D9.4-REPORT ON THE CONTRIBUTIONS TO INTEROPERABILITY INITIATIVES

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Lead Editor	**Alessandra Bagnato (SOFTEAM)**
Main Contributors	**Claudio Pastrone, Enrico Ferrera, Gianluca Prato, Davide Conzon (LINKS), Farshid Tavakolizadeh, René Reiners (FRAUNHOFER), Andreas Eckel (TTTECH, TTA), Omar Morando (DIGISKY), Philippe Desfray, Etienne Brosse, Kaïs Chaabouni (SOFTEAM), Melanie Schranz, Andreas Kercek (LAKE), Angel Soriano, Rafa Lopez (ROBOTNIK), Midhat Jdeed (UNIKLU)**

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Executive Summary

The present document is a deliverable of the CPSwarm project, funded by the European Commission's Directorate-General for Research and Innovation (DG RTD), under its Horizon 2020 Research and innovation program (H2020), reporting the results of the activities carried out by WP9 - Exploitation and Dissemination. The main objective of the CPSwarm project is to develop a workbench that aims to fully design, develop, validate and deploy engineered swarm solutions.
This document describes the Report on the contributions to interoperability initiatives of the CPSwarm project results at the M36 of the project.
The contributions to interoperability initiatives are grouped by their type.
The content of this deliverable has been created through different iterations, as described in the workplan, and has been refined through an iterative process that has led to its production at M36.

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1 Introduction

This document describes the results of T9.3 - Contribution to interoperability activities (M6-M36) and includes all the contributions to interoperability initiatives of the CPSwarm project results at the M36 of the project. The project website was created and has been running since March 2017 and included news of all the summarized initiatives.
The partners have been also active in representing the project in different commercial, scientific and promotional events such as HiPEAC conference 2017, 2018 and 2019, Digital Innovation Forum 2017, ACM Computing Frontiers 2017 as well as in workshops relevant to CPS and swarm topics (also organized by project partners) pursued individually or jointly by CPSwarm partners. CPSwarm was also present in the Summer School organized by the CERBERO project. Finally, CPSwarm has been active in the meetings related to the CPS Cluster, including the Concertation events. In 2018 representatives of the project participated to the CYBER-PHYSICAL SYSTEMS (CPS) Roadmap Workshop organized and facilitated by the PLATFORMS4CPS project. The CPSwarm project participated in the EFECS conference from December 5-7, and in the co-located event 'Smart Cyber-Physical Systems Collaboration and Clustering' on December 8, in Brussels. On December 2019, the CPSwarm Consortium has organized the CPSwarm final workshop in Turin, with the participation of H2020 projects, like: Teamplay, the H2020 projects funded within the ICT-01-2016 call i.e., BONSEYES, DEIS and CERBERO (part of the CPS Cluster) as well as Bugwright2.

1.1 Related documents

ID	Title	Reference	Version	Date
D2.4	Business Models	1.0	1.0	M18
D4.7	Initial Security threat and attack models	1.0	1.0	M22
D9.5	Initial Exploitation Plan	1.0	1.0	M24
D4.8	Final Security threat and attack models	1.0	1.0	M34
D9.6	Final Exploitation Plan	1.0	1.0	M36

1.2 Interoperability achievements in the CPSwarm consortium

The CPSwarm project consortium comprises different types of partner organisations like industrial, academic, and research organisation partners that will each have undertaken a set of dedicated actions to contribute to interoperability initiatives exploiting the technological results from the project.
The following sections briefly describe each partner focus in the project and their specific interests in interoperability during the project lifetime.

The Partner categories and the corresponding project partners assigned are identified in Table 1.

Organisation Type	Partners
"Research" Partners	LINKS FRAUNHOFER LAKE UNIKLU
"Industrial User" Partners	ROBOTNIK TTTECH DIGISKY
"Technology providing" Partners	SOFTEAM SLAB

Table 1: Organisation types of CPSwarm partners

The following chapters provide a detailed description of the contribution to interoperability initiatives of the CPSwarm existing solutions

1.3 Research partners

1.3.1 LINKS

LINKS (formerly known as ISMB) is organised in Research Areas focused on core sectors of ICT that can cover the entire research and development area, from basic technology up to its practical implementation (proof-of-concept). Since 2010, ISMB has extended its activities to process innovation, orienting its focus on priority themes of the European Research & Development agenda. Such an evolution aims at employing excellences and results of Research Areas into high- tech projects with a significant societal impact at European level. The institute is involved in several industrial cooperation arrangements with both large enterprises and SMEs, as well as in various higher-education initiatives in partnership with academic institutions.

In relation to CPSwarm, the main interest of LINKS lies on the tools supporting the design of swarms of Cyber Physical Systems (CPS), with a focus on simulations, on CPS-specific adaptation libraries supporting access to platform-specific information of a robotic system in a standard and coherent way and providing building blocks for the model-based design tools as well as on the integration with IoT systems.

The coordination of the project and the dissemination (e.g., scientific publications and participation to exhibitions) of the main relevant outcome will help LINKS to increase its visibility at regional, national and international level and in being recognised as a relevant research centre for CPSs.

The competence and knowledge acquired within CPSwarm will be used to attract new students and researchers both for post graduate and post doc work. This will in the long result in increased reputation and being recognized as a centre of excellence in the R&D community and at industrial level concerning the grant of new contracts in R&D assignments for industrial purpose. The CPSwarm reference architecture, the model-based methodology, libraries and tools as such are targeted for rapid design and deployment of swarms of CPS systems and its applications in applied science and research projects for i.e. Smart City and Smart Energy domains.

LINKS plans also to exploit some of the CPSwarm software components (mainly related to simulation and code generation) through technology transfer and research and development services, taking advantage of the community that could be created releasing such software under open source licences.

Finally, LINK will use CPSwarm project outcome as a basis for additional research activities involving swarm of UAVs and on relevant topics such as CPSs modelling, also through regional and EU funded projects.

Interoperability focus: interoperability is an important topic for LINKS, indeed one of its objectives is to develop systems that can be considered as assets to be not only used in CPSwarm, but also easily exploited and further developed in future activities, i.e. in future EU projects. To do this, LINKS has leveraged for the development of its components free and standard technologies that allow making them flexible and easily integrable. Specifically:

- The Code Generator has been based on the use of SCXML[1], a standard format to describe state machines.
- The Simulation and Optimization Environment leveraged XMPP[2] a standard and open communication protocol to connect the different components of the distributed architecture. Furthermore, Docker[3] and OSGI[4] has been used as base technologies for the development of the Simulation Managers used to integrate the external simulators, making them easily adaptable to new simulators and to be usable by other platforms. From the CPS point of view the work done by LINKS both in code generation and simulation topic has been based on the use of ROS[5], the flexible framework for writing robot software.

Furthermore, to promote the interoperability of the project's solutions, LINKS has organized, in collaboration with the other partners of the CPSwarm Consortium, an ESG physical meeting. The members of the ESG group have provided useful info and suggestions on how to adapt the CPSwarm solutions to be compatible with the current best practices in the sector where they expert, increasing the usability of the developed technologies beyond the project context.

1.3.2 LAKE

As its major core research focus, LAKE concentrates on self-organizing networked systems, in particular in connection to CPS, IoT, UAVs, robots, Smart Grid and wireless (sensor) networks. The results of the project will further strengthen LAKE's know-how, competences and leading position in the field of self-organizing systems, distributed intelligence and their application to swarming CPSs. Beside a positive impact on LAKE's competitiveness as a research institution, the know-how gained in the project will allow the acquisition of further national and international projects as well as start new collaborations including the CPSwarm Partners and beyond. In addition, the rise in reputation will attract new students, post graduates and post docs to join the team as well as new highly skilled researchers to enforce sustainable growth within the organization.

Scientific results will be disseminated via releasing articles in top technically oriented journals and dedicated conferences for cyber-physical systems, self-organizing networked systems, robotics, embedded systems as well as complex systems research. Communication within the research community will be incited by twitter posts where current results, reports and news about the project will be announced. LAKE will also target non-technical audience and will create awareness about project outcomes in the public. They will use multi-media facilities (professional audio, video) as well as their experience in press article writing, exploiting of social media as well as interviewing to support public awareness creation for CPSwarm.

LAKE's intention is to use the gained knowledge to design and conduct further research projects on CPS swarms and handling complexity with methods of self-organization, in general. This will be do with partners from the CPSwarm consortium as well as with new partners.

1 https://www.w3.org/TR/scxml/
2 https://xmpp.org/
3 https://www.docker.com/
4 https://www.osgi.org/
5 https://www.ros.org/

Interoperability focus:
LAKE supported the actions towards interoperability of Framework for EVOlutionary Design (FREVO)[6] components together with UNIKLU and SOFTEAM. A swarm model library was established in Modelio together with SOFTEAM to allow for using the swarm models in different application scenarios.

1.3.3 UNIKLU

UNIKLU activities are based on exploitation of models and software components released through open source licenses. Re-use of generated knowledge from the project shall be integrated into training and teaching activities. By providing excitingly new fields of application and by combining them with the gained results, the organization will rise in attractiveness for new researchers and students of different grades ranging from starting education up to post graduates and post docs. It is furthermore expected that the interest of industrial partners for cooperation with UNIKLU will rise significantly due to the growth in expertise and experience at the cutting edge of technology.

UNIKLU works on the open source design tool FREVO, which will be used and extended within CPSwarm. The "Spiderino" platform will be used for educational purposes and swarm research. The results from the project are planned to be published in ranked international conferences and journals to disseminate the obtained results.

Interoperability focus:
Identify several interoperable FREVO components, for different CPS scenarios, to be downloadable on the website. Currently, there are two components available on the CPSwarm website[7]:

- ***cDrones:*** is a problem component in FREVO. It is a 2D simulated scenario and can be used to study a coverage task where multiple drones fly over a given environment to localize targets.
- ***EmergencyExit:*** is a problem component in FREVO. Multiple swarm members move in a simple 2D discrete environment and try to find one out of the two emergency exits. In each discrete time step, a member senses the neighbouring cells and moves to a free cell. When a member reaches an emergency exit, it is removed from the environment. The goal is that all members exit the environment.

1.3.4 FRAUNHOFER

FRAUNHOFER will exploit the knowledge gained from designing and developing the CPSwarm workbench, deployment tools and pilot prototypes integrating swarms of CPSs and the advances in model driven engineering and the large-scale deployments. FRAUNHOFER aims to extend its portfolio of consultancy services to introduce and establish sustainable innovations with Small and Medium Enterprises (SME)s and large corporations in the area of swarms of distributed and heterogeneous CPSs. Secondly, FRAUNHOFER as the major driver of the LinkSmart® open source project, will use CPSwarm to generate new opportunities leveraging convergence of CPS and IoT communities.

Interoperability focus:
FRAUNHOFER has developed the Deployment Tool with the aim of interoperability with other relevant systems. The Deployment Tool is a recent addition to the LinkSmart open source platform[8], intended to ease software delivery life-cycle in the Internet of Things. Moreover, the Deployment Tool is currently being added to the

[6] http://frevo.sourceforge.net/
[7] https://www.cpswarm.eu/index.php/frevo-and-modelio/
[8] https://linksmart.eu/

BIMERR Middleware as part of the BIMERR project[9], a Horizon 2020 research and innovation program to design and develop an ICT-enabled Renovation 4.0 toolkit.

1.4 Technology partners

1.4.1 SOFTEAM

SOFTEAM plans to industrialize its modelling tool solution Modelio[10]. It will be used and adapted to the CPSwarm project in order to include new functionalities modelling and design and requirements in different fields including telecommunication, Automotive / Transport, Manufacturing, etc. SOFTEAM's exploitation business plan will be based on an open source solution that will help to attract the interest among open source communities as well as on a commercial licensed solution with advanced capabilities to be provided after the project end.

Interoperability focus:

SOFTEAM was engaged since the beginning of the project in Object Management Group (OMG[11]) standardization activities (SysML[12] and MARTE[13]) and in sharing the CPSwarm advances with the CPS community, SOFTEAM took part and represented the project in various CPS Cluster events lead by Platform4CPS CSA project to push towards interoperability among the currently running CPS projects. Identify several interoperable FREVO components, for different CPS scenarios. Latest model interoperability achievements were shown at the 24th International Conference on Reliable Software Technologies – Ada-Europe 2019 that took place in Warsaw, Poland, in the week of 11-14 June and in particular during the DeCPS 2019 - Workshop on Challenges and new Approaches for Dependable and Cyber-Physical Systems Engineering[14].

This workshop aimed to provide a platform to industrial practitioners, researchers and engineers in academia to exchange of their ideas, research results, experiences in the field of dependable and cyber physical systems engineering, both a theoretical and practical perspective to foster interoperability between different projects, namely for the 2019 edition together with two papers from CPSwarm (lead by SOFTEAM, LAKE and TTTech). Contributions from relevant projects in the domain, such as Future factories in the Cloud (FiC[15]), Productive 4.0[16], AMASS[17], ENABLE-S3[18], SafeCOP[19], SCOTT[20] and Megamart2[21] have been provided.

1.4.2 SLAB

SLAB, as a security evaluation laboratory and consultancy providing organisation will focus on exploiting the results of the threat assessment and mitigation activities to offer consultancy, evaluation and hardening services for industrial partners involved in the production of IoT hardware and software. Since the use cases of the project can serve as an excellent test case/case study for the security recommendations and best practices developed in response to the current threat landscape of CPS devices, SLAB will be able to offer its partners a

[9] https://bimerr.eu/
[10] https://www.modeliosoft.com
[11] https://www.omg.org/
[12] https://www.omg.org/spec/SysML/
[13] https://www.omg.org/spec/MARTE/
[14] https://ae2019.edc.pl/workshops.html
[15] http://www.es.mdh.se/fic/
[16] https://productive40.eu/
[17] https://www.amass-ecsel.eu/
[18] https://www.enable-s3.eu/
[19] http://safecop.deib.polimi.it/
[20] https://scottproject.eu/
[21] https://megamart2-ecsel.eu/

known working set of best practices and countermeasures, as well as evaluation services checking the correctness and completeness of their implementation.

Interoperability focus:
SLAB is mostly involved with Common Criteria outside of the project and taking active part in ISO/IEC DIS 23643, which is related to CPS. For the project, SLAB gathered the list of relevant safety and security standards, as listed in section 4.4.2, and gained inspiration from them.

1.5 Industrial User partners

1.5.1 ROBOTNIK

ROBOTNIK plans to exploit the new CPSwarm features on its mobile platforms, namely RB1-Base[22], firstly by exploiting the knowledge and expertise developed in the context of the CPSwarm project, and secondly by leveraging on the toolchains made available by the project.

ROBOTNIK plans to improve its impact on the robotics market, better addressing the domain of self-organizing and self-coordinating robot swarms.

The project outcomes are considered crucial to bootstrap new commercial offers including swarming behaviours in ROBOTNIK platforms (robots and rovers). More specifically, CPSwarm solution will be used to improve and enhance the capabilities of ROBOTNIK logistic robotic solutions generating a new market possibility among this new sector.

Interoperability focus:
CPSwarm results will offer a new set of useful tools for ROBOTNIK in multi-robot installations of autonomous operation. The management of a multi-fleet system in industrial logistics applications remains a difficult challenge to address today due to the uncontrolled situations that can occur in this type of applications. The distributed self-management proposed by CPSwarm is an innovative factor that allows us to offer a technology that is not yet implemented in the market and that has a great impact and innovation value. ROBOTNIK will exploit this methodology to demarcate from other existing solutions in the market offering a solution already matured thanks to the development within the framework of the project.

1.5.2 TTTECH

TTTECH's research work focuses on time-triggered protocols, determinism and real time performance for safety-relevant data communication and control in mixed-criticality applications. TTTECH targets for seamlessly integrating and combining such metrics with existing communication methods used in automotive, aerospace, space, off-highway, energy, railway and many industrial domains.

TTTECH is carrying on the time-triggered data communication approach initially invented by Prof. Hermann Kopetz at the University of Technology in Vienna, Austria. In the framework of the CPSwarm project, TTTECH is further deploying this enormous potential for solving complex technical problems for mixed-criticality system designs of future Cyber-Physical Systems and the Internet of Things, with special focus on wireless communication.

TTTECH will consider patenting the results related to the monitoring tool and plans to further carry on developments beyond the project to exploit such results as commercial product in the mid-term. This includes

[22] https://www.roscomponents.com/en/mobile-robots/20-rb-1-base.html#/zona_2_sensorizacion-orbbec_astra_s/rb_1_rb_1_base_docking_station-no/summit_xl_rgbd_zone-ust_20lx_scanner_laser/plataforma_elevadora-no/imu-pixhawk/cpu-boxnuc7i7bnh_i7_7567u

the wireless deterministic driver being developed as part of the Automotive Use Case. The latter is in-depth investigation being carried out in deterministic wireless data communication expecting to lead to relevant outcomes that would be implemented in the future automotive platforms commercialised by TTTECH. In addition, TTTECH would like to internally exploit the know-how gained, namely the company plans to use the simulation framework created in the project to test and evaluate automotive systems in house.

Interoperability focus:
The intention of TTTECH w.r.t. the interoperability of results is targeting two different centres of gravity: a) include the tool in the demonstrations of other partners where TTTECH succeeded to successfully integrate the monitoring tool in the Search & Rescue Use Case and the Automotive Use Case. This shows the potential of the tool and b) to investigate how time-triggered communication can be routed via wireless data communication links independently from the technology used (should be independent whether implemented via WLAN as TTTECH did in CPSwarm or a later selection in the automotive industrial domain like V2X or 5G technology). This is essential for TTTECH in order to be able in the long run to deploy the deterministic Ethernet approach also via wireless media. This will have an impact in any kind of highly automated controls or even autonomy in case wirelessly communicated data shall influence the safety-critical control of a vehicle. In CPSwarm it is thus interesting for TTTECH to investigate the results for different domains like the automotive / search & rescue applications to see if the wireless implementation is functioning properly in different situations.

1.5.3 DIGISKY

The goal of DIGISKY as a follow-up of CPSwarm is the application of the skills gained in the project to offer a new range of services related to the management of drone and rover swarms. Many areas in which DIGISKY is already present can benefit greatly from the use of drone swarms, particularly with regard to environment monitoring, surveillance, fire prevention and management operations. In addition to this, DIGISKY intends to address new areas such as precision farming, where the swarm approach combined with the use of the toolchain offered by the CPSwarm project will guarantee an interesting commercial advantage over the competition.

Interoperability focus:
The CPSwarm project has allowed the development of strategic competencies for DIGISKY, in particular related to the management of self-organizing swarm that will be used to improve the performance level of the current drones developed by the company.

2 Summary of Networking Activities

After the CPS Cluster Project Kick-off in Brussels on February 15th, 2017, CPSwarm represented by SOFTEAM took part in the following event to push towards interoperability among the currently running CPS projects and lead by Platform4CPS CSA project.

Representatives from CPSwarm projects took part in CPS Consensus on Roadmaps workshop in Paris. This workshop included together Leaders of CPS related roadmaps who seek to form consensus on the common and differing priorities. The CPSwarm team presence could gain insight into over 10 CPS related roadmaps. Discussions among roadmappers offered windows for other guests to raise flags on points needing further refinement after the meeting.

The Platforms4CPS[23] Roadmapping Consensus Workshop was set to discuss visions and priorities of recently produced roadmaps in the area of Cyber-Physical Systems (CPS) and related fields, draw recommendations for future research and innovation activities and elaborate more specifically on three Platforms4CPS focus themes. The workshop gathered 23 experts from industry, academia and policy-making, and started with presentations providing a broad overview on activities, challenges, priorities and recommendations in the area of 'Digitising the European Industry' and related fields like CPS, Cyber-Physical System-of-Systems (CPSoS), Embedded Components and Systems (ECS), Advanced Computing, and Factories of the Future (FoF). Above others, experts presenting results and perspectives from the ECS-SRA[24], HiPEAC[25], CPSoS, CyPhERS[26], Road2CPS[27], agendaCPS, PICASSO[28] and sCorPiuS roadmaps were present. Moreover, the European Commission (EC) representative provided insights into strategic developments and directions for the upcoming CPS research program as well as the related vision for beyond 2020. During the interactive sessions in the afternoon, the participants elaborated on current and future research priorities, especially regarding the three Platforms4CPS focus themes: 'CPS Platforms', 'Autonomous CPS' and 'Virtual/CPS Engineering'.

A high priority for the future, presented by the EC representative, was in Autonomous Cyber Physical Systems (ACPS), a topic that had also been highlighted in many roadmaps and chosen as a focus theme in Platforms4CPS. Its importance was broadly shared amongst the workshop participants and was a theme highlighted as 'emerging new theme' in the interactive session as well as group work.
Comparative presentation of the different roadmaps and an interactive session to build a matrix of priority themes revealed similarities but also differences amongst the roadmaps. Research priority themes of great consent between roadmaps, also confirmed by statements of the participants were:

- Interoperability, reference architectures, platforms, standards and seamless connectivity;
- Safety, reliability & (cyber) security, privacy, trust;
- Autonomous CPS, artificial intelligence, cognitive systems and situation awareness;
- CPS engineering of large, complex systems including modelling & simulation;
- Human machine interaction, human in the loop, human as part of the system;
- Computing and storage;
- CPS science and cross-disciplinary R&D and research on the foundations of CPS.

Furthermore, other important priorities to help CPS implementation were highlighted:

- Enhance multi-disciplinarity, cross-fertilisation (application domain & engineering domain);
- Foster collaboration, European coordination and de-fragmentation across Europe;
- Cross-disciplinary education, T-shape education, life-long learning;

[23] https://www.platforms4cps.eu/
[24] https://aeneas-office.org/wp-content/uploads/2019/01/ECS-SRA-2019.pdf
[25] https://www.hipeac.net/
[26] http://www.cyphers.eu/
[27] http://www.road2cps.eu/
[28] https://www.picasso-project.eu/

- CPS enabled business models and business services, facilitate access of SMEs and start-ups;
- CPS regulation, questions around liability and ethics;
- Raise awareness, promote societal dialogue, enhance user acceptance and trust.

Regarding the trends and new/emerging themes, 'autonomous systems' became very prominent in connection with 'artificial intelligence' and 'trust'. New or improved (virtual) CPS engineering approaches to manage the more and more complex systems including the human as a part, but also co-engineered safety and security were discussed intensively. Agile (open source) platforms as well as the federation of platforms also ranged high amongst the future challenge.

Moreover, the CPSwarm project, represented by SOFTEAM and FRAUNHOFER, has taken part in the European Forum for Electronic Components and Systems (EFECS) conference on December (5-7) 2017, and in the co-located event 'the Smart Cyber-Physical Systems Collaboration and Clustering' on December 8, 2017, in Brussels. It is set to consider enhancements to existing frameworks at both the policy and project level, enabling more effective collaboration on CPS. The all-day event, facilitated by Platform4CPS, has brought together over 30 professionals from major ICT programme policy makers, researchers and practitioners, and has focused on collaboration, consensus and constituency building between the various EU-funded research programmes. Further key topics at the EFECS conference include strategy, collaboration, vision, and exhibition. For details, please consult the EFECS programme.

The CPSwarm project has been selected and hosted an exhibition during the ICT Proposers' Day in Vienna 6-8 December 2018.

SOFTEAM participated to the CYBER-PHYSICAL SYSTEMS (CPS) Roadmap Workshop organized and facilitated by the Platform4CPS project. The workshop gathered CPS experts from industry, academia, and policy-making, which will elaborate on specific related CPS-themes (including Platforms, Autonomy and CPS Engineering) and discuss these in relation to industrial demand and customer needs.

LAKE gave a presentation at the Cross-Disciplinary Approaches for Building Intelligent Swarms of Drones workshop in Toulouse. The presentation highlighted the CPSwarm project's work on system integration and tools to support the engineering of CPS swarms.

UNIKLU presented the Spiderino swarm robots at 10 Year anniversary of Technical Faculty of Alpen-Adria Universität. Furthermore.

UNKLU gave a presentation about the project and the Spiderino robot platform in the SelfOrg-cluster workshop at the University of Klagenfurt. Furthermore, two publications resulted from the ongoing work in the project have been presented: the first paper is with the title 'Modelling a CPS Swarm System: A Simple case study' and presented at The IndTrack of the International Conference on Model-Driven Engineering and Software Development in Madeira by SOFTEAM, 2018. The second one is with the title' Distributed Simulation for Evolutionary Design of Swarms of Cyber-Physical Systems' and presented during the IARIA conference 2018 in Barcelona by LAKE. Also, LAKE gave a talk about the project during the Computational World conference in Barcelona, 2018.

During the sixth quarter, the CPSwarm project, represented by UNIKLU and LAKE, participated in the 'Lange Nacht der Firsching (long night of research)', Austria's largest research event on April 13, 2018, at Lakeside Labs, Klagenfurt. During this event, UNIKLU and LAKESIDE presented the fundamentals of swarm intelligence and swarm robotics and highlight the project's work in supporting the engineering of CPS swarms. SOFTEAM also participated to the CPS Cluster Platform4CPS CSA lead activities and followed up CPS cluster teleconferences (TELCO)s and meetings to achieve a common vision and set up the basis for collaboration

between the various ICT1 Smart Cyber-Physical System Cluster projects (DEIS[29], BONSEYES[30], CERBERO[31] and CPSwarm).

Furthermore, the project was presented and discussed during the Lakeside Research Days, first by LINKS in 2017 and then by SOFTEAM in 2019. The CPSwarm Project, represented by LINKS, participated in the Euro Science Open Forum (ESOF). The event took place in Toulouse, France, from July 9-14, 2018
During the last quarter in 2018, the CPSwarm project presented its approach and case studies at ICT2018: IMAGINE-Connect Europe in Vienna. This event focused on the European Union's priorities in the digital transformation of society and industry. The CPSwarm tools have been presented, and as well two live demos: one using drones and ground robots, and the second was for presenting the educational platform, Spiderino. Also, CPSwarm has been presented using a poster and leaflets by TTTECH at the EFECS 20-22/Nov/2018 conference in Lisbon, Portugal (Figure 1), where in this conference, several large poster sessions and an industrial exhibition were run in parallel. Alike, TTTECH presented a poster and actively participated by a speech in a dedicated project session in the HIPEAK 2019 in Valencia. In addition, the project was supported in its presentation including demonstrations of the results via working demonstrators in the ICT Event in Vienna in December 2018.

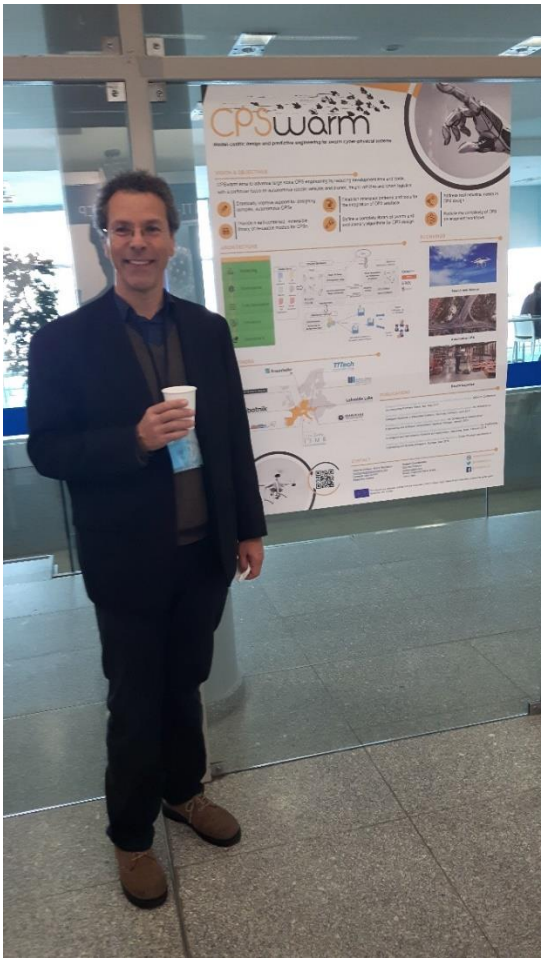

Figure 1: Poster Presentation and Leaflets in the EFFECS 20-22-/Nov/2018

[29] http://deis-project.eu/
[30] https://www.bonseyes.eu/
[31] https://www.cerbero-h2020.eu/

On 13th December in Turin, the CPSwarm Consortium, coordinated by LINKS has organized the CPSwarm final workshop with title "Towards Smart Autonomous Cyber-Physical Systems: Unmanned Aerial/Ground Vehicles and Robots". presenting several EU relevant initiatives on CPSs with high degree of autonomy.
In the starting phase of the workshop, several EU projects that share the objective to support the engineering of autonomous CPSs has presented their mean outcomes. The list includes few H2020 projects: Teamplay, the H2020 projects funded within the ICT-01-2016 call i.e., BONSEYES, DEIS and CERBERO (part of the CPS Cluster) as well as Bugwright2. Then, the workshop has focused on the results obtained by CPSwarm project, aimed to provide tools that ease design, development and integration of complex herds of heterogeneous CPSs, which collaborate based on local policies and that exhibit a collective behaviour capable of solving complex, industrial-driven, real-world problems.
Furthermore, the workshop will introduce few challenges in promoting the adoption of smart CPSs in urban areas. More specifically, the Turin ecosystem has been presented along with the relevant initiatives.
The workshop has included also a session where the posters related to the workshop topics has been presented and the attendees has been able to discuss directly with the people involved in research and innovation projects. Furthermore, the CPSwarm open-source components has been introduced in detail and the attendees have discussed their features with the CPSwarm developers. All the sessions have involved partners and professionals, coming from all over Europe.

Collaboration with the Cluster, Prossimo[32] has been carried out during the last months of the project and material exchange has been released in the last weeks especially including the CPSwarm modelling part and the Modelio modelling tool.

Collaboration will continue throughout the CPSwarm GitHub open source Community.

[32] http://www.cluster-prossimo.it/

3 CPSwarm Interoperability strategy

CPSwarm consortium targeted two ecosystems, respectively GitHub[33] and RoS[34], for its interoperability strategy. Detailed strategy for each ecosystem is detailed in the following section.

3.1 GitHub Interoperability strategy

The following topics were pursued within our GitHub Interoperability Strategy: publish on GitHub: public API, wiki, tutorials, and videos.

One of the main goals of CPSwarm is to develop a software system which is interoperable with other existing solutions. To achieve that, the consortium has focused on making sure the developed components are available and reusable beyond the scope of the project. An important step to achieve this objective was to maintain the outputs of the project on a public infrastructure with high visibility and rich collaboration capabilities. GitHub provides public hosting for many services useful for the development and dissemination of software. The Consortium is particularly interested in services for source code management, wikis, issue tracking, static web hosting, as well as rich access control features. Utilizing GitHub for the aforementioned functionalities not only ensures the availability of CPSwarm output for long term, but also adds high visibility in the open source communities. GitHub is by far the most popular source code hosting service with more than 100 million projects and 30 million users[35]. This potentially exposes the CPSwarm outcomes to this large community, many of which are the industry leaders in CPS technologies.

Concretely, the consortium benefits from GitHub in the following ways:

Version Control and Source Code Management

All open source components of CPSwarm are maintained and available publicly on GitHub. This adds no costs to the project because GitHub provides free and unlimited hosting for public materials. The source codes of the components are indexed, versioned, and visible to interested external communities. The external community members may report component issues directly on GitHub and discuss relevant problems with the authors or other community members. The communities may take the code and extend it to their needs by forking the repositories. It is also possible to incorporate such external contributions by creating pull request on the master repositories. GitHub offers various other tools to smoothen the collaboration activities such as branching, code reviews, change history, and merge conflict management.

Wiki

GitHub provides integrated wiki spaces to individual source code repositories. The CPSwarm components are documented in such wikis and available to the public. The wikis usually consist of technical descriptions, API documentations, and detailed usage and development guidelines. The documentation may be supported by tutorial documents and links to associated videos and external documents.

Static Pages

[33] https://github.com/
[34] https://wiki.ros.org/
[35] https://en.wikipedia.org/wiki/Comparison_of_source-code-hosting_facilities

Richer documentation is possible with GitHub Pages which is a hosting feature for static web pages. Certain components of CPSwarm use GitHub Pages to host Software Development Kit (SDK) documentations. GitHub pages may also be used to host comprehensive tutorials for the CPSwarm Workbench and other tools.

CPSwarm Workbench Page

To present our results, the partners created a page on the CPSwarm website[36] to disseminate the Consortium open-source components and to introduce CPSwarm workbench. The main objectives of such a page are illustrating the final architecture of developed components in the project, to provide a walkthrough of the CPSwarm system, and the set of libraries, Modelling and Behaviour libraries, provided by the CPSwarm project. Links to download the released components and the related GitHub projects are also provided.

3.2 ROS Interoperability strategy

The choice of the consortium to select the ROS operating system as the main development platform offers a wide visibility to the project since from the same official distribution of ROS, the packages will be accessible, and any user can have access to them. This opportunity to invite the wide community of ROS to test the software developed in CPSwarm will accelerate the maturation process of the algorithms as well as their reuse in other areas and different use cases.

[36] https://www.cpswarm.eu/index.php/cpswarm-workbench/

4 Summary of follow-up of standardization activities

Dissemination of the CPSwarm results not only occurs through the website, or conferences, but also through interaction with standardization bodies.

4.1 Project-relevant modelling standards

SOFTEAM is involved in two standardization bodies and one association in with CPSwarm result might be relevant.

SysML [http://www.omgsysml.org/]

SysML concepts are widely used for both CPSwarm modelling purpose. For CPSwarm hardware modelling is specified by both SysML Block Definition Diagrams (BDD) (cf. Figure 2) and Internal Block Diagrams (IBD) (cf. Figure 3).

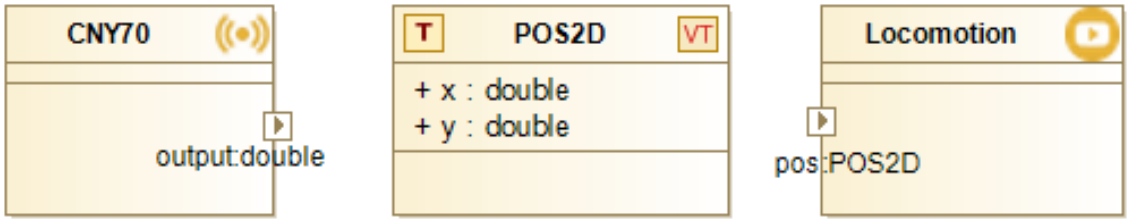

Figure 2: CPSwarm type modelling

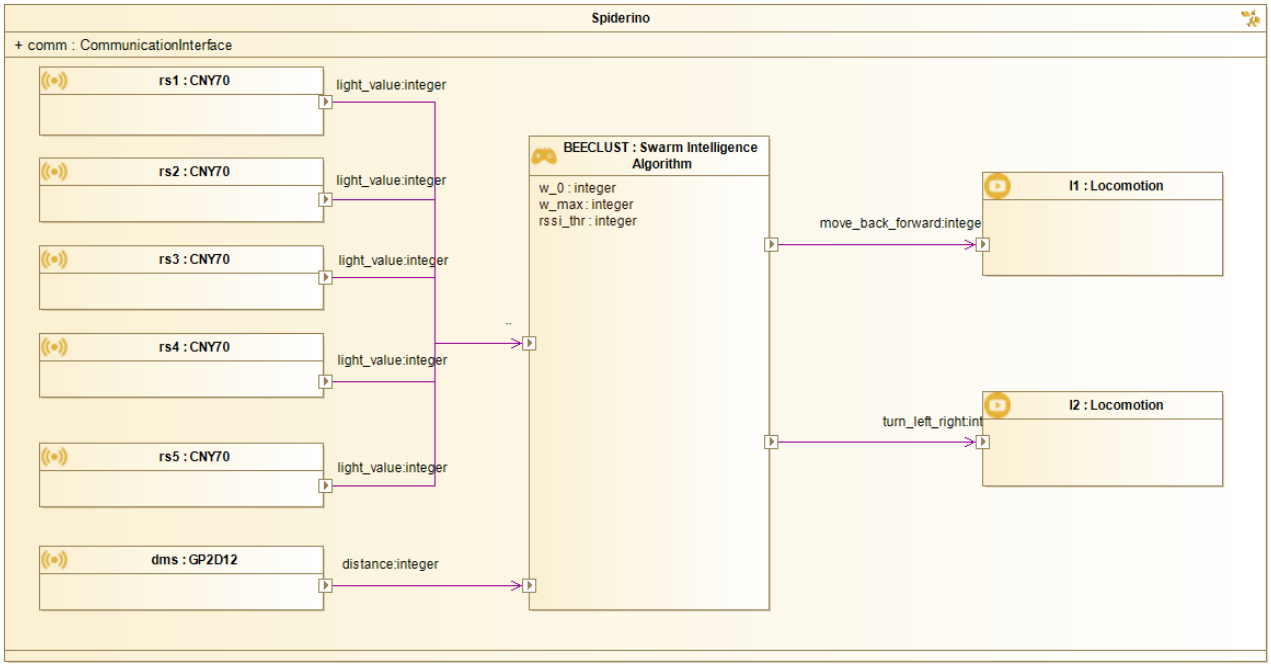

Figure 3: CPSwarm architecture modelling

Concerning the behavioural modelling, CPSwarm language is based on SysML/UML state machine concepts (cf. Figure 4).

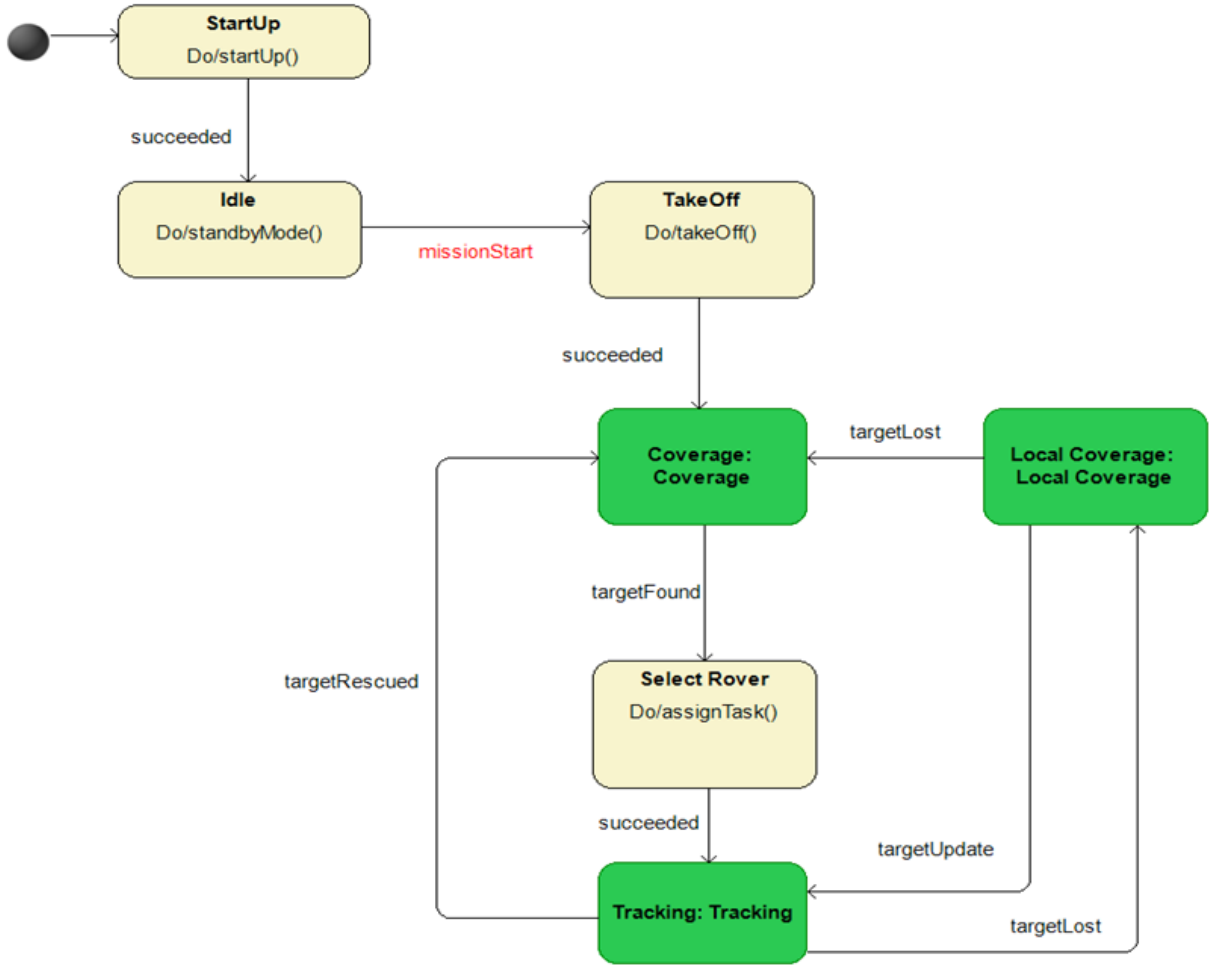

Figure 4: CPSwarm behaviour modelling

Specific effort has also been made in SysML Physical Interaction and Signal Flow Simulation Specification (SysPISF) Working Group in order to coupling, develop and improve SysML model simulation[37].

MARTE [http://www.omg.org/spec/MARTE]

MARTE standard aims to "add capabilities to UML for model-driven development of Real Time and Embedded Systems". In CPSwarm context, SOFTEAM analysed latest version of the standard (released in April 2019) to improve both MARTE and CPSwarm modelling language.

INTO-CPS Association [http://into-cps.org/]

A work has been set up to carry out an INTO-CPS Association where SOFTEAM is involved into the modelling of CPSs. INTO-CPS Association aims to provide an open source tool chain focused on Model-Based Design (MBD) of CPS where CPSwarm aims to provide support and tools for MBD of swarm of CPSs. By being involved into the INTO-CPS Association, SOFTEAM want to be able to use and influence as soon as possible relevant technologies coming from it for CPSwarm project purpose.

[37] http://www.omg.org/spec/SysPISF/About-SysPISF/

SOFTEAM participated to the OMG Technical Meeting in Amsterdam on June 2019 to mainly assist to physical meetings of standards mentioned previously but also following other standards activities as Systems Engineering DSIG[38]. Robotics[39] and IoT related standards[40], e.g. Data Distribution Service (DDS[41]).

Investigations are currently under work in SysML Physical Interaction and Signal Flow Simulation Specification (SysPISF[42]) Working Group and INTO-CPS Association to couple, develop and improve FMI co-simulation of SysML models.

4.2 Project-relevant code-generation standards

The final implementation of CPSwarm Code Generator supports the generation of code starting from the description of an algorithm in the form of a Finite State Machine (FSM). This state machine can be provided as input to the Code Generator using a standard data format called SCXML. SCXML stands for State Chart XML and is an XML-based mark-up language developed by W3C. According to the W3C SCXML specification[43], SCXML is a general-purpose event-based state machine language that can be used in different and various ways. In general, anything that can be described and modelled as an UML state machine or state chart can be brought back to an SCXML engine library.

The choice of using the SCXML standard into the CPSwarm project was driven by different factors:

- SCXML is a well-known standard and is supported by many different platforms. For Java, Apache Commons SCXML is the most popular SCXML Engine. SCION is another SCXML engine which aims to provide an SCMXL environment for web application leveraging JavaScript. Another very popular platform that uses SCXML is the Qt SCXML, an interpreter module to ease the embedding of state charts logics into Qt applications.
- SCXML is on its own not specialized toward any particular application domain, and it's up to the developer to do the work of integrating SCXML into whatever language, framework, runtime, or environment they are targeting in their application.

In the scope of the CPSwarm project, even though the main semantic of the language has been preserved, part of the language has been slightly adapted to fulfil the project needs. For this reason, the release of the open source version of the CPSwarm Code Generator on GitHub will be accompanied by a support guide to describe the small adaptations applied to the standard. Furthermore, for the state machine design, the use of a graphical tool such as Modelio will hide the complexity of the standard.

4.3 Project-relevant communication standards

LINKS is member of the XMPP standard foundation[44], this has allowed LINKS to promote the results of CPSwarm in the eXstensible Messagging and Presence Protocol (XMPP) community, specifically the ones of the Simulation and Optimization Environment. This has been done through dissemination on the XMPP communication channels (mailing lists, newsletters, social, etc.). The use of XMPP for the API of the Simulation and Optimization Environment allows making the components of the environment easily integrable and extensible by third-party developers using a XMPP client in their software. The API defined have not yet been

38 https://www.omg.org/syseng/
39 https://www.omg.org/robotics/
40 https://www.omg.org/hot-topics/iot-standards.htm
41 https://www.omg.org/omg-dds-portal/
42 https://www.omg.org/spec/SysPISF/About-SysPISF/
43 https://www.w3.org/TR/scxml/
44 https://xmpp.org/about/xmpp-standards-foundation.html

pushed to XMPP standard Foundation to be officially defined in a standard specification, but they are potentially ready to be integrated, increasing the interoperability level of the CPSwarm solutions.

4.4 Project-relevant security and safety standards

4.4.1 Contributions from TTTECH

TTTECH has been involved in the following standard:

- ISO26262, ISO/TC22/SC32-WG8, TTTECH is the official Austrian representative in this Working Group (contribution to the "Safety of the Intended Functionality" (SOTIF). TTTECH contributed by the network communication means including wireless function for safety critical application.
- Zentralverband Elektrotechnik & Elekrotechnik Industrie (ZVEI) contributing to UG SW AK Funktionale Sicherheit ISO26262 (contributions for wireless communication for safety critical application

4.4.2 Contributions from SLAB

SLAB has been involved in the creation of the following standard as part of the VESSEDIA[45] project:

- ISO/IEC DIS 23643 – Capabilities of software safety and security verification tools: https://www.iso.org/standard/76517.html

SLAB has been monitoring and gained inspiration during the security assessment of the project (D4.7 - Initial Security threat and attack models and D4.8 - Final Security threat and attack models) to gather possible assets and attack scenarios from the following standards:

- Information technology – Security techniques – Information security management systems – Requirements: ISO/IEC 27001: https://www.iso.org/obp/ui/#iso:std:iso-iec:27001:ed-2:v1:en
- Common Criteria for Information Technology Security Evaluation: ISO/IEC 15408: https://www.iso.org/standard/50341.html
- ISO 12100, Safety of machinery – General principles for design – Risk assessment and risk reduction: https://www.iso.org/standard/51528.html
- ISO 13849-1, Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design: https://www.iso.org/standard/69883.html
- IEC 62061, Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems: https://webstore.iec.ch/publication/6426
- ISO 10218-1, Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots Requirements for the design of manipulators for industrial environments: https://www.iso.org/standard/51330.html
- ISO 10218-2, Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration: https://www.iso.org/standard/41571.html
- ISO/TS 15066, Robots and robotic devices – Collaborative robots: https://www.iso.org/standard/62996.html
- ISO 13482, Robots and robotic devices – Safety requirements for personal care robots: https://www.iso.org/standard/53820.html
- ISO 13850 Specification of functional requirements and design principles: https://www.iso.org/standard/59970.html
- IEC 60204-1 Safety of machinery w.r.t. electrical equipment of machines: https://webstore.iec.ch/publication/26037

[45] https://vessedia.eu/

- IEC 62433: Security for Industrial Automation Control Systems (IACS)Case study I. – Swarm of drones: https://webstore.iec.ch/publication/59660

SLAB has been monitoring and applying the following secure software development standards and best practices during trainings and evaluations.

- OWASP Software Assurance Maturity Model – prescriptive framework for securing the development process: https://github.com/OWASP/samm/raw/master/Supporting%20Resources/v1.5/Final/SAMM_Core_V1-5_FINAL.pdf
- Build Security In Maturity Model – descriptive framework for identifying security activities used in the real world: https://www.bsimm.com/content/dam/bsimm/reports/bsimm9.pdf
- Build Security In - best practices for secure software design and implementation: https://www.us-cert.gov/bsi
- Software Assurance Forum for Excellence in Code (SAFECode) – fundamental rules for secure software development: https://safecode.org/wp-content/uploads/2018/03/SAFECode_Fundamental_Practices_for_Secure_Software_Development_March_2018.pdf
- Microsoft Security Development Lifecycle (SDL) – prescriptive framework for securing the development process: https://www.microsoft.com/en-us/securityengineering/sdl/
- International Council on Systems Engineering: Systems Security Engineering working group (INCOSE SSE): https://www.incose.org/incose-member-resources/working-groups/analytic/systems-security-engineering
- Team Software Process for Secure Systems Development (SEI-CERT, 2002): https://apps.dtic.mil/dtic/tr/fulltext/u2/a634138.pdf
- SEI CERT C Secure Coding Standard: https://wiki.sei.cmu.edu/confluence/display/c
- SEI CERT C++ Coding Standard: https://wiki.sei.cmu.edu/confluence/pages/viewpage.action?pageId=88046682

5 Summary of collaborations/potential interoperability with other projects and external organisations

5.1 BRAIN-IoT[46]

BRAIN-IoT is an H2020 project, started at January 2018 (LINKS is coordinator of this project), focused mainly on complex scenarios, where actuation and control are cooperatively supported by populations of IoT systems. BRAIN-IoT aims at establishing a framework and methodology supporting smart cooperative behaviour in fully de-centralized, composable and dynamic federations of heterogeneous IoT platforms.
The collaboration between the projects has started because BRAIN-IoT has identified the CPSwarm Simulation Environment as possible external testing environment to integrate in their platform to support the testing and validation of smart behaviours in robotics scenarios. Since BRAIN-IoT solution is based on OSGi, for this collaboration. the BRAIN-IoT developers, supported by CPSwarm LINKS Team, have worked on the OSGi porting of the Simulation Managers originally developed in CPSwarm, keeping the same XMPP APIs. This collaboration has led the following advantage to the CPSwarm project: the simulation managers have been based on OSGi, a standard for modular and flexible software development, allowing the easy integration of new ROS based simulation engines, to extend the Simulation Environment.

[46] http://www.brain-iot.eu/

5.2 TeamPlay[47]

TeamPlay is an H2020 project, started at January 2018, which aims at developing new, techniques that will allow execution time, energy usage, security, and other important non-functional properties of parallel software to be treated effectively, and as first-class citizens. Such techniques will form a toolbox to be used to develop highly parallel software for low-energy systems, as required by the IoT paradigm and CPS integration.
CPSwarm and TeamPlay have many points in common:

To present our results to them and in general for our open-source dissemination strategy the Consortium used the created CPSwarm Workbench page on the website, see section 3, which introduces the CPSwarm workbench architecture and "guide" the user among the released components (and related GitHub projects), see Figure 5.

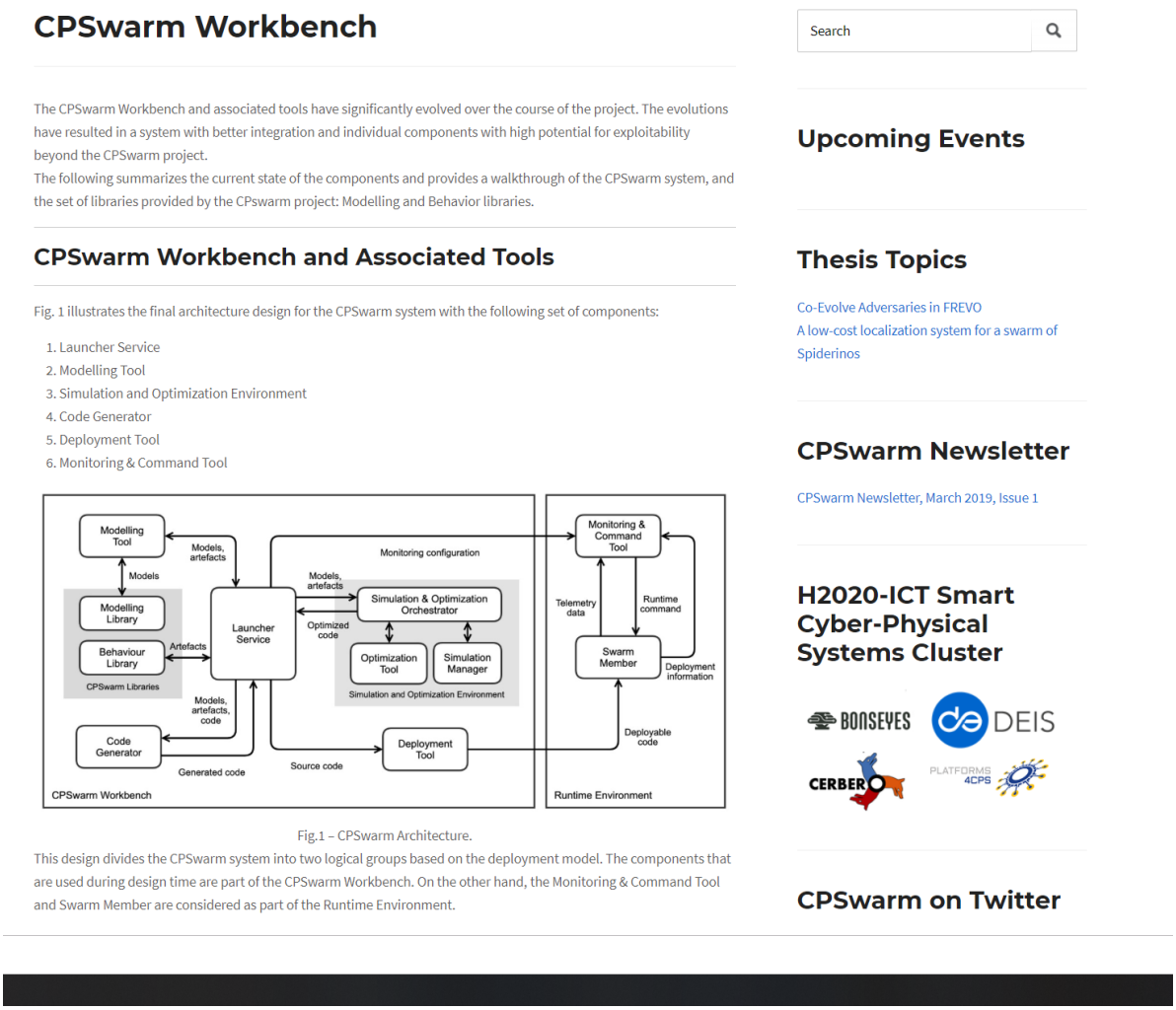

Figure 5: Screenshot of the CPSwarm Workbench page

TeamPlay has attended the final CPSwarm Workshop organized in Turin on December 2019, this has been the occasion for the two projects to exchange the respective main outcomes.

[47] https://www.teamplay-h2020.eu/

Specifically, the CPSwarm consortium has provided to TeamPlay the following libraries:

- For security aspects: the communication library, which is the library used to provide a unified interface that swarm members and Workbench tools can use to interact with each other.
- For ROS functionalities, the set of libraries, which span from simple functionalities to entire complex behaviours, all implemented using ROS packages. For this, you can check the behaviour library.
- Finally, the modelling language, for swarm modelling.

6 Conclusion

The CPSwarm project partners believe the results from the project will substantially address key challenges facing European CPS industry.

Overall, the pillars that underpin the contributions to interoperability initiatives dissemination and exploitation for the project have been the following:

- Publish the interfaces and methodologies used for the CPSwarm technologies.
- Make the as many as possible technologies available as open source products using the well-established exploitation and dissemination channels of the project partners to encourage their broad take-up by industry.

Acronyms

Acronym	Explanation
ACPS	Autonomous Cyber Physical Systems
API	Application Programming Interface
BDD	Block Definition Diagram
CPS	Cyber Physical System
CPSoS	Cyber-Physical System-of-Systems
DG RTD	Directorate-General for Research and Innovation
EC	European Commission
EFECS	European Forum for Electronic Components and Systems
ECS	Embedded Components and Systems
FoF	Factories of the Future
FREVO	Framework for EVOlutionary Design
FMI	Function Mock up Interface
HAL	Hardware Abstraction Layer
IBD	Internal Block Diagram
IoT	Internet of Things
IP	Intellectual Property
IPR	Intellectual Property Rights
MARTE	Modeling and Analysis of Real-time and Embedded systems
OMG	Object Management Group
OSGi	Open Services Gateway initiative
RE	Requirement Engineering
ROS	Robot Operating System
SCXML	State Chart XML
SDK	Sofware Development Kit
SME	Small and Medium Enterprise
SOO	Simulation and Optimization Orchestrator
SysML	System Modeling Language
SysPISF	SysML Physical Interaction And Signal Flow Simulation Specification

UAV	Unmanned Air Vehicule
UC	Use case
UML	Unified Modeling anguage
WLAN	Wireless Local Area Network
XML	eXtensible Markup Language
XMPP	eXtensible Messaging and Presence Protocol
W3C	World Wide Web Consortium

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