Project number: 826276

CPS4EU

Cyber Physical Systems for Europe

D10.21 - Road mapping and Benchmark v1

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Dissemination level: Public

Version	Date	Author (name – company)	Comments
V1.0	25/05/2020	Antoine Dupret - CEA	Creation of the document

This project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 826276

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Table of Acronyms

Definition / acronym / abbreviation	Description
CPS	Cyber-Physical System
AI	Artificial Intelligence
DL	Deep Learning
NN	Neural Network
DT	Digital Twin
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
IoT	Internet of Things
FPP	Full Project Proposal (FPP)
KPI	Key Progress Indicator
SoS	System of Systems

1. CONTEXT AND IMPLEMENTATION OF ROAD MAPPING AND BENCHMARK

1.1. Scope of Task 10.5 "Road mapping and Benchmark of CPS Activities"

Task 10.5 "Road mapping and Benchmark of CPS Activities" aims at following the evolution of the market trends and the state of arts of the innovations in Cyber Physical Systems (CPS) so as to adapt the vision of the project and use cases to these latest developments. Owing to the distinctive natures of such a task, the works requires specialists of strategic surveys. Indeed, the marketing office of the CEA will be in charge of the practical implementation of this task and will manage a market study through a questionnaire. Yet, the questionnaire must be carefully defined and specified, hence it must be established from the analysis of the latest evolutions of the state of the art, on the scientific and technological trends and the own inflections of the works carried out in CPS4EU.

1.2. CPS context

Recent reports, notably from funding institutions (i.e. EU ARTEMIS [1], USA's National Institute of Standards and Technology (NIST) [2]) regard Cyber Physical Systems (CPS) as game changers. Indeed CPS constitute the new generation of systems that allow combining intensive connectivity, embedded computing and local intelligence that create a link between physical and digital worlds and enable cooperation among systems. The importance of CPS is increasing with massive digitalization. CPS are opening new market opportunities and bringing Europe new challenges to maintain, strengthen and extend the strong European position in this enabling technology.

As so, CPS represent key drivers for the innovation capacity of European industries, large and small, generating sustainable economic growth while providing meaningful jobs for citizens. CPS also appear as powerful solutions to some of the difficult societal challenges addressing European policies for 2030 and beyond. The US administration shares the same analysis, leading both the National Science Foundation (NSF) and the NIST to fund CPS research works related to CPS since 2012. For both reasons, it is vital that the funded investments assure collaboration among European industries along the CPS chain and eventually develop technologies, expertise, capacities and competitiveness.

A first challenge hence comes from the nature of CPS. As illustrated by the M2M sector map from of Beecham Research1 of Figure 1, CPS embraces a very broad the range of markets and scientific topics. Yet, this figure only displays CPS focused on the Internet of Things (IoT). This broad CPS scope includes crosscutting functions (i.e., functions that are derived from critical and overriding CPS concerns) that are likely to influence multiple interacting CPS domains.

[1] http://www.beechamresearch.com/article.aspx?id=4

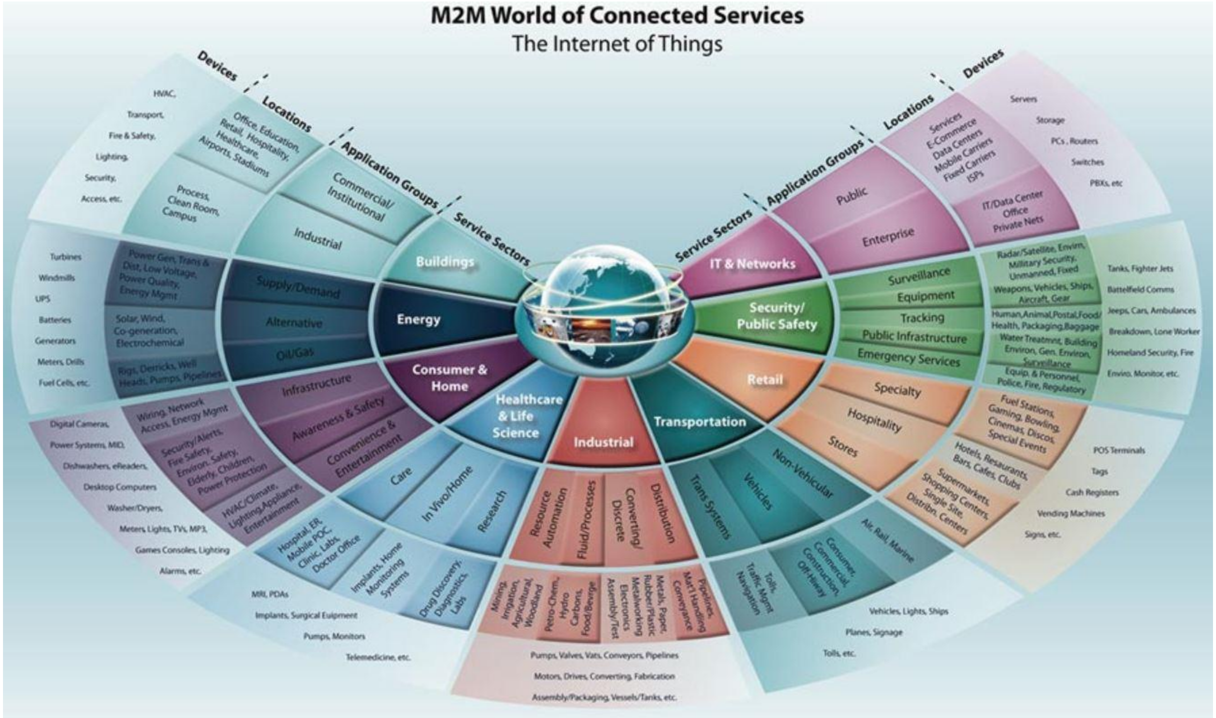

Figure 1: Segmentation of M2M Market

As shown in respectively Figure 2 and Figure 3, the ARTEMIS report distinguishes four to five domains of applications and six main research streams where the CPS will become ubiquitous.

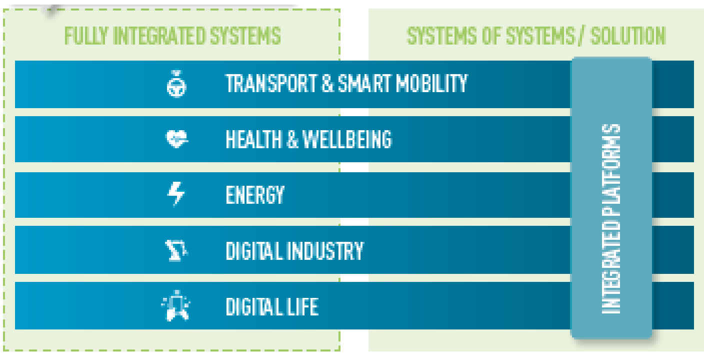

Figure 2: Segmentation of key domains of application

To increase both its relevance and its impact, the CPS 4EU project focuses on important sectors of the European economy, i.e. automotive, energy and industry automation. Thanks to massive European and national cooperative programs in several key enabling technologies (e.g. nanoelectronics, sensors, AI, cybersecurity and computing), these sectors have benefited from breakthroughs that, in turn, have already led to the arousal of innovative systems. The position of the European industry in these areas was thus strengthened because of their leading position across the whole value chain. This value chain includes the components, the equipment (sub-systems) and electronic products.

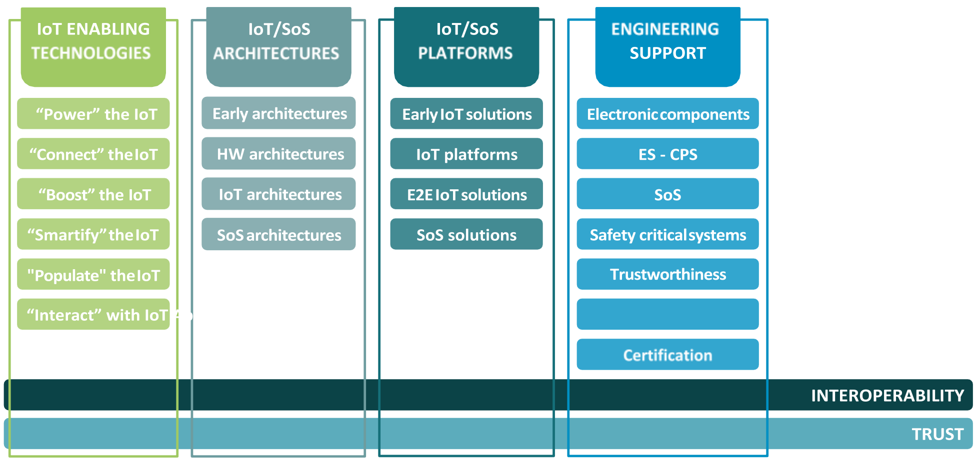

Figure 3: IoT/SoS primary and cross research streams.

As shown in Figure 4, CPS4EU addresses two of the four constituents of CPS: components (i.e. computing, connectivity, components and collaborative systems) and systems developed for or by end users in three major sectors of the industry of the EU (Automotive, Industry Automation and Smart Grids).

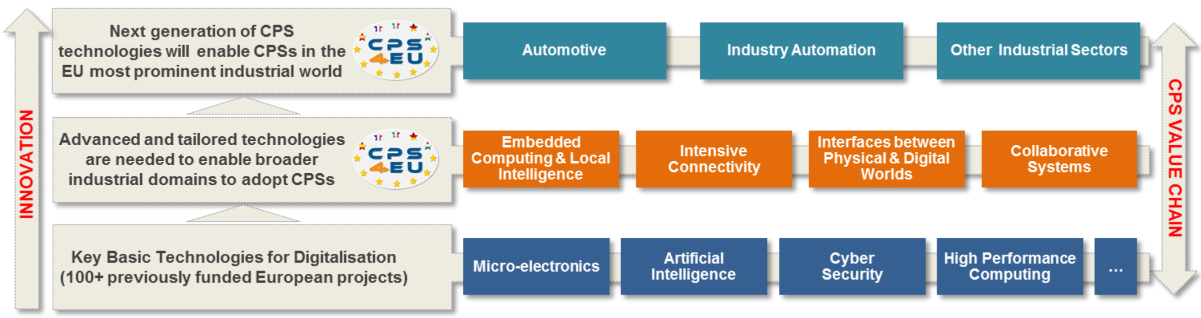

Figure 4: CPS4EU positioning within the value chain

1.3. Business in CPS4EU

One critical task to be carried out in the project relates to the market take-up and the deployment plan for the commercial deployment of the project results (devices, systems, solutions or services) once the project has finished. These activities are monitored in WP10, Task 10.3 "Business Assessment, and Exploitation and Standardization". The exploitation plan aims at specifying the service models to be delivered first, the target end users to be addressed during the initial stage of the project, and the technical parts to be prepared first, etc. The plan has to identify requirements for further development of CPS4EU solutions and sustainable implementation scenarios. It also aims at describing the direct benefits from the project results for the consortium and its individual partners and include the lessons learnt along the project. This last point is of high interest for the adjustment of tasks and for follow-up initiatives.

One key in the exploitation strategy is the existence of a special committee dedicated to that task, the BOOM (Business Opportunity Outcome Monitoring) in the governance structure of the project, described in the paragraph 3.2 of the Grant Agreement. It is composed of representatives of the value chain within the project such as component suppliers, providers of pre-integrated architectures, editors of software and tools, integrators for industrial applications, and engineering or academics entities. It aims at providing guidance and tools to maximize the exploitation opportunities and monitor the business KPIs. The exploitation strategy, impacting/impacted by most of CPS4EU WPs, with a continuous iterative process supervised by task 10.3, is structured in four main phases shown in Figure 5.

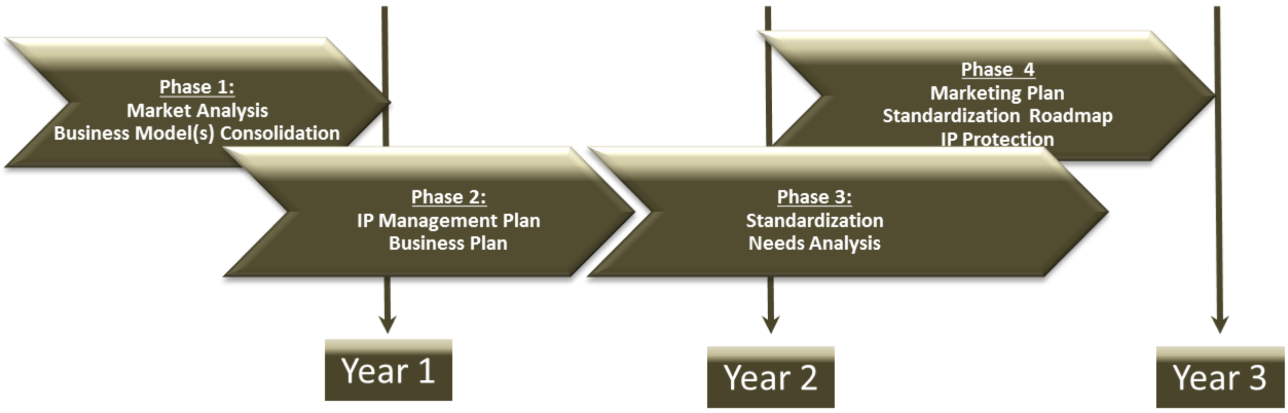

Figure 5: Exploitation steps

Regarding this report, Phase 1 is the relevant phase and it focuses on:

- **Market analysis:** The potential market will be reviewed and updated in the light of the project's objectives and intended outputs, as well as in the light of latest available market data. The market analysis will define, characterize and segment the potential opportunities for different solutions developed in the project, as well as describe the value chains serving each technology.
- **Business model(s) consolidation:** Preliminary business models will be reviewed and consolidated considering the outcomes of the market analysis, the identified value chains and the intended customers for each developed product. The business model(s) will map how CPS4EU will create and deliver value by identifying: (a) the relevant customers segments; (b) the value proposition; (c) the channels to deliver the value proposition to customers; (d) the resources required, (e) the activities to be performed and (f) the required partnership. The elements above will be linked to revenue and costs streams, which will be further quantified in the business plan. Furthermore, it will investigate possible elements for the success of the business model, such as the importance of relationships with customers, partners, providers and other key stakeholders.

A preliminary analysis of the market sector was provided in the Full Project Proposal (FPP). The Business KPIs of CPS4EU result from this analysis and its resulting projections, notably Table 21 of the FPP. With respect to the planed actions, the COVID-19 crisis has slightly slowed down the marketing and benchmarking actions. Indeed, several conferences and workshops have been cancelled, hence limiting exchanges with colleagues from academia, clients and competitors. The plans to circumvent the impact of the COVID-19 crisis also have resulted in the concentration onto short-term marketing efforts at the expense of the update of the analysis of the market sector.

As a result, based on the first deliverables and the analysis of CPS4EU partners, it is necessary to setup a market analysis to trace the evolution of the CPS both in terms of Scientific and Technological progress and in terms of market perspectives. This report aims at providing the first clue to the marketing analysis that will be initiated in December 2020.

2. EVOLUTION OF CPS LANDSCAPE SINCE CPS4EU START

A thorough study of the evolution of the state of the art and the market analysis is beyond the scope of this first deliverable, which aims at stating the orientation and the requirements for a study to the CEA business study office (SBEM). Yet the analysis of key actors, both on academic and industry side, already provides an overview of the main trends and key benchmarks.

2.1. Evolution of the international landscape

2.1.1. Analysis of IEEE papers

Covering all the topics of the CPS and comprising publications or conferences of references in their respective domains, IEEExplore -the digital library of the Institute of Electrical and Electronics Engineers (IEEE) - provides a convenient database to follow the trends of the research activities in the field of CPS. Since the quick-off of CPS4EU, i.e. from 2019 to 2020, IEEExplore comprises more than 600 papers –either journal, conferences papers or magazine articles- relates to CPS (e.g. [3], [4], [5], [6]).

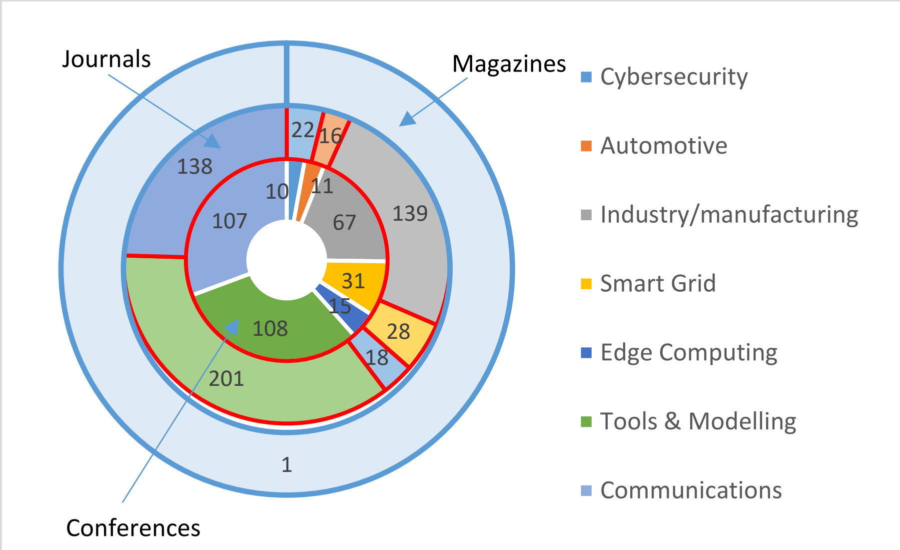

Figure 6: CPS related papers in IEEE magazines, journals and conferences in 2019-2020

With over 600 papers in one year period, the amount of papers related to CPS demonstrate that the topics related to CPS are highly vivid and drive the axis of researches of the core technologies of the CPS. Figure 6 shows the breakdown of the topics that the papers dealing with CPS address. The number of papers related to the core technologies, - i.e. communications, computing, tools or cybersecurity- or to the use cases – i.e. Manufacturing, Smart grids, Automotive- are well balanced. It shows that the global approach allowed by the concept of CPS leads to actual developments, not only in components, but also at system level. Interestingly, the number of papers related to Security is relatively low even if these papers are usually of higher impact since there are either published in highly visible magazines or published in journals with high h-index. Communications related papers raise similar comment. Yet, in late case, the relatively reduced number of papers can be explained by the prevalence of well-established standards, which limit the possibility to develop novel approaches.

2.1.2. Analysis of NSF projects

The NSF has funded CPS systems and basic technologies as such for almost a decade. Since 2019, the NSF has funded more than 60 projects for a total amount more than $30M. Figure 7 shows the topics addressed in these funded projects.

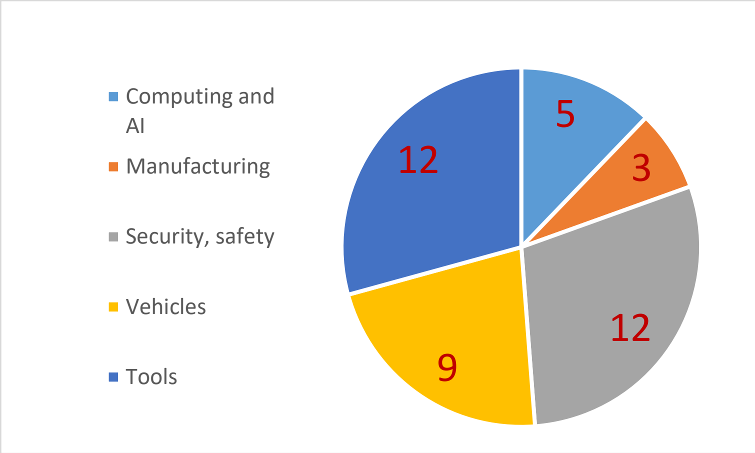

Figure 7: Major topics of CPS funded by NIST in 2019, number of funded projects by topic

This Figure shows that the topics addressed in the "components" work packages of CPS4EU closely relate to the main topics funded by the NSF. Yet, the use cases are less represented and, more important, contrarily to the approach followed in CPS4EU, and contrarily of what appears in the analysis of IEEE papers, the links between core technologies and use case miss in these funded projects.

Overall, the projects funded in the USA do not show novelties nor shifts in the existing trends that would challenge the topics and the orientation of works in CPS4EU.

2.1.3. Analysis from EU perspective

The Artemis-IA Whitepaper "From Internet of Things to System of System" [1] is also a key reference to benchmark the proposed approaches developed in CP4EU and their potential impact in terms of business from a European perspective.

Regarding AI and AI oriented components, the Artemis-IA Whitepaper emphasizes the increasing processing power of IoT devices. It concludes that it is just one of the enabling factors to improve analytical and decisional autonomy of IoTs, but a rich set of different technologies, including AI, can be further considered. The Artemis-IA Whitepaper mentioned SOFIA that largely anticipated the need for extracting insightful information that could be used on the edge and entirely based its solution for smart environments on semantics. The creation of knowledge in a smart object provides the ingredients required for reasoning that, in turn, allows to formulate decisions and to actuate them. This analysis is clearly aligned with works carried out in WP1, WP3 and WP4 of CPS4EU.

Regarding the architectures –in the sense of their definition in WP6-, the report states that the architecture of an IoT solution is a fundamental element to conceptually command and control a complex system of systems (SoS), i.e. a CPS. The report also mentioned that, thanks to is flexibility, the architecture of an SoS can be adapted to many vertical domains. The uptake of IoT would hence strongly depend on the adequacy of the architecture and research works. Three important aspects should so be considered:

- IoT and SoS cannot be a mere assembly of disparate improvements issued from previous steps but need to be a smart combination of them to provide efficient solutions.
- Growing number of devices, massive amount of generated data, mission critical apps requiring low latency … are drivers for decentralisation, embeddable computational intelligence and edge computing. IoT architectures must reflect and embrace these trends.
- "Security by design" should be considered also in the definition of the architecture, because of the increased attack surface exposed by IoT.

These aspects are aligned with CPS4EU objectives, especially WP6.

The Artemis-IA Whitepaper also states that ARTEMIS and ECSEL projects have dedicated a lot of effort to the development of the IoT/SoS platforms research stream. The research and innovation activities covered and currently covering this topic notably includes:

- Middleware and platforms for WSN.
- Legacy systems integration/inclusion.
- Control and manage the IoT infrastructure and its nodes.
- Enable the information flow and processing.
- Promote service creation.
- IoT/SoS integration platforms.
- End-to-end IoT solutions.
- SoS oriented solutions.

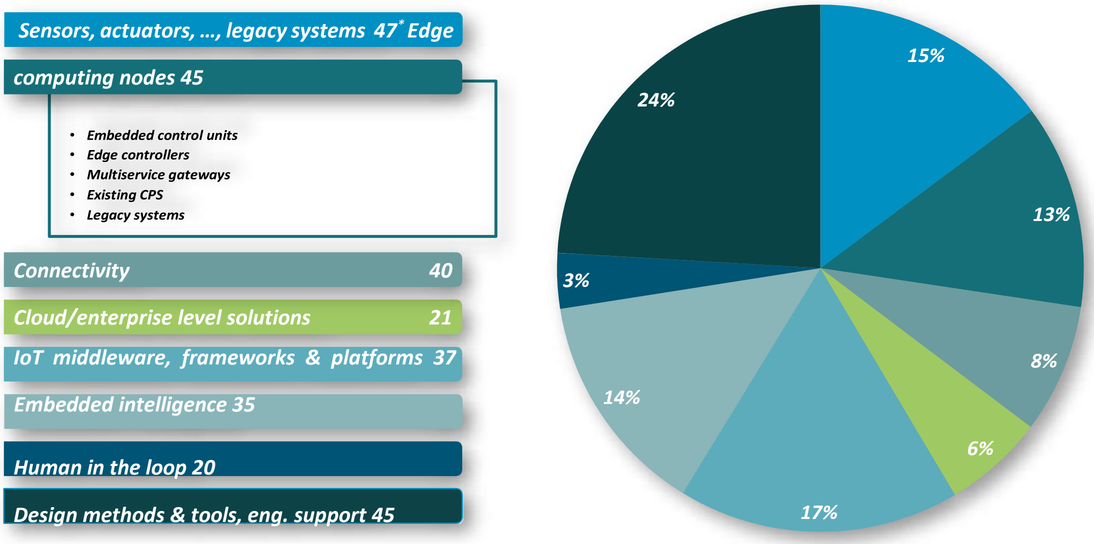

Figure 8: Percentages of investments by IoT stack macro-components

Finally, Figure 8 shows the relative investments of ARTEMIS and ECSEL initiatives to the different constituents of the IoTs and CPS. Most CPS4EU core technologies are mentioned and the relative efforts are somewhat similar to what is displayed in the above Figure, except for the communication. The perception of the evolution allowed by the 5G may be higher in CPS4EU than in previously funded projects.

2.2. Evolution through the analysis within the CPS4EU Project

2.2.1. Evolution through the analysis of first CPS4EU deliverables

The deliverable D1.1 of WP1 provides a set of analysis regarding the needs and trends in computing components. The analysis of the computational and architectural needs related to big data computing of CPS in the context of WP8 Industry Automation reveals heterogeneous requirements. Even if there exists a general reference architecture to address bigdata enabled information systems ([7] or, e.g. Kappa Architecture), its deployment should be broken into different levels, cloud, edge, or fog computing to satisfy the computational and data-ownership needs.

The deliverable D2.1 of WP2 provides a short survey of existing connecting technologies for CPS. 4G appears as a good starting point since it proposes a framework meeting most of the requirements, thanks to the various LTE categories. However, for most stringent requirements, such as low latency, time deterministic communication, 4G is somehow limited and WP2 has to work on building blocks, enabled by 5G to fulfil the complete set of requirements expressed by verticals. This report proposes three axis of research for WP2, investigating Time Sensitive Networking, URLLC, and a DSP framework that could combine communication and AI processing.

The deliverable D3.1 of WP3 "SW specification for AI methods for perception and detection" provides a broad overview of the software requirements, and to present evaluation and validation methods. Since the project is still at an early stage, the requirements presented are the requirements defined by the technology providers themselves, based on their knowledge of their use cases. Yet, as a general synthesis of these requirements, the needs for robust flexible, comprehensive and useful data processing achieved at real time, hence reinforcing the choice for AI based methods. Moreover, regarding AI, D3.1 identifies the following trends:

- Approaches based on Deep learning models to address domain adaptation for image classification
- Domain adaptation methods for semantic segmentation
- Data augmentation (supervised and unsupervised data augmentation)

The deliverable D3.2 of WP3 "Specification and requirements of perception for localization" provides localization requirements for autonomous vehicles and industry applications. Regarding autonomous vehicle, the analysis from the state of the art leads to identify three major origins in errors: the error arising for heading initialization, the error arising from the attitude estimation of the vehicle (roll, pitch, etc.) and the error arising from the drift of the gyrometer. The trends in the mitigation of these errors are approaches based on multi feature matching, map sharing and update and mapping using occupancy grids.

The deliverable D6.1–Pre-Integrated Architectures Specifications of WP6 deals with the design and specification of four pre-integrated architectures. These architectures are meant to study the integration of CPS modules into complex systems and applications. Therefore, they accompany the development of next-generation building blocks, as well as aim to reduce the design and integration time required to make use of today and tomorrow CPS building blocks.

To conclude on the analysis of the first deliverables of CPS4EU, the need for AI based systems appears as a still growing trend. Yet, the growing complexity of the implementation of AI based systems generate needs in both computing, tools and architecture.

2.2.2. Evolution through the analysis from CPS4EU partners

2.2.2.1. Main observed trends in the field of WP3 Sensors

Some other trends are observed in the field of WP3. Thermal cameras are now mentioned for the detection of objects and vulnerable road users when 24/7 usage in all weather conditions is necessary. The picture below shows the mobility kit of the Cruise Origin automated vehicles, equipped with a visible camera, a radar and a thermal camera.

Cruise's Kyle Vogt demonstrates swiveling sensors. Credit: The Robot Report

Figure 9: Mobility kit of the Cruise Origin automated vehicles

Another trend relates to the detection of intentions: perception meets psychology. For the calculation of object trajectory, a key question is related to the probability of presence in a given location in the future timescale up to 5 seconds. This prediction is necessary to calculate the trajectory of the ego-vehicle, and maximize the customer satisfaction without any compromise on safety.

This prediction of intentions applies to human behaviors, for instance pedestrians, cyclists, or drivers in a motor vehicle. The sensors must now determine with the best possible accuracy the nature of the surrounding objects, their headings, and their speed. Likewise, the sensors must be able to detect partially obstructed pedestrians, and detect their physical attitude. The paper from Uber provides an improvement with Neural Network algorithms to estimate probabilities of vehicle trajectories at intersections:

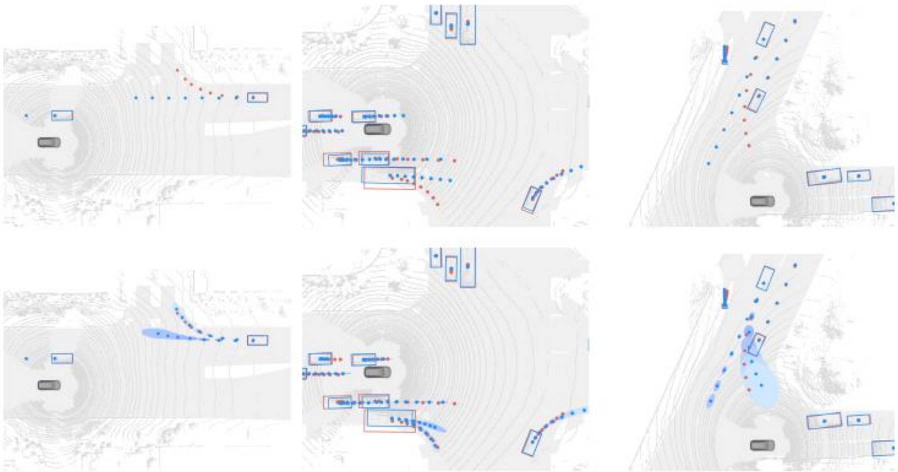

Fig. 4: Qualitative results of the competing models, top row: IntentNet, bottom row: MultiXNet; ground truth shown in red, predictions shown in blue, while colored ellipses indicate one standard deviation of inferred uncertainty for future predictions

Figure 10: Qualitative results of the competing models in Multiclass Multistage Multimodal Motion Prediction (from [8])

2.2.2.2. Main observed trends in the field of WP7 Automotive

Several trends on the Automated Driving Systems have taken place since the filing of the CPS4EU project:

- The homologation process of Automated Driving Level 3 functions (Conditional Automation, Hands/Feet/Eyes OFF) was clarified by the publication of three documents from UNECE/TRANS/WP29:
  - Homologation for an Automated Lane Keeping System (ALKS), on dual-carriage roads, up to 60kph
  - Homologation of resistance to cyber-security threats
  - Homologation of the process related to Software updates including Software Over The Air (SOTA) updates
- The introduction of Automated Driving Level 4 functions for passenger cars is being postponed by the main traditional carmakers. During this time, the definition process for the homologation of the automated driving functions is still on-going. The parties involved in the discussions in the UN ECE working groups agree on a homologation process built on three pillars: virtual testings, validation on test track, validation on open roads. This trend motivates even more the need to develop extensive simulation models and digital twins so that the carmakers or fleet operators can provide the necessary evidence for the homologation process (see Figure 11).

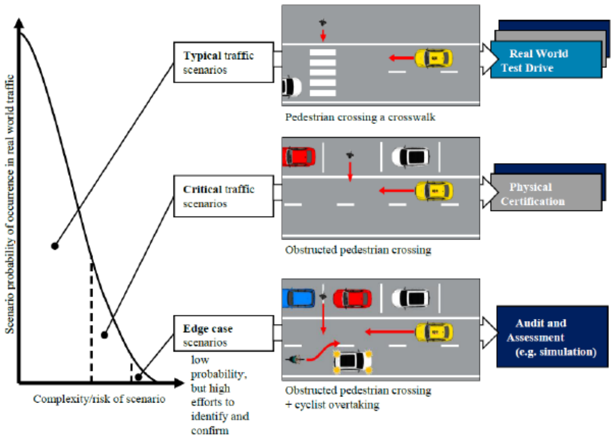

Figure 11: scenarios to be considered for a homologation process

- New players on the Delivery service markets take some advantage of the booming retail sales on the internet to push their own automated vehicles for the delivery of goods. The COVID-19 crisis and the related confinement of the populations provided an additional use case illustrating the benefits of these services. See two illustrations in Figure 12 below.

Figure 12: Nuro R2 (left) and Valeo eDeliver4EU (right)

- Vehicle electrification: the 'battle for every electron' will push even more the need for accessories with low power consumption. In the field of Driving Assistance and Automated Driving, this applies mostly to the Electronic Computing Units, which run the Deep Neural Network software for perception, localization, trajectory planning and mission planning. Figure 13 illustrates the Tesla FSD chipsets in the Automated Driving computer.

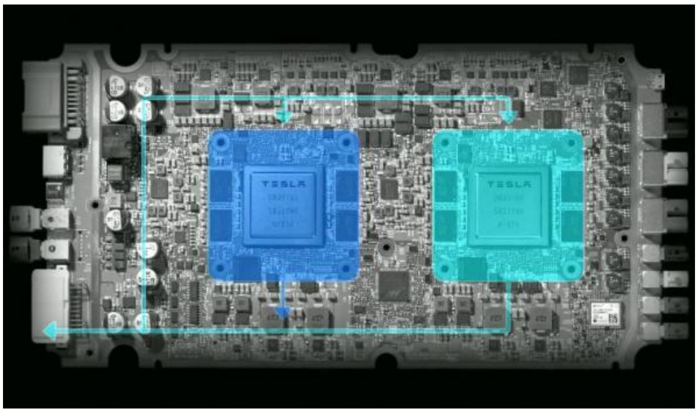
Figure 13: Tesla FSD chipsets in the Automated Driving computer

- Partnership Daimler-NVidia: On June 23rd, 2020, Daimler and NVidia have announced a strategic partnership. Starting from 2024, the Daimler vehicles with Level 2 and 3 Automated Driving functions (and Valet Parking Level 4) will be performed thanks to an NVidia Orin system-on-chip, built with the NVidia Ampere architecture. This Orin chipset is located in the Figure 14 in the Level 3 Orange region at 200 TOps. The description of the Orin chipset mentions:

- ○ The platform is powered by a new system-on-a-chip (SoC) called Orin, which consists of 17 billion transistors and is the result of four years of R&D investment. The Orin SoC integrates NVIDIA's next-generation GPU architecture and Arm Hercules CPU cores, as well as new deep learning and computer vision accelerators that, in aggregate, deliver 200 trillion operations per second—nearly 7x the performance of NVIDIA's previous generation Xavier SoC.
- ○ Orin is designed to handle the large number of applications and deep neural networks that run simultaneously in autonomous vehicles and robots, while achieving systematic safety standards such as ISO 26262 ASIL-D.

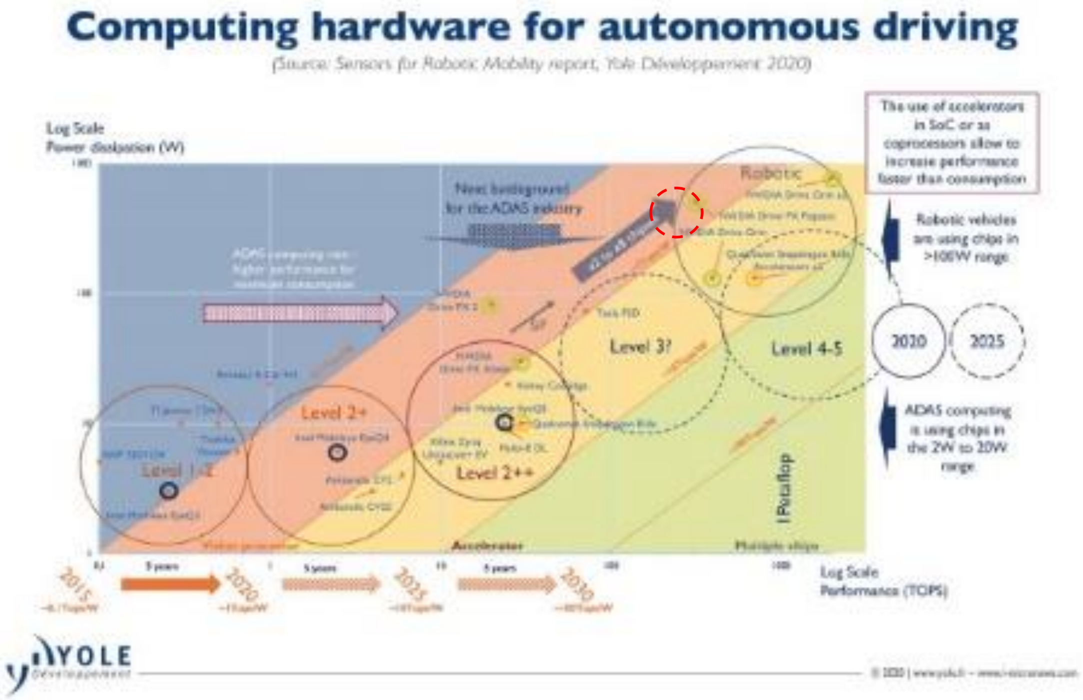

Figure 14: Yole analysis of computing hardware evolution for Automated Driving computer[2]

- Intelligent Connected Vehicle (ICV) roadmap in China: In a document published by the German Verband des Automobilindustrie (VDA) in 6/2020, the strategy in China to deploy Intelligent and Connected vehicles is clearly outlined. The step 3 corresponds to the integration of the transportation system inside the Smart City network. The main players involved in the eco-system are mentioned in the picture below.

Figure 15: VDA analysis of China strategy to deploy Intelligent and Connected vehicles [3]

[2] Source: Sensors for Robotic Mobility report, Yole Développement 2020

[3] https://www.vda.de/en

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2.2.3. Edge Computing

Even if the concept of Edge computing emerged in the 1990s, this trend in system architecture is pushed by the massive quantity of data generated by our sensors. The high computing power needed to run the AI algorithms, the need for minimal latency in the data transmission, and the constraints related to safety, security and privacy also build the case for the Edge Computing. Valeo recently joined the Automotive Edge Computing Consortium. Schneider Electric, which is also a CPS4EU project partner, is member of the European Edge Computing Consortium. At the European level, the ARTEMIS Industry Association published recently a white paper 'From Internet of Things to Systems of Systems', supervised by P.Azzoni from Eurotech. This whitepaper can be interpreted as a roadmap for the deployment of Edge computing and Embedded intelligence to consolidate the competitiveness or European industries

To conclude on the analysis of the first deliverables of CPS4EU, the need for AI based systems appears as a still growing trend. Yet, the growing complexity of the implementation of AI based systems generate needs in both computing, tools and architecture.

2.3. First business forecast and preliminary conclusions

As for the business trends, in CPS4EU Trumpf and Wika reported they are identifying an increasing demand for localization systems for industrial use (i.e. production plants, incl. distance and geometry measurements), machine perception systems for mobile machines as well intelligent power management solutions for distributed industrial automation, especially for battery driven communication issues. These trends should be qualified more thoroughly for the next deliverable.

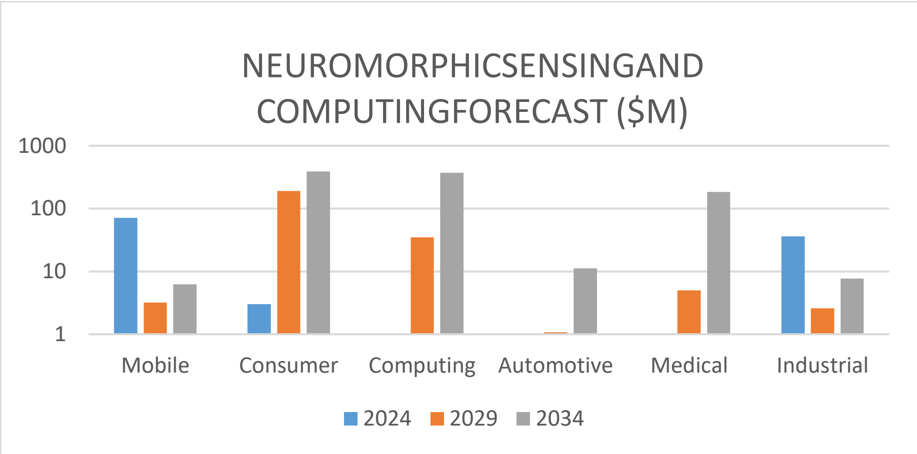

Figure 16: Market and Technology forecast from Yole Neuromorphic Sensing and Computing 2019 report

The 2019 analysis from Yole[4] provides a somewhat different enlightening. This Yole report considers two of the three use cases present in CPS4EU. Yet it does not mentioned Smart grids as specific use case whereas an IEEE 2016 survey had shown that out 67 utilities, 41% were using or planning to use an Advance Distribution Management Systems (ADMS), where AI may be relevant [9], [10]. It concludes that until 2024, AI implementation will be limited to niche applications and proofs of concept using digital hybrid chips. It should be not before 2024 to 2029 that mass-market adoption would become established for simple tasks such as always-on awareness and industrial motion-related imaging. Yet, these applications will still use digital hybrids. From 2029, tasks that are more complex will go far beyond current AI capabilities, especially in automotive and robotics applications. In-memory computing technologies such as embedded RRAM will be used.

Such an analysis is somewhat more conservative than what is observed in CPS4EU partners requirements and in the reports previously mentioned. Consequently, a more in deep analysis of the trends and their impact from a business perspective must be carefully conducted. The next section is devoted to the definition of the objective, requirements and specifications of the survey to be conducted by the CEA/SBEM

[4] Neuromorphic Sensing and Computing 2019, Market and Technology, Report 2019

3. OBJECTIVES, REQUIREMENTS AND SPECIFICATIONS FOR THE DEFINITION OF THE QUESTIONNAIRE

3.1. Objective

The questionnaire will aim at questioning and refining the first and coarse analysis stated in this document.

3.2. Requirements and specifications

Domain	Requirements	Specifications
Computing	Provide an analysis of the evolution of AI processor technical trends and markets	Question key AI circuits providers and major end users in the field of automotive, smart grids and industry 4.0
Communication	Provide an analysis of main technical trends and markets trends in communication for CPS	Question key communication systems providers and major end users in the field of automotive, smart grids and industry 4.0
Security	Provide an analysis of main technical trends and markets trends in security for CPS	Question key security solution providers and major end users in the field of automotive, smart grids and industry 4.0
Tools	Provide an analysis of the evolution of technical trends and markets trends in system level simulation/verification tools	Question key system level simulation tool providers and major end users in the field of automotive, smart grids and industry 4.0
	Provide an analysis of the evolution of technical trends and markets trends in simulation tools for digital twins	Question key digital twin simulation tool providers and major end users in the field of automotive, smart grids and industry 4.0
Sensors	Provide an analysis of the evolution of sensors technical trends and market trends	Question key sensors providers and major end users in the field of automotive, smart grids and industry 4.0
Architecture	Provide an analysis of the evolution of technical trends and markets trends in generic computing platforms	Question key AI circuits integrators and major end users in the field of automotive, smart grids and industry 4.0
	Provide an analysis of the evolution of technical trends and markets trends in generic communication platforms	Question key communication systems providers and major end users in the field of automotive, smart grids and industry 4.0
	Provide an analysis of the evolution of technical trends and markets trends in generic multisensory platforms	Question key multisensory integrators, sensors providers and major end users in the field of automotive, smart grids and industry 4.0

4. RÉFÉRENCES

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