily defines the criteria for real-time Linux and focuses on benchmarking the identified kernel in different processors using a Quality Assurance (QA) farm.
- The tests are performed in the systems hosted in the QA farm on OSADL Test Racks in several OSADL testing labs to monitor the systems under stress test.
- One pair of real-time verified nodes (latency value < 70us in cyclictest results) is used to run OPC UA Publisher/Subscriber over TSN application at 250us cycle time and the round trip time latency of the application is monitored for 24*7. (https://www.osadl.org/?id=3394)

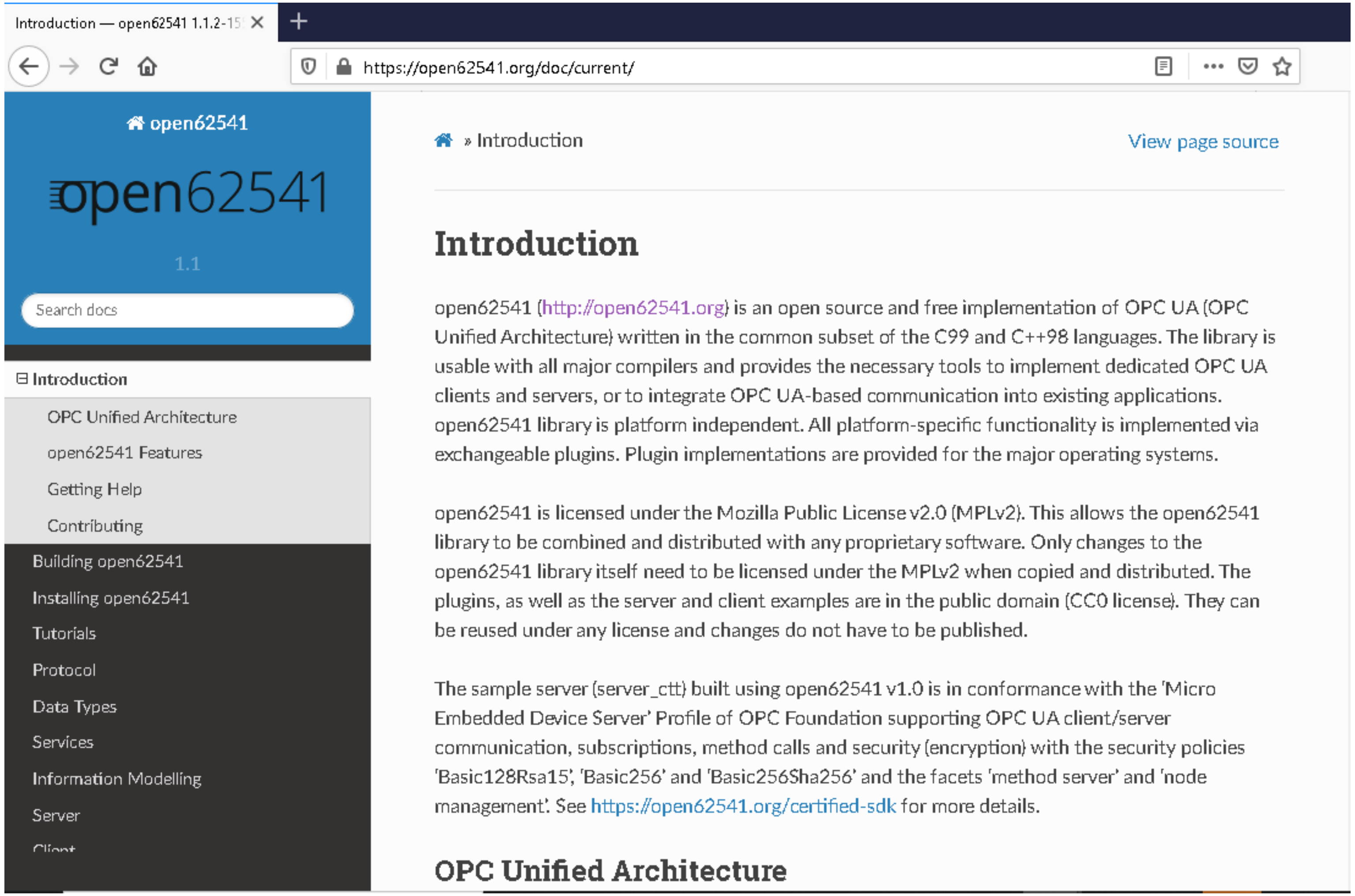
OPC UA PubSub TSN Application

Round Trip Time Results – 24 * 7



This shows the performance graph with Round Trip Time (RTT) of PubSub TSN Application running in peer to peer connected nodes with 250 microseconds cycle time.

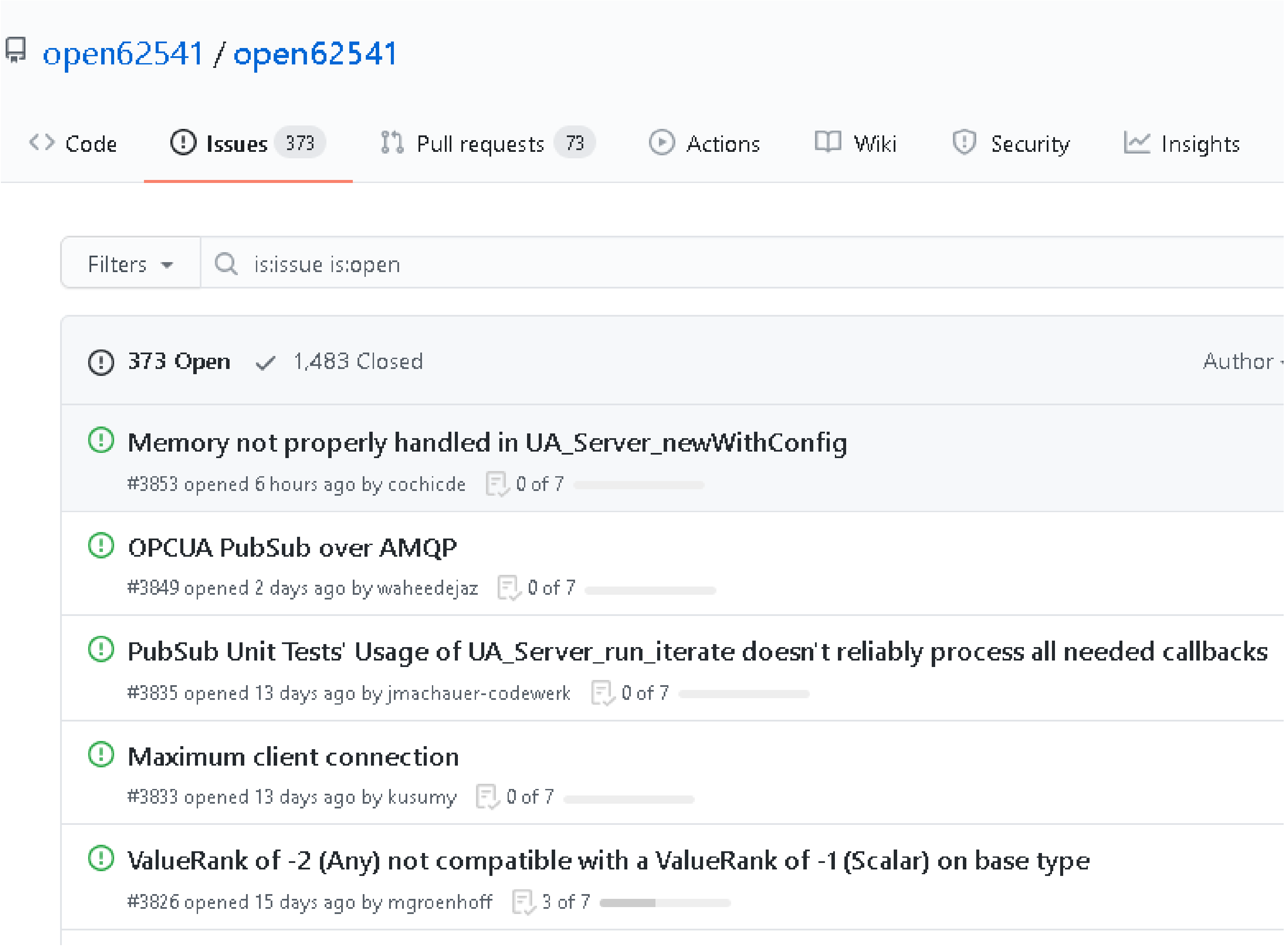
open62541 documentation



This open62541 documentation page serves as a starting point for a user in learning OPC UA technology using open62541for their products/projects.

https://open62541.org/doc/current/

open62541 forum support



This forum exhibits active collaboration and support in improving open62541 stack.

https://github.com/open62541/open62541/issues/new

Help us help you
Its easy, just a few steps

1) Print the LOI document - OSADL-OPC-UA-TSN-Open-Source-Ecosystem-LoI-Phase-3-V11.pdf
2) Choose the contribution level in page 8
3) Choose the split between Project #1 and Project #2 in page 8
4) Sign the document (page 8)
5) Send it to office@osadl.org